ICDCS 2017

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Message from the General Chairs and PC Chair

We would like to welcome you to ICDCS 2017, the 37th IEEE International Conference on Distributed Computing Systems, being held from June 5 to June 8, 2017, in Atlanta, Georgia, USA. The conference is held in the J.W. Marriott Hotel, conveniently located in Buckhead, Atlanta.

As a premier forum for the presentation of research results on a broader spectrum of distributed computing systems, the 2017 ICDCS continues the tradition with similar organizational structure, and introduces some innovations.

The research tracks have received a total of 531 original submissions to the eleven research tracks. Each paper was reviewed by at least three independent reviewers, and discussed during the online PC meeting held by track chairs. Furthermore, the top ranked papers from each track were further discussed during the face to face track chairs meeting held at Georgia Institute of Technology in Atlanta. A total of 89 papers have been accepted by the research tracks with the acceptance ratio of 16.8%. We would like to express our heartfelt thanks to all of the track chairs: Michael Kozuch and Anshul Gandhi (Cloud and Data Centers), Srinivas Aluru (Big Data Systems and Analytics), Fred Douglis (OS and Middleware), Doug Blough (Distributed Fault Tolerant Computing), Elisa Bertino (Security, Privacy and Trust), Karthik Sundaresan (Wireless and Mobile Computing), Kui Ren (Distributed Algorithms), Canturk Isci (Distributed Green Computing), Thiemo Voigt (Internet of Things and Cyber Physical Systems), Weisong Shi and Tao Zhang (Edge and Fog Computing), Munindar Singh (Social and Crowd Computing).

In addition, ICDCS 2017 technical program also consists of industrial and experimentation sessions, applications and experiences sessions, short papers sessions, posters and demos sessions, tutorials, and co-located workshops. Another two highlights of ICDCS 2017 are: (1) the three keynotes by distinguished speakers: Dr. C. Mohan from IBM Almaden, Prof. Dr. Tamer Ozsu from Waterloo University, and Dr. Kenneth Calvert from National Science Foundation, and (2) the Blue Skye Ideas and Vision sessions featuring thought-provoking and forward looking blue sky ideas and visions on broader spectrums of future distributed computing systems. In addition, the 2017 ICDCS main conference is preceded by eight co-located workshops, described in the workshop chairs’ message. These workshops provide an opportunity for small groups of like-minded researchers to discuss areas of interest and new ideas, and we are pleased to see a diverse ecosystem of workshops at ICDCS.

The success of 2017 ICDCS relied on the contributions of a great team of volunteers, including the program committee members from all tracks. We would like to thank all of them for their time, high quality service, and tireless efforts. We would like to express our special appreciation to the industry and experimentation chairs (Scott Klasky, Aameek Singh), the blue sky ideas and vision track chairs (Manfred Hauswirth, Manish Parashar), the applications and experiences chairs (Songqing Chen, Sangeetha Seshadri), the short paper chairs (Laksmish Ramaswamy, Jianwei Yin), and the demo and posters track chairs (Gerald Lofstead, Balaji Palanisamy), the workshop program chairs (Joao E. Ferreira, Teruo Higashino), tutorial chairs (James Caverlee, Vaidy Sunderam), panel chairs (Dimitrios Georgakopoulos, Yi Pan, Yinglong Xia), publication chair (Kisung Lee), publicity chair (Aibek Musaev, Emre Yigitoglu), local arrangement chairs (Aibek Musaev, Joshua Kimball, Wei Zhou), and finance/registration chair (Carrie Stein).

Finally, on behalf of the 2017 ICDCS organization and program committee, we would like to express our sincere gratitude to everyone who has contributed to the conference, especially the authors and the participants. We would like to thank Xiaodong Zhang (ICDCS Steering Committee Chair) and Cheng-Zhong Xu (chair of IEEE Computer Society Technical Committee on Distributed Processing) for their support, advice and trusting us to organize the conference. They also spearheaded the successful effort to obtain and disburse funding to sponsor the student travel awards. In addition, we would like to acknowledge the sponsorship support by the National Science Foundation (NSF/USA) and Japan Science and Technology Agency (JST/Japan) for the 1st US-Japan Workshop on Enabling Global Collaborations in Big Data Research.
We wish you an enjoyable and productive conference and a pleasant stay in Atlanta.

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Ling Liu, Georgia Institute of Technology, USA

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- Fan Zhang, IBM, USA
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- Kisung Lee, Louisiana State University, USA
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- Fei Li, George Mason University, USA
- Baochun Li, University of Toronto, Canada
- Yao Liu, SUNY Binghamton, USA
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• Viswanathan Swaminathan, Adobe, USA
• Masashi Toyoda, Univ Tokyo, Japan
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• Ting Wang, Lehigh University, USA
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• Rui Zhang, Institute of Information Engineering, Chinese Academy of Sciences, China
• Yanqing Zhang, Georgia State University, USA
• Zhao Zhang, University of Illinois at Chicago, USA
• Xuan Zhou, Renmin University of China, China

• **Vision / Blue Sky Thinking**
  
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  Co-Chair: Manish Parashar, Rutgers University, USA

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• Umesh Bellur, IIT Bombay, India  
• Jesus Carretero, Universidad Carlos III de Madrid, Spain  
• Frederic Desprez, INRIA, France  
• Dieter Kranzlmüller, Ludwig-Maximilians-Universitaet Muenchen, Germany  
• Christine Morin, INRIA, France  
• Thu Nguyen, Rutgers University, USA  
• Vladimir Vlassov, Royal Institute of Technology (KTH), Sweden

**Short Papers Track**

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Co-Chair: Jianwei Yin, Zhejiang University, PR China

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• Cao Bin, College of Computer Science and Technology, Zhejiang University of Technology, China  
• Vinay Boddula, University of Georgia, USA  
• Arash Fard, Hewlett Packard Enterprise, USA  
• Rong Ge, Clemson University, USA  
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• Kyu Lee, University of Georgia, USA  
• Wenhua Li, New York Institute of Technology, USA  
• Xinjian Lu, East China University of Science and Technology, China  
• Shuai Ma, Beihang University, China  
• Rohit Mullangi, University of Georgia, USA  
• Aibek Musaev, University of Alabama, USA  
• Surya Nepal, CSIRO, Australia  
• Balaji Palanisamy, University of Pittsburgh, USA  
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• Michael Sheng, The University of Adelaide, Australia  
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Yun Yang, Swinburne University of Technology, Australia
Emre Yigitoglu, Georgia Institute of Technology, USA

Demonstration and Posters Track

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Co-Chair: Balaji Palanisamy, University of Pittsburg, USA

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- Suren Byna, Lawrence Berkeley National Laboratory, USA
- Toni Collis, EPCC, UK
- Liting Hu, Florida International University, USA
- Suzanne McIntosh, NYU Courant Institute, and Cloudera Inc., USA
- Devesh Tiwari, ORNL, USA
- Ming Zhao, Arizona State University, USA
Keynotes

Keynote 1: C. Mohan (IBM Research)

New Era in Distributed Computing with Blockchains and Databases

A new era is emerging in the world of distributed computing with the growing popularity of blockchains (shared, replicated and distributed ledgers) and the associated databases as a way of integrating inter-organizational work. Originally, the concept of a distributed ledger was invented as the underlying technology of the cryptocurrency Bitcoin. But the adoption and further adaptation of it for use in the commercial or permissioned environments is what is of utmost interest to me and hence will be the focus of this keynote. Computer companies like IBM and Microsoft, and many key players in different vertical industry segments have recognized the applicability of blockchains in environments other than cryptocurrencies. IBM did some pioneering work by architecting and implementing Fabric, and then open sourcing it. Now Fabric is being enhanced via the Hyperledger Consortium as part of The Linux Foundation. A few of the other efforts include Enterprise Ethereum, R3 Corda and BigchainDB.

While there is no standard in the blockchain space currently, all the ongoing efforts involve some combination of database, transaction, encryption, consensus and other distributed systems technologies. Some of the application areas in which blockchain pilots are being carried out are: smart contracts, supply chain management, know your customer, derivatives processing and provenance management. In this talk, I will survey some of the ongoing blockchain projects with respect to their architectures in general and their approaches to some specific technical areas. I will focus on how the functionality of traditional and modern data stores are being utilized or not utilized in the different blockchain projects. I will also distinguish how traditional distributed database management systems have handled replication and how blockchain systems do it. Since most of the blockchain efforts are still in a nascent state, the time is right for database and other distributed systems researchers and practitioners to get more deeply involved to focus on the numerous open problems.

Bio: Dr. C. Mohan has been an IBM researcher for 35 years in the database area, impacting numerous IBM and non-IBM products, the research and academic communities, and standards, especially with his invention of the ARIES family of database locking and recovery algorithms, and the Presumed Abort commit protocol. This IBM (1997), and ACM/IEEE (2002) Fellow has also served as the IBM India Chief Scientist for 3 years (2006-2009). In addition to receiving the ACM SIGMOD Innovation Award (1996), the VLDB 10 Year Best Paper Award (1999) and numerous IBM awards, Mohan was elected to the US and Indian National Academies of Engineering (2009), and was named an IBM Master Inventor (1997). This Distinguished Alumnus of IIT Madras (1977) received his PhD at the University of Texas at Austin (1981). He is an inventor of 50 patents. He is currently focused on Big Data, HTAP and Blockchain technologies. In 2016, he was named a Distinguished Visiting Professor of China’s prestigious Tsinghua University. He has served on the advisory board of IEEE Spectrum, and on numerous conference and journal boards. Mohan is a frequent speaker in North America, Europe and India, and has given talks in 40 countries. He is very active on social media and has a huge network of followers. More information could be found in the Wikipedia page at http://bit.ly/CMwIkP
Web data management has been a topic of interest for many years during which a number of different modelling approaches have been tried. The latest in this approaches is to use RDF (Resource Description Framework), which seems to provide real opportunity for querying at least some of the web data systematically. RDF has been proposed by the World Wide Web Consortium (W3C) for modeling Web objects as part of developing the “semantic web”. W3C has also proposed SPARQL as the query language for accessing RDF data repositories. The publication of Linked Open Data (LOD) on the Web has gained tremendous momentum over the last number of years, and this provides a new opportunity to accomplish web data integration. A number of approaches have been proposed for running SPARQL queries over RDF-encoded Web data: data warehousing, SPARQL federation, and live linked query execution. In this talk, I will review these approaches with particular emphasis on some of our research within the context of gStore project (joint project with Prof. Lei Zou of Peking University and Prof. Lei Chen of Hong Kong University of Science and Technology), chameleon-db project (joint work with Günes Aluç, Dr. Olaf Hartig, and Prof. Khuzaima Daudjee of University of Waterloo), and live linked query execution (joint work with Dr. Olaf Hartig).

Bio: M. Tamer Özsu is Professor of Computer Science at the David R. Cheriton School of Computer Science. His research is in data management focusing on large-scale data distribution and management of non-traditional data. He is a Fellow of the Royal Society of Canada, of the Association for Computing Machinery (ACM), and of the Institute of Electrical and Electronics Engineers (IEEE). He is an elected member of the Science Academy of Turkey, and a member of Sigma Xi and American Association for the Advancement of Science (AAAS). His publications include the book Principles of Distributed Database Systems (with Patrick Valduriez), which is now in its third edition. He has also edited, with Ling Liu, the Encyclopedia of Database Systems, which is now in its second edition. He was the Founding Series Editor of Synthesis Lectures on Data Management (Morgan & Claypool), and is now the Editor-in-Chief of ACM Books. He serves on the editorial boards of three journals, and two book Series. Prof. Dr. M. Tamer Özsu was awarded the ACM SIGMOD Test-of-Time Award in 2015, ACM SIGMOD Contributions Award in 2008 and the Ohio State University College of Engineering Distinguished Alumnus Award in 2008.
Keynote 3: Kenneth Calvert (National Science Foundation)

A Perspective on Distributed Computing Systems: Past, Present and Future

This keynote talk will offer a broad view of distributed computing from the perspective of past and present NSF investments. It will include a look toward future challenges and opportunities facing the distributed computing research community.

Bio: Dr. Kenneth Calvert is Division Director for Computer and Network Systems in the Computer and Information Science and Engineering (CISE) Directorate at the National Science Foundation. He is on rotation from the University of Kentucky, where he is Gartner Group Professor in Network Engineering in the Department of Computer Science. His research deals with the design and implementation of advanced network protocols and services, with particular interest in routing and incentives in future network architectures. He received his Ph.D. in computer science from the University of Texas at Austin. He holds a M.S. in computer science from Stanford University and a B.S. in computer science and engineering from the Massachusetts Institute of Technology. Prior to his appointment at the University of Kentucky, he was a Member of the Technical Staff at Bell Laboratories in Holmdel, NJ, and served on the faculty in the College of Computing at the Georgia Institute of Technology. He is an IEEE Fellow and a member of the ACM.
## Program at a Glance

### Day 1: Monday, June 5, 2017

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<thead>
<tr>
<th>Time</th>
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<th>Track 2 (Salon IV)</th>
<th>Track 3 (Salon VI)</th>
<th>Track 4 (Atlanta)</th>
<th>Track 5 (Columbia)</th>
<th>Track 6 (Savannah)</th>
<th>Track 7 (Charleston 1)</th>
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<td>7:00-8:00</td>
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<td>Continental Breakfast</td>
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<td>8:00-9:30</td>
<td>Workshop: CCN-CPS</td>
<td>Workshop: HotPOST</td>
<td>Workshop: PSBD</td>
<td>Workshop: JCC</td>
<td>Workshop: NSF-JST</td>
<td>Tutorial 1: Serverless Programming (Function as a Service)</td>
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<td>9:30-10:00</td>
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<td>Tutorial 1: Serverless Programming (Function as a Service)</td>
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<td>10:00-12:00</td>
<td>Workshop: CCN-CPS</td>
<td>Workshop: ADSN</td>
<td>Workshop: HotPOST</td>
<td>Workshop: PSBD</td>
<td>Workshop: JCC</td>
<td>Workshop: NSF-JST</td>
<td>Day 1 Tutorial 1: Serverless Programming (Function as a Service)</td>
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<td>15:30-16:00</td>
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<td>Tutorial 1: Serverless Programming (Function as a Service)</td>
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<tr>
<td>16:00-17:00</td>
<td>Workshop: CCN-CPS</td>
<td>Workshop: ADSN</td>
<td>Workshop: PED-BGP</td>
<td>Workshop: IoTCA</td>
<td>Workshop: WoSC</td>
<td>Workshop: NSF-JST</td>
<td>Lunch (Phoenix Ballroom)</td>
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### Day 2: Tuesday, June 6, 2017

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<td>8:00-8:30</td>
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<td>Conference Opening</td>
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<td>Tutorial 1: Serverless Programming (Function as a Service)</td>
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<td>10:00-12:00</td>
<td>Research 1: Distributed Fault Tolerance and Dependability</td>
<td>Research 2: Distributed Operating Systems and Middleware</td>
<td>Vision 1: Internet of Things, Smart Cities and Cyber-Physical Systems</td>
<td>Application 1: Internet of Things, Smart Cities and Cyber-Physical Systems</td>
<td>Application 2: Social Networks and Crowdsourcing</td>
<td>Industry 1: Cloud Data Centers and Performance</td>
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<td>15:30-16:00</td>
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<td>16:00-18:00</td>
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<td>Tutorial 1: Serverless Programming (Function as a Service)</td>
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<tr>
<td>18:00-20:00</td>
<td>The 1st US-Japan Workshop on Collaborative Global Research on Applying Information Technology</td>
<td>Day 2 (Savannah)</td>
<td>Tutorial 1: Serverless Programming (Function as a Service)</td>
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<td>7:30-8:30</td>
<td>Continental Breakfast (Foyer)</td>
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<td>8:30-9:30</td>
<td>Keynote 2 (Phoenix Ballroom)</td>
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<td>9:30-10:00</td>
<td>Coffee Break (Foyer)</td>
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<td>12:00-13:30</td>
<td>Conference Luncheon (Phoenix Ballroom)</td>
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<td>15:30-16:00</td>
<td>Coffee Break (Foyer)</td>
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<tr>
<td>19:00-21:00</td>
<td>Organization Event (Invitation Only)</td>
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### Day 4: Thursday, June 8, 2017

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<td>8:30-9:30</td>
<td>Keynote 3 (Phoenix Ballroom)</td>
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<td>9:30-10:00</td>
<td>Coffee Break (Foyer)</td>
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<tr>
<td>12:00-13:30</td>
<td>Business Lunch including Awards and ICDCS 2018 Announcements (Phoenix Ballroom)</td>
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<tr>
<td>13:30-15:30</td>
<td>Plenary Panel &amp; Conference Closing Remarks (Phoenix Ballroom)</td>
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## Day 1 – Monday, June 5, 2017

Ten Workshops and two tutorials (see Program at a glance and workshops website and ICDCS 2017 website for details)

### 7:00-8:00 Monday, June 5, 2017

Continental Breakfast  
**Location:** Foyer

### 8:00-9:30 Monday, June 5, 2017

**Tutorial 1: Serverless Programming (Function as a Service)**  
**Location:** Charleston 1

Paul Castro (IBM T.J. Watson Research Center), Vatche Ishakian (Bentley University), Vinod Muthusamy (IBM T.J. Watson Research Center), Aleksander Slominski (IBM T.J. Watson Research Center)

**Workshop: CCN-CPS, Session 1**  
**Location:** Salon II

**Session Chair: Nader Mohamed (Middleware Technologies Lab.)**

**Policies Guiding Cohesive Interactions among Internet of Things with Communication Cloud and Social Networks**  
Henry Hexmoo (Southern Illinois University)

**Enhanced Security of Building Automation Systems Through Microkernel-Based Controller Platforms**  
Xiaolong Wang (University of South Florida), Richard Habeeb (University of South Florida), Xinming Ou (University of South Florida), Siddharth Amaravadi (Kansas State University), John Hatcliff (Kansas State University), Masaaki Mizuno (Kansas State University), Mitchell L Neilsen (Kansas State University), Raj Rajagopalan (Honeywell), Sridatsan Varadarajan (Honeywell Aerospace Advanced Technology Labs)

**High level Design of a Home Autonomous System Based on Cyber Physical System Modeling**  
Basman Alhafidh (Florida Institute of Technology), William H. Allen (Florida Institute of Technology)

**Workshop: HotPOST, Session 1**  
**Location:** Salon VI

**Keynote Speech:** A Markov Game Theoretic Approach for Power Grid Security  
Charles A. Kamhoua (Air Force Research Laboratory)

**Router-based Brokering for Surrogate Discovery in Edge Computing**  
Julien Gedeon (Technische Universität Darmstadt), Christian Meurisch (Technische Universität Darmstadt), Disha Bhat (Technische Universität Darmstadt), Michael Stein (Technische Universität Darmstadt), Lin Wang (Technische Universität Darmstadt), Max Mühlhäuser (Technische Universität Darmstadt)

**Modeling the Spread of Influence for Independent Cascade Diffusion Process in Social Networks**  
Zesheng Chen (Indiana University - Purdue University Fort Wayne), Kurtis Taylor (Indiana University - Purdue University Fort Wayne)

**Workshop: PSBD, Opening and Invited Talks**  
**Location:** Atlanta

**Keynote Speech:** Big Data - Security and Privacy (and Transparency)  
Elisa Bertino (Purdue University)

**Invited Talk:** Supporting Time-varying Privacy with Self-emerging Data  
Balaji Palanisamy (University of Pittsburgh)

**Workshop: JCC, Session 1**  
**Location:** Columbia

**Heterogeneous Malware Spread Process in Star Network**  
Libo Jiao (Tsinghua University), Hao Yin (Tsinghua University), Dongchao Guo (Tsinghua University), Yongqiang Lyu (Tsinghua University)

**Cost Reduction in Hybrid Clouds for Enterprise Computing**
Biyu Zhou (Institute of Computing Technology, Chinese Academy of Sciences), Fa Zhang (Institute of Computing Technology, Chinese Academy of Sciences), Jie Wu (Temple University), Zhiyong Liu (Institute of Computing Technology, Chinese Academy of Sciences)

**DC-RSF: A Dynamic and Customized Reputation System Framework for Joint Cloud Computing**
Fanghua Ye (Sun Yat-sen University), Zibin Zheng (Sun Yat-sen University), Chuan Chen (Sun Yat-sen University), Yuren Zhou (Sun Yat-sen University)

**Web Service Appliance Based on Unikernel**
Kai Yu (National Lab for Parallel and Distributed Processing), Chengfei Zhang (National Lab for Parallel and Distributed Processing), Yunxiang Zhao (National Lab for Parallel and Distributed Processing)

**Analysis and Evaluation of the GAS Model for Distributed Graph Computation**
Wang Jinyan (National Lab for Parallel and Distributed Processing), Zhang Chengfei (National Lab for Parallel and Distributed Processing)

**Traffic Signs Detection Based on Faster R-CNN**
Zhongrong Zuo (National Lab for Parallel and Distributed Processing), Kai Yu (National Lab for Parallel and Distributed Processing), Qiao Zhou (National Lab for Parallel and Distributed Processing), Xu Wang (National Lab for Parallel and Distributed Processing), Ting Li (National Lab for Parallel and Distributed Processing)

**JCLedger: A Blockchain Based Distributed Ledger for JointCloud Computing**
Xiang Fu (National University of Defense Technology), Huaimin Wang (National University of Defense Technology), Peichang Shi (National University of Defense Technology), Yingwei Fu (National University of Defense Technology), Yijie Wang (National University of Defense Technology)

**Corporation Architecture for Multiple Cloud Service Providers in JointCloud Computing**
Peichang Shi (National University of Defense Technology), Huaimin Wang (National University of Defense Technology), Xikun Yue (National University of Defense Technology), Shilan Yang (National University of Defense Technology), Shangzhi Yang (National University of Defense Technology), Yuxing Peng (National University of Defense Technology)

**Sharing Privacy Data in Semi-Trustworthy Storage through Hierarchical Access Control**
Yuzhao Wu (Tsinghua University), Yongqiang Lyu (Tsinghua University), Qian Fang (Tsinghua University), Geng Zheng (Tsinghua University), Hao Yin (Tsinghua University), Yuanchun Shi (Tsinghua University)

**Workshop: NSF-JST**
**Location: Savannah**

**9:30-10:00 Monday, June 5, 2017**

Coffee Break
**Location: Phoenix Ballroom**

**10:00-12:00 Monday, June 5, 2017**

**Tutorial 1: Serverless Programming (Function as a Service)**
**Location: Charleston 1**
Paul Castro (IBM T.J. Watson Research Center), Vatche Ishakian (Bentley University), Vinod Muthusamy (IBM T.J. Watson Research Center), Aleksander Slominski (IBM T.J. Watson Research Center)

**Workshop: CCN-CPS, Session 2**
**Location: Salon II**

**Session Chair: Jameela AlJaroodi (Robert Morris University)**

**A Cyber Physical Buses-and-Drones Mobile Edge Infrastructure for Large Scale Disaster Emergency Communications**
Mamta Narang (Auckland University of Technology), William Liu (Auckland University of Technology), Jairo A Gutierrez (Auckland University of Technology), Luca Chiaraviglio (University of Rome Tor Vergata)

**A Performance Comparison of Containers and Virtual Machines in Workload Migration Context**
Kumar Gaurav (VMware Software India Pvt Ltd), Pavan Karkun (VMware Software India pvt LTD), Y. C. Tay (National University of Singapore)
Towards Service-Oriented Middleware for Cyber Physical Systems
Nader Mohamed (Middleware Technologies Lab.), Sanja Lazarova-Molnar (University of Southern Denmark)

Networking and Communication in Cyber Physical Systems
Imad Jawhar (UAE University), Jameela Al-Jaroodi (Robert Morris University)

Workshop: ADSN, Session 1: Keynote, Session 2: Assuring Temporal Fairness and Securing Communication
Location: Salon IV

Keynote Speech: Dependability Challenges in 5G Cellular Networks
Douglas M. Blough (Georgia Institute of Technology)

Understanding and Improving Temporal Fairness on an Electronic Trading Venue
Hayden Melton (Deakin University)

CertificateLess Cryptography-based Rule Management Protocol for Advanced Mission Delivery Networks
Jongho Won (Purdue University), Ankush Singla (Purdue University), Elisa Bertino (Purdue University)

Workshop: HotPOST, Session 2
Location: Salon VI

Thank You For Being A Friend: An Attacker View on Online-Social-Network-based Sybil Defenses
David Koll (University of Goettingen), Martin Schwarzaier (University of Goettingen), Jun Li (University of Oregon), Xiang-Yang Li (University of Science and Technology of China), Xiaoming Fu (University of Goettingen)

Efficient Dynamic Service Function Chain Combination of Network Function Virtualization
Wenke Yan (Beijing University of Posts and Telecommunications), Konglin Zhu (Beijing University of Posts and Telecommunications), Lin Zhang (Beijing University of Posts and Telecommunications), Sixi Su (Beijing University of Posts and Telecommunications)

When Augmented Reality meets Big Data
Carlos Bermejo (The Hong Kong University of Science and Technology), Zhanpeng Huang (The Hong Kong University of Science and Technology), Tristan Braud (The Hong Kong University of Science and Technology), Pan Hui (The Hong Kong University of Science and Technology)

Sampling Based Efficient Algorithm to Estimate the Spectral Radius of Large Graphs
Samar Abbas (Lahore University of Management Sciences), Juvaria Tariq (Lahore University of Management Sciences), Arif Zaman (Lahore University of Management Sciences), Imdadullah Khan (Lahore University of Management Sciences)

Extemporaneous Micro-Mobile Service Execution Without Code Sharing
Zheng Song (Virginia Tech), Minh Le (Utah State University), Young-Woo Kwon (Utah State University), Eli Tilevich (Virginia Tech)

Preventing Colluding Identity Clone Attacks in Online Social Networks
Georges A. Kamhoua (Florida International University), Niki Pissinou (Florida International University), S.S. Iyengar (Florida International University), Jonathan Beltran (Florida International University), Charles Kamhoua (Air Force Research Laboratory), Brandon L Hernandez (UTRGV), Laurent Njilla (Air Force Research Laboratory)

Workshop: PSBD, Research Session
Location: Atlanta

A novel game-theoretic model for content-adaptive image steganography
Qi Li (Hunan University), Xin Liao (Hunan University), Guoyong Chen (Hunan University), Liping Ding (Guangzhou Branch of Institute of Software, Chinese Academy of Science)

A Fine-grained Access Control Scheme for Big Data Based on Classification Attributes
Tengfei Yang (State Key Laboratory of Information Security, Institute of Information Engineering, Chinese Academy of Sciences), Peisong Shen (State Key Laboratory of Information Security, Institute of Information Engineering, Chinese Academy of Sciences), Xue Tian (State Key Laboratory of Information Security, Institute of Information Engineering, Chinese Academy of Sciences), Chi Chen (State Key Laboratory of Information Security, Institute of Information Engineering, Chinese Academy of Sciences)

Social-Aware Decentralization for Efficient and Secure Multi-Party Computation
Yuzhe Tang (Syracuse University), Sucheta Soundarajan (Syracuse University)

Statistical Anomaly Detection on Metadata Streams via Commodity Software to Protect Company
Christine Chen (University of Portland), James Gurganus (Micro Systems Engineering, Inc.)

Computational improvements in parallelized k-anonymous microaggregation of large databases
Ahmad Mohamad Mezher (Universitat Politècnica de Catalunya (UPC)), Alejandro García Álvarez (Universitat Politècnica de Catalunya (UPC)), David Reblolo-Monedero (Universitat Politècnica de Catalunya (UPC)), Jordi Forné (Universitat Politècnica de Catalunya (UPC))
**Workshop: JCC, Session 2**

**Location: Columbia**

**A Reliability Benchmark for Big Data Systems on JointCloud**
Yingying Zheng (Institute of Software, Chinese Academy of Sciences), Lijie Xu (Institute of Software, Chinese Academy of Sciences), Wei Wang (Institute of Software, Chinese Academy of Sciences), Wei Zhou (KSYUN), Ying Ding (Changchun University of Science and Technology)

**UCPR: User Classification and Influence Analysis in Social Network**
Cong Zha (Tsinghua University), Yongqiang Lv (Tsinghua University)

**Adaptive Routing Algorithm for Joint Cloud Video Delivery**
Zexun Jiang (Tsinghua University), Hao Yin (Tsinghua University)

**Towards Efficient Resource Management in Virtual Clouds**
Bo An (Peking University), Junming Ma (Peking University), Donggang Cao (Peking University), Gang Huang (Peking University)

**Monitoring and Billing of A Lightweight Cloud System Based on Linux Container**
Yujian Zhu (Peking University), Junming Ma (Peking University), Bo An (Peking University), Donggang Cao (Peking University)

**Building emulation framework for non-volatile memory**
Guoliang Zhu (National University of Defense Technology), Kai Lu (National University of Defense Technology), Xiaoping Wang (National University of Defense Technology)

**Seflow: Efficient Flow Scheduling for Data-Parallel Jobs**
Qiao Zhou (National Lab for Parallel and Distributed Processing), Ziyang Li (National Lab for Parallel and Distributed Processing), Ping Zhong (Central South University), Tian Tian (National Lab for Parallel and Distributed Processing), Yuxing Peng (National Lab for Parallel and Distributed Processing)

**Online Encoding for Erasure-Coded Distributed Storage Systems**
Fangliang Xu (National University of Defense Technology), Yijie Wang (National University of Defense Technology), Xingkong Ma (National University of Defense Technology)

**Workshop: NSF-JST, Session 1**

**Location: Savannah**

**Accelerating Big Data Infrastructure and Applications**
Kevin Brown (Tokyo Institute of Technology), Tianqi Xu (Tokyo Institute of Technology), Keita Iwabuchi (Tokyo Institute of Technology), Kento Sato (Lawrence Livermore National Laboratory), Adam Moody (Lawrence Livermore National Laboratory), Kathryn Mohror (Lawrence Livermore National Laboratory), Nikhil Jain (Lawrence Livermore National Laboratory), Abhinav Bhave (Lawrence Livermore National Laboratory), Martin Schulz (Lawrence Livermore National Laboratory), Roger Pearce (Lawrence Livermore National Laboratory), Maya Gokhale (Lawrence Livermore National Laboratory), Satoshi Matsuoka (Tokyo Institute of Technology)

**Disaster Network Evolution Using Dynamic Clustering of Twitter Data**
Krishna Kant (Temple University), Yilang Wu (Aizu University), Shanshan Zhang (Temple University), Junbo Wang (Aizu University), Amitangshu Pal (Temple University)

**Single-epoch supernova classification with deep convolutional neural networks**
Akisato Kimura (NTT), Chihiro Akiyama (Kavli IPMU, The University of Tokyo), Masaomi Tanaka (National Astronomical Observatory of Japan), Naoki Yasuda (Kavli IPMU, The University of Tokyo), Naonori Ueda (NTT), Naoki Yoshida (Kavli IPMU, The University of Tokyo)

**Enabling Large Scale Deliberation using Ideation and Negotiation-Support Agents**
Katsuhide Fujita (Tokyo University of Agriculture and Technology), Takayuki Ito (Nagoya Institute of Technology), Mark Klein (MIT)

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**12:00-13:30 Monday, June 5, 2017**

**Lunch**

**Location: Foyer**

**13:30-15:30 Monday, June 5, 2017**

**Workshop: CCN-CPS, Session 3**

**Location: Salon II**

**Session Chair: Uttam Ghosh (Tennessee State University)**

**Optimal Deployment of Charging Stations for Electric Vehicles: A Formal Approach**
Amarjit Datta (Tennessee Technological University), Brian Ledbetter (Tennessee Technological University), Mohammad Ashiqur Rahman (Tennessee Technological University)

**Formal Verification of Control Strategies for a Cyber Physical System**
Amjad Gawanmeh (Khalifa University of Science and Technology), Ali Alwadi (Auckland University of Technology), Sazia Parvin (University of New South Wales)

**Lightweight Detection and Isolation of Black Hole Attacks in Connected Vehicles**
Sami Albouq (Oakland University), Erik Fredericks (Oakland University)

**A new threat assessment method for integrating an IoT infrastructure in an information system**
Bruno Dorsemaine (Orange Labs), Jean-Philippe Gaulier (Orange Labs), Jean-Philippe Wary (Orange Labs), Nizar Kheir (Thales), Pascal Urien (Telecom ParisTech)

**Workshop: ADSN, Session 3: Network Assurance**

**Location: Salon IV**

**Faulty Sensor Data Detection in Wireless Sensor Networks Using Logistical Regression**
Tianyu Zhang (University of Hyogo), Qian Zhao (University of Hyogo), Yukikazu Nakamoto (University of Hyogo)

**An Adaptable Enhanced Routing Method for Multiple Gateway-based Wireless Sensor Networks Using Secure Dispersed Data Transfer**
Ryuma Tani (Hiroshima City University), Kento Aoi (Hiroshima City University), Eitaro Kohno (Hiroshima City University), Yoshiaki Kakuda (Hiroshima City University)

**Progressive Download Method Based on Timer-Driven Requesting Schemes Using Multiple TCP Flows on Multiple Paths**
Hiroaki Horiba (Hiroshima City University), Tokumasa Hiraoka (Hiroshima City University), Junichi Funasaki (Hiroshima City University)

**Workshop: PED-BGP, Session 1**

**Location: Salon VI**

**Keynote speech: Application-aware data dissemination**
Bettina Kemme (McGill University)

Bruno Padilha (University of Sao Paulo), André Luis Schwerz (Federal University of Technology), Rafael Liberato Roberto (Federal University of Technology)

**Querying Workflow Logs**
Yan Tang (University of California at Santa Barbara), Jianwen Su (University of California at Santa Barbara)

**On the integration of event-based and transaction-based architectures for Supply Chains**
Zhijie Li (Indiana University–Purdue University Indianapolis), Haoyan Wu (Indiana University–Purdue University Indianapolis), Brian King (Indiana University–Purdue University Indianapolis), Zina Ben-Miled (Indiana University–Purdue University Indianapolis), John Wassick (The Dow Chemical Company), Jeffrey Tazelaar (The Dow Chemical Company)

**Workshop: IoTCA, Session 1**

**Location: Atlanta**

**Keynote Speech: The Internet of Things, People, and Systems: From the Edge to the Cloud**
Schahram Dustdar (TU Wien)

**Towards Privacy-Aware Smart Buildings: Capturing, Communicating, and Enforcing Privacy Policies and Preferences**
Primal Pappachan (University of California Irvine), Martin Degelingy (Carnegie Mellon University), Roberto Yus (University of California Irvine), Anupam Dasy (Carnegie Mellon University), Sruti Bhagavatulay (Carnegie Mellon University), William Melichery (Carnegie Mellon University), Pardis Emami Naeiniy (Carnegie Mellon University), Shikun Zhangy (Carnegie Mellon University), Luo Baiy (Carnegie Mellon University), Alfred Kobsh (University of California Irvine), Sharad Mehrotra (University of California Irvine), Norman Sadeh (Carnegie Mellon University), Nalini Venkatasubramanian (University of California Irvine)

**Deploying Data-Driven Security Solutions on Resource-Constrained Wearable IoT System**
Hang Cai (Worcester Polytechnic Institute), Tianlong Yun (Worcester Poltechnic Institute), Josiah Hester (Dartmouth College), Krishna K. Venkatasubramanian (Clemson University)

**A Motif based IoT Framework for Data Efficiency**
Akash Sahoo (Texas A&M University), Rabi Mahapatra (Texas A&M University)

**Workshop: WoSC, Session 1**
Location: Columbia

Keynote Speech: Serverless Computing: Patterns and Road Ahead
Roger Barga (Amazon Web Services)

Ripple: Home Automation for Research Data Management
Ryan Chard (Argonne National Laboratory), Kyle Chard (Computation Institute, University of Chicago and Argonne National Lab), Jason Alt (National Center for Supercomputing Applications), Dilworth Parkinson (Lawrence Berkeley National Laboratory), Steve Tuecke (Computation Institute, University of Chicago and Argonne National Lab), Ian Foster (Argonne National Laboratory & The University of Chicago)

Pipsqueak: Lean Lambdas with Large Libraries
Edward Oakes (University of Wisconsin-Madison), Leon Yang (University of Wisconsin-Madison), Kevin Houck (University of Wisconsin-Madison), Tyler Harter (Microsoft Gray Systems Lab), Andrea C. Arpaci-Dusseau (University of Wisconsin-Madison), Remzi H. Arpaci-Dusseau (University of Wisconsin-Madison)

Leveraging the Serverless Architecture for Securing Linux Containers
Nilton Bila (IBM), Paolo Dettori (IBM), Ali Kanso (IBM), Yuji Watanabe (IBM), Alaa Youssef (IBM)

Workshop: NSF-JST
Location: Savannah

15:30-16:00 Monday, June 5, 2017
Coffee Break
Location: Foyer

16:00-17:00 Monday, June 5, 2017
Workshop: CCN-CPS, Session 4
Location: Salon II

Session Chair: Bruno Dorsemaine (Orange Labs)

A Security Framework for SDN-enabled Smart Power Grids
Uttam Ghosh (Tennessee State University), Pushpita Chatterjee (SRM RESEARCH INSTITUTE), Sachin Shetty (Old Dominion University)

Real-time Monitoring Steam Generators using a Hybrid Imaging System
Mahmoud Meribout (Petroleum Institute), Imran Saied (Petroleum Institute), Esra Al Hosani (Adco Group)

Securing big Data Efficiently through Microaggregation Technique and Huffman Compression
Shakila Mahjabin Tonni (Bangladesh Army International University of Science and Technology), Mohammad Zahidur Rahman (Jahangirnagar University), Sazia Parvin (University of New South Wales), Amjad Gawanmeh (Khalifa University of Science and Technology)

Model Based Energy Consumption Analysis of Wireless Cyber Physical Systems
Jing Liu (Peking University), Ping Wang (Peking University), Jinlong Lin (Peking University), Chao-Hsien Chu (Pennsylvania State University)

Workshop: ADSN, Session 4: Panel on “Assurance in Internet of Things (IoT)”
Location: Salon IV

Moderator: Eitaro Kohno

Workshop: PED-BGP, Session 2
Location: Salon VI

CacheDOCS: A Dynamic Key-Value Object Caching Service
Julien Gascon-Samson (University of British Columbia), Michael Coppinger (McGill University), Fan Jin (McGill University), Jörg Kienzle (McGill University), Bettina Kemme (McGill University)

WolfPath: Accelerating iterative traversing-based graph processing algorithms on GPU
Huanzhou Zhu (University of Warwick), Ligang He (University of Warwick)

A Novel Auction-based Query Pricing Schema
Xingwang Wang (Jilin University), Xiaohui Wei (Jilin University), Shang Gao (Jilin University), Yuanyuan Liu (Jilin University), Zongpeng Li (University of Calgary)

BlockGraphChi: Enabling Block Update in Out-of-core Graph Processing
Workshop: IoTCA, Session 2  
Location: Atlanta

CoTWare: A Cloud of Things Middleware  
Jameela Al-Jaroodi (Robert Morris University), Nader Mohamed (Middleware Technologies Lab.), Imad Jawhar (Midcomp Research Center)

Securing the Internet of Things: A Meta-Study of Challenges, Approaches, and Open Problems  
Mahmud Hossain (University of Alabama at Birmingham), Ragib Hasan (University of Alabama at Birmingham), Anthony Skjellum (Auburn University)

Internet of Things Framework for Smart Learning Analytics  
Ali Yavari (Swinburne University of Technology), Reza Soltanpoor (RMIT University)

Workshop: WoSC, Session 2  
Location: Columbia

Serverless Computing: Design, Implementation, and Performance  
Garrett McGrath (University of Notre Dame), Paul R. Brenner (University of Notre Dame)

Panel debate on the novelty and challenges of serverless computing  
Participants: TBA

Workshop: NSF-JST  
Location: Savannah

17:00-18:00 Monday, June 5, 2017

Workshop: PED-BGP, Session 2  
Location: Salon VI

Incremental Parallel Computing using Transactional Model in Large-scale Dynamic Graph Structures  
Anand Tripathi (University of Minnesota), Rahul R. Sharma (University of Minnesota), Manu Khandelwal (University of Minnesota), Tanmay Mehta (University of Minnesota), Varun Pandey (University of Minnesota)

Against Signed-Graph Deanonymization Attacks: Privacy Protection for Social Networks  
Jianliang Gao (Central South University), Yu Liu (Central South University), Ping Zhong (Central South University), Jianxin Wang (Central South University)
Day 2 – Tuesday, June 6, 2017

7:00-8:00 Tuesday, June 6, 2017
Continental Breakfast
Location: Foyer

8:00-8:30 Tuesday, June 6, 2017
Conference Opening
Location: Phoenix Ballroom

8:30-9:30 Tuesday, June 6, 2017
Keynote 1 by C. Mohan (IBM Research)
Location: Phoenix Ballroom
Session Chair: Masaru Kitsuregawa (University of Tokyo)

9:30-10:00 Tuesday, June 6, 2017
Coffee Break
Location: Foyer

10:00-12:00 Tuesday, June 6, 2017
Research 1: Distributed Fault Tolerance and Dependability
Location: Salon I
Session Chair: Mudhakar Srivatsa (IBM T.J. Watson Research Center)
Timely, Reliable, and Cost-Effective Internet Transport Service using Dissemination Graphs
Amy Babay (Johns Hopkins University), Emily Wagner (Johns Hopkins University, LTN Global Communications), Michael Dinitz (Johns Hopkins University), Yair Amir (Johns Hopkins University, LTN Global Communications)
Pronto: Efficient Test Packet Generation for Dynamic Network Data Planes
Yu Zhao (University of Kentucky), Huazhe Wang (University of California at Santa Cruz), Xin Lin (University of California at Santa Cruz), Tingting Yu (University of Kentucky), Chen Qian (University of California at Santa Cruz)
Agar: A Caching System for Erasure-Coded Data
Raluca Halalai (University of Neuchâtel), Pascal Felber (University of Neuchâtel), Anne-Marie Kermarrec (INRIA), François Taïani (IRISA)
High performance recovery for parallel state machine replication
Odorico Mendizabal (FURG), Fernando Luis Dotti (PUCRS), Fernando Pedone (University of Lugano)
On Data Parallelism of Erasure Coding in Distributed Storage Systems
Jun Li (University of Toronto), Baochun Li (University of Toronto)
MeteorShower: Minimizing Request Latency for Majority Quorum-based Data Consistency Algorithms in Multiple Data Centers
Ying Liu (KTH Royal Institute of Technology), Xi Guan (KTH Royal Institute of Technology), Vladimir Vlassov (KTH Royal Institute of Technology), Seif Haridi (KTH Royal Institute of Technology)

Research 2: Distributed Operating Systems and Middleware
Location: Salon II
Session Chair: Peter Pietzuch (Imperial College London)
LSbM-tree: Re-enabling high-speed caching in Data Management for Mixed Reads and Writes
Dejun Teng (The Ohio State University), Lei Guo (Google), Rubao Lee (The Ohio State University), Feng Chen (Louisiana State University), Siyuan Ma (The Ohio State University), Xiaodong Zhang (The Ohio State University), Yanfeng Zhang (Northeastern University)
Incremental Topology Transformation for Publish/Subscribe Systems Using Integer Programming
Pooya Salehi (Technical University of Munich), Kaiwen Zhang (Technical University of Munich), Hans-Arno Jacobsen (University of Toronto)
milliScope: a Fine-Grained Monitoring Framework for Performance Debugging of n-Tier Web Services
Chien-An Lai (Georgia Institute of Technology), Josh Kimball (Georgia Institute of Technology), Tao Zhu (Georgia Institute of Technology), Qingyang Wang (Louisiana State University), Calton Pu (Georgia Institute of Technology)

**Stark: Optimizing In-Memory Computing For Dynamic Dataset Collections**
Shen Li (IBM Research), Md Tanvir Al Amin (UIUC), Raghu Ganti (IBM Research), Mudhakar Srivatsa (IBM Research), Shaohan Hu (IBM Research), Yiran Zhao (UIUC), Tarek Abdelzaher (UIUC)

**CRESON: Callable and Replicated Shared Objects over NoSQL**
Pierre Sutra (Télécom SudParis, CNRS, Université Paris-Saclay, France), Etienne Rivière (University of Neuchatel), Cristian Cotes (Universitat Rovira i Virgili), Marc Sánchez Artigas (Universitat Rovira i Virgili), Pedro Garcia Lopez (Universitat Rovira i Virgili), Emmanuel Bernard (Red Hat), William Burns (Red Hat), Galder Zamarreno (Red Hat)

**Virtualized Network Coding Functions on the Internet**
Linquan Zhang (University of Calgary), Shangqi Lai (The University of Hong Kong), Chuan Wu (The University of Hong Kong), Zongpeng Li (University of Calgary), Chuanxiong Guo (Microsoft Research)

**Vision 1: Internet of Things, Smart Cities and Cyber-Physical Systems**
Location: Atlanta

**Session Chair: Ling Liu (Georgia Institute of Technology)**

**Observable-by-Design**
Masaru Kitsuregawa (National Institute of Informatics (NII)/Institute of Industrial Science, University of Tokyo)

**An Architectural Vision for a Data-Centric IoT: Rethinking Things, Trust and Clouds**
Eve M. Schooler (Intel), David Zage (Intel), Jeff Sedayao (Intel), Hassnaa Moustafa (Intel), Andrew Brown (Intel), Moreno Ambrosin (University of Padua)

**Edge Computing and IoT Based Research for Building Safe Smart Cities Resistant to Disasters**
Teruo Higashino (Osaka University), Hirozumi Yamaguchi (Osaka University), Akihito Hiromori (Osaka University), Akira Uchiyama (Osaka University), Keiichi Yasumoto (Nara Institute of Science and Technology)

**The Internet of Things and Multiagent Systems: Decentralized Intelligence in Distributed Computing**
Munindar Singh (North Carolina State University), Amit Chopra (Lancaster University)

**Internet of Things: From Small- to Large-Scale Orchestration**
Charles Consel (Inria / Bordeaux INP), Milan Kabac (Imperial College)

**EdgeOS_H: A Home Operating System for Internet of Everything**
Jie Cao (Wayne State University), Lanyu Xu (Wayne State University), Raef Abdallah (Wayne State University), Weisong Shi (Wayne State University)

**Application 1: Security, Privacy, Trust in Distributed Systems**
Location: Columbia

**Session Chair: Songqing Chen (George Mason University)**

**Privacy Preserving User-based Recommender System**
Shahriar Badsha (RMIT University), Xun Yi (RMIT University), Ibrahim Khalil (RMIT University), Elisa Bertino (Purdue University)

**Privacy Preserving Optimization of Participatory Sensing in Mobile Cloud Computing**
Ye Yan (Oakland University), Dong Han (Oakland University), Tao Shu (Auburn University)

**SPHINX: A Password Store that Perfectly Hides Passwords from Itself**
Maliheh Shirvanian (University of Alabama at Birmingham), Stanislaw Jarecki (University of California at Irvine), Hugo Krawczyk (IBM Research), Nitesh Saxena (University of Alabama at Birmingham)

**When Smart TV Meets CRN: Privacy-preserving Fine-grained Spectrum Access**
Chaowen Guan (State University of New York at Buffalo), Aziz Mohaisen (State University of New York at Buffalo), Zhi Sun (State University of New York at Buffalo), Lu Su (State University of New York at Buffalo), Kui Ren (State University of New York at Buffalo), Yaling Yang (Virginia Tech)

**Revisiting Security Risks of Asymmetric ScalarProduct Preserving Encryption and Its Variants**
Weipeng Lin (Simon Fraser Univeristy), Ke Wang (Simon Fraser University), Zhilin Zhang (Simon Fraser University), Hong Chen (Renmin University of China)

**An Adversary-Centric Behavior Modeling of DDoS Attacks**
An Wang (George Mason University), Aziz Mohaisen (SUNY Buffalo), Songqing Chen (George Mason University)
Application 2: Social Networks and Crowdsourcing
Location: Nashville

Session Chair: Yao Liu (SUNY Binghamton)

Anti-Malicious Crowdsourcing Using the Zero-Determinant Strategy
Qin Hu (Beijing Normal University), Shengling Wang (Beijing Normal University), Liran Ma (Texas Christian University), Rongfang Bie (Beijing Normal University), Xizhen Cheng (George Washington University)

JPR: Exploring Joint Partitioning and Replication for Traffic Minimization in Online Social Networks
Jingya Zhou (Soochow University), Jianxi Fan (Soochow University)

Optimizing Source Selection in Social Sensing in the Presence of Influence Graphs
Huajie Shao (UIUC), Shiguang Wang (UIUC), Shen Li (UIUC), Shuochoao Yao (UIUC), Yiran Zhao (UIUC), Md Tanvir Al Amin (UIUC), Tarek Abdelzaher (UIUC), Lance Kaplan (UIUC)

Dynamic Contract Design for Heterogeneous Workers in Crowdsourcing for Quality Control
Chenxi Qiu (Pennsylvania State University), Anna Squicciarini (Pennsylvania State University), Sarah Rajtmajer (Pennsylvania State University), James Caverlee (Texas A&M University)

Joint Request Balancing and Content Aggregation in Crowdsourced CDN
Ming Ma (Tsinghua University), Zhi Wang (Tsinghua University), Kun Yi (Tsinghua University), Jiangchuan Liu (South China Agricultural University), Lifeng Sun (Tsinghua University)

Shrink: A Breast Cancer Risk Assessment Model Based on Medical Social Network
Ali Li (University of Science and Technology Beijing), Rui Wang (University of Science and Technology Beijing), Lei Xu (University of Science and Technology Beijing)

Industry 1: Cloud Data Centers and Performance
Location: Charleston 1

Session Chair: Raghu Ganti (IBM T.J. Watson Research Center)

Phoenix: Constraint aware scheduling for heterogeneous datacenters
Prashanth Thinakaran (Pennsylvania State University), Jashwant Raj Gunasekaran (Pennsylvania State University), Bikash Sharma (Microsoft Corp), Mahmut Kandemir (Pennsylvania State University), Chita Das (Pennsylvania State University)

Dual Scaling VMs and Queries: Cost-effective Latency Curtailment
Juan Pérez (University of Melbourne), Robert Birke (IBM Research Zurich), Mathias Björkqvist (IBM Research Zurich), Lydia Y. Chen (IBM Research Zurich)

A framework for enabling security services collaboration across multiple domains
Daniel Migault (Ericsson Security Research), Marcos Simplicio Junior (Escola Politécnica), Bruno Barros (Escola Politécnica), Makan Pourzandi (Ericsson Security Research), Thiago Almeida (Escola Politécnica), Ewerton Andrade (Escola Politécnica), Tereza Carvalho (Escola Politécnica)

Group Clustering Using Inter-Group Dissimilarities
Debessay Fesehaye Kassa (VMware), Lenin Singaravelu (Google), Chien-Chia Chen (VMware), Xiaobo Huang (VMware), Amitabha Banerjee (VMware), Ruijin Zhou (VMware), Rajesh Somasundaran (VMware)

Comprehensive Measurement and Analysis of the User-Perceived I/O Performance in a Production Leadership-Class Storage System
Lipeng Wan (Oak Ridge National Laboratory), Matthew Wolf (Oak Ridge National Laboratory), Feiyi Wang (Oak Ridge National Laboratory), Jong Youl Cho (Oak Ridge National Laboratory), George Ostruchov (Oak Ridge National Laboratory), Scott Klasky (Oak Ridge National Laboratory)

12:00-13:30 Tuesday, June 6, 2017

Lunch
Location: Phoenix Ballroom

13:30-15:30 Tuesday, June 6, 2017

Research 3: Security and Privacy in Distributed Systems I
Location: Salon I

Session Chair: Roland Yap (National University of Singapore)
Consensus Robustness and Transaction De-Anonymization in the Ripple Currency Exchange System
Adriano Di Luzio (Sapienza University of Rome), Alessandro Mei (Sapienza University of Rome), Julinda Stefa (Sapienza University of Rome)

Learning privacy habits of PDS owners
Bikash Singh (University of Insubria), Barbara Carminati (university of insubria), Elena Ferrari (university of insubria)

City-Hunter: Hunting Smartphones in Urban Areas
Xuefeng Liu (Hong Kong Polytechnic University), Jiaqi Wen (Hong Kong Polytechnic University), Shaojie Tang (University of Texas at Dallas), Jinnong Cao (Hong Kong Polytechnic University), Jiaxing Shen (Hong Kong Polytechnic University)

When Seeing Isn't Believing: On Feasibility and Detectability of Scapegoating in Network Tomography
Shangqing Zhao (University of South Florida), Zhuo Lu (University of South Florida), Cliff Wang (North Carolina State University/Army Research Office)

You Can Hear But You Cannot Steal: Defending against Voice Impersonation Attacks on Smartphones
Si Chen (University at Buffalo / West Chester University), Kui Ren (University at Buffalo), Sixu Piao (University at Buffalo), Cong Wang (City University of Hong Kong), Qian Wang (Wuhan University), Jian Weng (Jinan University), Lu Su (University at Buffalo), Aziz Mohaisen (University at Buffalo)

Flow Reconnaissance via Timing Attacks on SDN Switches
Sheng Liu (University of North Carolina at Chapel Hill), Michael Reiter (University of North Carolina at Chapel Hill), Vyas Sekar (Carnegie Mellon University)

Research 4: Cloud Computing and Data Center Systems
Location: Salon II

Session Chair: Vladimir Vlassov (KTH Royal Institute of Technology)

A Study of Long-Tail Latency in n-Tier Systems: RPC vs. Asynchronous Invocations
Qingyang Wang (Louisiana State University), Chien-An Lai (Georgia Tech), Yasuhiro Kanemasa (Fujitsu Laboratories Ltd.), Shungeng Zhang (Louisiana State University), Calton Pu (Georgia Tech)

Rain or Shine? - Making Sense of Cloudy Reliability Data
Iyswarya Narayanan (The Pennsylvania State University), Bikash Sharma (Microsoft), Di Wang (Microsoft), Sriram Govindan (Microsoft), Laura Caulfield (Microsoft), Anand Sivasubramaniam (The Pennsylvania State University), Aman Kansal (Microsoft), Jie Liu (Microsoft), Badriddine Khesbibi (Microsoft), Kushagra Vaid (Microsoft)

Right-sizing Geo-distributed Data Centers for Availability and Latency
Iyswarya Narayanan (The Pennsylvania State University), Aman Kansal (Microsoft), Anand Sivasubramaniam (The Pennsylvania State University)

Performance Driven Resource Sharing Markets for the Small Cloud
Sung-Han Lin (University of Southern California), Ranjan Pal (University of Southern California), Marco Paolieri (University of Southern California), Leana Golubchik (University of Southern California)

Fault-scalable Virtualized Infrastructure Management
Mukil Kesavan (VMware Inc.), Ada Gavrilovska (Georgia Institute of Technology), Karsten Schwan (Georgia Institute of Technology)

DeltaCFS: Boosting Delta Sync for Cloud Storage Services by Learning from NFS
Quanlu Zhang (Peking University), Zhenhua Li (Tsinghua University), Zhi Yang (Peking University), Shenglong Li (Peking University), Yangze Guo (Peking University), Yafei Dai (Peking University), Shouyang Li (Peking University)

Vision 2: Future Networking and Cyberinfrastructure
Location: Atlanta

Session Chair: Manish Parashar (Rutgers University)

A Vision for Zero-Hop Networking (ZeN)
Mostafa Ammar (School of Computer Science, Georgia Tech), Ellen Zegura (School of Computer Science, Georgia Tech), Yimeng Zhao (School of Computer Science, Georgia Tech)

Structured Overlay Networks for a New Generation of Internet Services
Amy Babay (Johns Hopkins University), Claudiu Danilov (Boeing Research and Technology), John Lane (LTN Global Communications), Michal Miskin-Amir (LTN Global Communications, Spread Concepts LLC), Daniel Obenshain (Johns Hopkins University), John Schultz (LTN Global Communications, Spread Concepts LLC), Jonathan Stanton (LTN Global Communications, Spread Concepts LLC), Thomas Tantillo (Johns Hopkins University), Yair Amir (Johns Hopkins University, LTN Global Communications, Spread Concepts LLC)
Ensuring Network Neutrality for Future Distributed Systems
Thiago Garrett (Federal University of Parana), Schahram Dustdar (TU Wien), Luis C. E. Bona (Federal University of Parana), Elias P. Duarte Jr. (Federal University of Parana)

Uncovering the Useful Structures of Complex Networks in Socially-Rich and Dynamic Environments
Jie Wu (Temple University)

Future Networking Challenges: The Case of Mobile Augmented Reality
Tristan Braud (The Hong Kong University of Science and Technology), Farshid Hassani Bijarbooneh (The Hong Kong University of Science and Technology), Dimitris Chatzopoulos (The Hong Kong University of Science and Technology), Pan Hui (The Hong Kong University of Science and Technology)

Software Defined Cyberinfrastructure
Ian Foster (Argonne National Laboratory and The University of Chicago), Ben Blaiszik (The University of Chicago), Kyle Chard (Computation Institute, University of Chicago and Argonne National Lab), Ryan Chard (Victoria University of Wellington)

Application 3: Internet of Things, Smart Cities, and Cyber-Physical Systems

Session Chair: Guanhua Yan (Binghamton University)

Opportunistic Energy Sharing Between Power Grid and Electric Vehicles: A Game Theory-Based Pricing Policy
Ankur Sarker (University of Virginia), Zhuozhao Li (University of Virginia), William Kolodzey (Clemson University), Haiying Shen (University of Virginia)

Energy Efficient Object Detection in Camera Sensor Networks
Tuan Dao (UC Riverside), Karim Khalil (UC Riverside), Amit Roy-Chowdhury (UC Riverside), Srikant Krishnamurthy (UC Riverside), Lance Kaplan (U.S. Army Research Laboratory)

DeepOpp: Context-aware Mobile Access to Social Media Content on Underground Metro Systems
Di Wu (Hunan University & Imperial College London), Dmitri Arkhipov (University of California Irvine), Thomas Przepiorka (Imperial College London), Qiang Liu (Dartmouth College), Julie McCann (Imperial College London), Amelia Regan (University of California Irvine)

PhaseBeat: Exploiting CSI Phase Data for Vital Sign Monitoring with Commodity WiFi Devices
Xuyu Wang (Auburn University), Chao Yang (Auburn University), Shiwen Mao (Auburn University)

REX: Rapid Ensemble Classification System for Landslide Detection using Social Media
Aibek Musaev (University of Alabama), De Wang (Georgia Institute of Technology), Jiateng Xie (Georgia Institute of Technology), Calton Pu (Georgia Institute of Technology)

Toward An Integrated Approach to Localizing Failures in Community Water Networks
Qing Han (UC Irvine), Phu Nguyen (UC Irvine), Ronald T. Eguchi (ImageCat), Kuo-Lin Hsu (UC Irvine), Nalini Venkatasubramanian (UC Irvine)

Application 4: Mobile, Wireless, and Edge Computing

Session Chair: Shiwen Mao (Auburn University)

MobiQoR: Pushing the Envelope of Mobile Edge Computing via Quality-of-Result Optimization
Yongbo Li (George Washington University), Yurong Chen (George Washington University), Tian Lan (George Washington University), Guru Venkataramani (George Washington University)

Truthful Auctions for User Data Allowance Trading in Mobile Networks
Zhongxing Ming (Tsinghua University), Mingwei Xu (Tsinghua University), Ning Wang (Surrey University), Beiye Gao (Tsinghua University), Qi Li (Tsinghua University)

Online Resource Allocation for Arbitrary User Mobility in Distributed Edge Clouds
Lin Wang (TU Darmstadt), Lei Jiao (University of Oregon), Jun Li (University of Oregon), Max Mühlhäuser (TU Darmstadt)

Leveraging Target k-Coverage in Wireless Rechargeable Sensor Networks
Pengzhan Zhou (Stony Brook University), Cong Wang (Stony Brook University), Yuanyuan Yang (Stony Brook University)

Reducing Cellular Signaling Traffic for Heartbeat Messages via Energy-Efficient D2D Forwarding
Yangji Jin (Huazhong University of Science & Technology), Fangming Liu (Huazhong University of Science and Technology), Xiaomeng Yi (Huazhong University of Science & Technology), Minghua Chen (The Chinese University of Hong Kong)

k-Protected Routing Protocol in Multi-hop Cognitive Radio Networks
Chin-Jung Liu (Michigan State University), Li Xiao (Michigan State University)

**Short Paper 1: Distributed Operating Systems, Middleware, and Algorithms**

**Location: Charleston 1**

**Session Chair: Sripad Nadagowda (IBM TJ Watson Research Center)**

**SRLB: The Power of Choices in Load Balancing with Segment Routing**
Yoann Desmouceaux (École Polytechnique), Pierre Pfister (Cisco Systems), Jérôme Tollet (Cisco Systems), Mark Townsley (Cisco Systems), Thomas Clausen (École Polytechnique)

**Improving Efficiency of Link Clustering on Multi-Core Machines**
Guanhua Yan (Binghamton University)

**S3: Joint Scheduling and Source Selection for Background Traffic in Erasure-Coded Storage**
Shijing Li (George Washington University), Tian Lan (George Washington University), Moo-Ryong Ra (AT&T Labs Research), Rajesh Panta (AT&T Labs Research)

**On the Feasibility of Inter-domain Routing via a Small Broker Set**
Dong Lin (Huawei Technologies Ltd Co.), David Hui (Huawei Technologies Ltd Co.), Weijie Wu (Huawei Technologies Ltd Co.), Tingwei Liu (The Chinese University of Hong Kong), Yating Yang (Beijing Institute of Technology), Yi Wang (Tsinghua University), John Chi-Shing Lui (Chinese University of Hong Kong), Gong Zhang (Huawei Technologies Ltd Co.), Yingtao Li (Huawei Technologies Ltd Co.)

**Subscription Covering for Relevance-based Filtering in Content-Based Publish/Subscribe Systems**
Kaiwen Zhang (Technische Universität München), Vinod Muthusamy (IBM Research), Mohammad Sadoghi (Purdue University), Hans-Arno Jacobsen (University of Toronto)

**Workflow Optimization in PAW**
Maxim Filatov (UNIGE), Verena Kantere (University of Geneva)

**A First Look at Information Entropy-Based Data Pricing**
Xijun Li (Shanghai Jiao Tong University), Jianguo Yao (Shanghai Jiao Tong University), Xue Liu (McGill University), Haibing Guan (Shanghai Jiao Tong University)

**Restrospective Lightweight Distributed Snapshots Using Loosely Synchronized Clocks**
Aleksey Charapko (SUNY Buffalo), Ailidani Ailijiang (SUNY Buffalo), Murat Demirbas (SUNY Buffalo), Sandeep Kulkarni (Michigan State University)

**Power-Aware Population Protocols**
Chuan Xu (LRI(CNRS/UPSud)), Janna Burman (LRI(CNRS/UPSud)), Joffroy Beauquier (LRI(CNRS/UPSud))

**MultiPub: Latency and Cost-Aware Global-Scale Cloud Publish/Subscribe**
Julien Gascon-Samson (McGill University), Jörg Kienzle (McGill University), Bettina Kemme (McGill University)

**Reachability in Binary Multithreaded Programs Is Polynomial**
Alexander Malkis (Technische Universität München), Steffen Borgwardt (UC Davis)

**An Event-Level Abstraction for Achieving Efficiency and Fairness in Network Update**
Ting Qu (National University of Defense Technology), Deke Guo (National University of Defense Technology), Xiaomin Zhu (National University of Defense Technology), Jie Wu (Temple University), Xiaolei Zhou (National University of Defense Technology), Zhong Liu (National University of Defense Technology)

**15:30-16:00 Tuesday, June 6, 2017**

**Coffee Break**

**Location: Foyer**

**16:00-18:00 Tuesday, June 6, 2017**

**Research 5: Edge and Fog Computing**

**Location: Salon I**

**Session Chair: Weisong Shi (Wayne State University)**

**Cachier: Edge-caching for recognition applications**
Utsav Drolia (Carnegie Mellon University), Katherine Guo (Bell Labs), Jiaqi Tan (Nokia), Rajeev Gandhi (Carnegie Mellon University), Priya Narasimhan (Carnegie Mellon University)
Content Centric Peer Data Sharing in Pervasive Edge Computing Environments
Xintong Song (Peking University), Yaodong Huang (Stony Brook University), Qian Zhou (Stony Brook University), Fan Ye (Stony Brook University), Yuanyuan Yang (Stony Brook University), Xiaoming Li (Peking University)

FLARE: Coordinated Rate Adaptation for HTTP Adaptive Streaming in Cellular Networks
Youngbin Im (University of Colorado at Boulder), Jinyoung Han (Hanyang University), Ji Hoon Lee (Juni Korea), Yoon Kwon (Kakao), Carlee Joe-Wong (Carnegie Mellon University), Taekyoung Kwon (Seoul National University), Sangtae Ha (University of Colorado at Boulder)

Networked Drone Cameras for Sports Streaming
Xiaoli Wang (Princeton University), Aakanksha Chowdhery (Princeton University), Mung Chiang (Princeton University)

Research 6: Distributed Green Computing and Energy Management
Location: Salon II

Session Chair: Gerald F Lofstead (Sandia National Lab)

Dynamic Control of Flow Completion Time For Power Efficient Data Center Networks
Kuangyu Zheng (The Ohio State University), Xiaorui Wang (The Ohio State University)

On-Energy-Efficient Congestion Control for Multilpath TCP
Jia Zhao (Simon Fraser University), Jiangchuan Liu (Simon Fraser University), Haiyang Wang (University of Minnesota Duluth)

A Mechanism for Cooperative Demand-Side Management
Guangchao Yuan (Microsoft), Chung-Wei Hang (IBM), Michael Huhns (University of South Carolina), Munindar Singh (North Carolina State University)

Ning Liu (Syracuse University), Zhe Li (Syracuse University), Zhiyuan Xu (Syracuse University), Jielong Xu (Syracuse University), Sheng Lin (Syracuse University), Qinru Qiu (Syracuse University), Jian Tang (Syracuse University), Yanzhi Wang (Syracuse University)

SunChase: Energy-Efficient Route Planning for Solar-Powered EVs.
Landu Jiang (McGill University), Yu Hua (Huazhong University of Science and Technology), Chen Ma (McGill University), Xue Liu (McGill University)

Vision 3: Next Generation Cloud and Edge Services
Location: Atlanta

Session Chair: Manfred Hauswirth (TU Berlin)

Computing in the Continuum: Combining Pervasive Devices and Services to Support Data-driven Applications
Manish Parashar (Rutgers University), Moustafa Abdelbaky (Rutgers University), Mengsong Zou (Rutgers University), Ali Reza Zamani (Rutgers University), Eduard Renart (Rutgers University), Javier Diaz-Montes (Rutgers University)

Decision-driven Execution: A Distributed Resource Management Paradigm for the Age of IoT
Tarek Abdelzaher (UIUC), Tanvir Al Amin (UIUC), Amotz Bar-Noy (UIUC), William Dron (BBN), Ramesh Govindan (USC), Reginald Hobbs (ARL), Shaohan Hu (IBM), Jung-Eun Kim (UIUC), Shuochao Yao (UIUC), Yiran Zhao (UIUC)

ACTiCLOUD: Enabling the Next Generation of Cloud Applications
Georgios Goumas (National Technical University of Athens), Konstantinos Nikas (Computing Systems Laboratory, NTUA), Ewenet Bayuh Lakew (Dept. of Computing Science, Umea University), Christos Kotselidis (The University of Manchester), Vasilios Karakostas (Computing Systems Laboratory, NTUA), Atle Vesterjaer (Nusmascale), Einar Rustad (Nusmascale), John Goodacre (Kaleao), Andrew Attwood (Kaleao), Michail Flouris (OnApp), John Thomson (OnApp), Nikos Foutris (The University of Manchester), Mikel Lujan (The University of Manchester), Ying Zhang (MonetDB Solutions), Panagiotis Koutsourakis (MonetDB Solutions), Martin Kersten (MonetDB Solutions), Jim Webber (Neo Technology), Davide Grohmann (Neo Technology), Erik Elmoth (Dept. of Computing Science, Umea University), Luis Tomas (Dept. of Computing Science, Umea University), Nektarios Koziris (National Technical University of Athens)

JointCloud: A Cross-Cloud Cooperation Architecture for Integrated Internet Service Customization
Huaamin Wang (National University of Defense Technology), Peichang Shi (National University of Defense Technology), Yiming Zhang (National University of Defense Technology)
Supporting Data Analytics Applications Which Utilize Cognitive Services
Arun Iyengar (IBM Research)

Trillion Operations Key-Value Storage Engine: Revisiting the Mission Critical Analytics Storage Software Stack
Sangeetha Seshadri (IBM Almaden Research Center), Lawrence Chiu (IBM Almaden Research Center), Paul Muench (IBM Almaden Research Center)

Short Paper 2: Cloud and Data Center Systems and Networks
Location: Columbia
Session Chair: Qingyang Wang (Louisiana State University)

DCM: Dynamic Concurrency Management for Scaling n-Tier Applications in Cloud
Hui Chen (Louisiana State University), Qingyang Wang (Louisiana State university), Balaji Palanisamy (University of Pittsburgh), Pengcheng Xiong (Hortonworks)

More Peak, Less Differentiation: Towards A Pricing-aware Online Control Framework for Inter-Datacenter Transfers
Wenxin Li (Dalian University of Technology), Xiaobo Zhou (Tianjin University), Keqiu Li (Dalian University of Technology), Heng Qi (Dalian University of Technology), Deke Guo (National University of Defence Technology)

Robust Multi-Tenant Server Consolidation in the Cloud for Data Analytics Workloads
Joseph Mate (University of Waterloo), Khuzaima Daudjee (University of Waterloo), Shahin Kamali (MIT CSAIL)

Flow-Aware Adaptive Pacing to Mitigate TCP Incast in Data center Networks
Shaojun Zou (Central South University), Jiawei Huang (Central South University), Yutao Zhou (Central South University), Jianxin Wang (Central South University), Tian He (University of Minnesota)

Real-Time Power Cycling in Video on Demand Data Centres using Online Bayesian Prediction
Vincent Sanz Marco (Lancaster University), Zheng Wang (Lancaster University), Barry Porter (Lancaster University)

A Distributed Access Control System for Cloud Federations
Shorouq Alansari (University of Southampton), Federica Paci (University of Southampton), Vladimiro Sassone (University of Southampton)

Voyager: Complete Container State Migration
Shripad Nadgowda (IBM TJ Watson Research Center), Sahil Suneja (IBM TJ Watson Research Center), Nilton Bila (IBM TJ Watson Research Center), Canturk Isci (IBM TJ Watson Research Center)

Keddah: Capturing Hadoop Network Behaviour
Jie Deng (Queen Mary University London), Gareth Tyson (Queen Mary), Félix Cuadrado (Queen Mary University of London), Steve Uhlig (Queen Mary University of London)

A Scalable and Distributed Approach for NFV Service Chain Cost Minimization
Zijun Zhang (University of Calgary), Zongpeng Li (University of Calgary), Chuan Wu (University of Hong Kong), Chuanhe Huang (Wuhan University)

Elastic Paxos: A Dynamic Atomic Multicast Protocol
Samuel Benz (Università della Svizzera italiana), Fernando Pedone (Università della Svizzera italiana)

Boosting The Benefits Of Hybrid SDN
Wen Wang (McGill University), Wenbo He (McMaster University), Jinshu Su (National University of Defense Technology)

Adopting SDN Switch Buffer: Benefits Analysis and Mechanism Design
Fuliang Li (Northeastern University), Jiannong Cao (The Hong Kong Polytechnic University), Xingwei Wang (Northeastern University), Yinchu Sun (Northeastern University), Tian Pan (Beijing University of Posts and Telecommunication), Xuefeng Liu (The Hong Kong Polytechnic University)

Efficient Z-order Encoding Based Multi-model Data Compression in WSNs
Xiaofei Cao (Missouri University of Science and Technology), Sanjay Madria (Missouri University of Science and Technology), Takahiro Hara (Osaka University)

PTrack: Enhancing the Applicability of Pedestrian Tracking with Wearables
Source Location Privacy-Aware Data Aggregation Scheduling for Wireless Sensor Networks
Jack Kirton (University of Warwick), Matthew Bradbury (The University of Warwick), Arshad Jhumka (University of Warwick)

Velocity Optimization of Pure Electric Vehicles with Traffic Dynamics Consideration
Liuwang Kang (University of Virginia), Haiying Shen (University of Virginia), Ankur Sarker (University of Virginia)

PIANO: Proximity-based User Authentication on Voice-Powered Internet-of-Things Devices
Neil Zhenqiang Gong (Iowa State University), Altay Ozen (Iowa State University), Yu Wu (UC Davis), Xiaoyu Cao (Iowa State University), Richard Shin (UC Berkeley), Dawn Song (UC Berkeley), Hongxia Jin (Samsung Research America), Xuan Bao (Google Inc.)

Category Information Collection in RFID Systems
Jia Liu (Nanjing University), Shigang Chen (University of Florida), Bin Xiao (The Hong Kong Polytechnic University), Yanyan Wang (Nanjing University), Lijun Chen (Nanjing University)

Scalable Role-based Data Disclosure Control for the Internet of Things
Ali Yavari (RMIT University), Arezou Soltani Panah (RMIT University), Dimitrios Georgakopoulos (Swinburne University of Technology), Prem Prakash Jayaraman (Swinburne University of Technology), Ron van Schyndel (RMIT University)

Multi-representation based Data Processing Architecture for IoT Applications
Vaibhav Arora (University of California, Santa Barbara), Faisal Nawab (University of California, Santa Barbara), Divyakant Agrawal (University of California, Santa Barbara), Amr El Abbadi (University of California, Santa Barbara)

Long Term Sensing via Battery Health Adaptation
Greg Jackson (Imperial College London), Zhijin Qin (Imperial College London), Julie A McCann (Imperial College London)

Detecting Time Synchronization Attacks in Cyber-Physical Systems with Machine Learning Techniques
Jingxuan Wang (The University of Hong Kong), Wenting Tu (Shanghai University of Finance and Economics), Lucas C.K. Hui (The University of Hong Kong), Siu Ming Yiu (The University of Hong Kong), Eric Ke Wang (Harbin Institute of Technology Shenzhen Graduate School)

Speed-based Location Tracking in Usage-based Automotive Insurance
Lu Zhou (Shanghai Jiao Tong University), Qingrong Chen (Shanghai Jiao Tong University), Zutian Luo (Shanghai Jiao Tong University), Haojin Zhu (Shanghai Jiao Tong University), Cailian Chen (Shanghai Jiao Tong University)

Poster 1:
Toward Vehicle Sensing: An integrated application with sparse video cameras and intelligent taxicabs
Yang Wang (University of Science and Technology of China), Wuji Chen (University of Science and Technology of China), Wei Zheng (Sanofi-Aventis US LLC), He Huang (Soochow University), Wen Zhang (University of Science and Technology of China), Hengchang Liu (University of Science and Technology of China)

Segmentation of Time Series based on Kinetic Characteristics for Storage Consumption Prediction
Beibei Miao (Baidu, Inc), Yu Chen (Baidu, Inc), Xuebo Jin (School of Computer and Information Engineering, Beijing Technology and Business University), Bo Wang (Baidu, Inc), Xianping Qu (Baidu, Inc), Dong Wang (Baidu, Inc), Shimin Tao (Baidu, Inc), Zhi Zang (Baidu, Inc)

A Multi-stage Hierarchical Window Model with Application to Real-Time Graph Analysis
Sachini Jayasekara (University of Melbourne), Shanika Karunasekera (University of Melbourne), Aaron Harwood (University of Melbourne)

Dynamic Pricing at Electric Vehicle Charging Stations for Queueing Delay Reduction
Xiaoshan Sun (University of Science and Technology of China), Peng Xu (University of Science and Technology of China), Jinyin Li (University of Science and Technology of China), Hengchang Liu (University of Science and Technology of China), Wei Zheng (Sanofi-Aventis)

Pairwise Ranking Aggregation by Non-interactive Crowdsourcing with Budget Constraints
Changjiang Cai (Stevens Institute of Technology), Haipei Sun (Stevens Institute of Technology), Boxiang Dong (Montclair State University), Bo Zhang (Stevens Institute of Technology), Ting Wang (Lehigh University), Wendy Hui Wang (Stevens Institute of Technology)

Buffer-Based Reinforcement Learning for Adaptive Streaming
Yue Zhang (SUNY Binghamton), Yao Liu (SUNY Binghamton)

The case for using content-centric networking for distributing high-energy physics software
Mohammad Alhowaidi (University of Nebraska-Lincoln), Byrav Ramamurthy (University of Nebraska-Lincoln), Brian Bockelman (University of Nebraska-Lincoln), David Swanson (University of Nebraska-Lincoln)

**LAVEA: Latency-aware Video Analytics on Edge Computing Platform**
Shanhe Yi (College of William and Mary), Zijiang Hao (College of William and Mary), Qingyang Zhang (Wayne State University), Quan Zhang (Wayne State University), Weisong Shi (Wayne State University), Qun Li (College of William and Mary)

**Complete Tolerance Relation based Filling Algorithm using Spark**
Jingling Yuan (Wuhan University of Technology), Yao Xiang (Wuhan University of Technology), Xian Zhong (Wuhan University of Technology), Mincheng Chen (Wuhan University of Technology), Tao Li (University of Florida)

**Poster 2: Security and Privacy Cluster**

**Towards Secure Public Directory for Privacy-Preserving Data Sharing**
Amin Fallahi (Syracuse University), Xi Liu (Syracuse University), Yuzhe Tang (Syracuse University), Shuang Wang (UCSD), Rui Zhang (Chinese Academy of Sciences)

**Anonymous Routing to Maximize Delivery Rates in DTNs**
Kazuya Sakai (Tokyo Metropolitan University), Min-Te Sun (National Central University), Wei-Shinn Ku (Auburn University), Jie Wu (Temple University)

**Evaluating Connection Resilience for the Overlay Network Kademia**
Henner Heck (Universität Kassel), Olga Kieselmann (Universität Kassel), Arno Wacker (Universität Kassel)

**Shortfall-based Optimal Security Provisioning for Internet of Things**
Antonino Rullo (University of Calabria), Edoardo Serra (Boise State University), Jorge Lobo (Universitat Pompea Fabra), Elisa Bertino (Purdue University)

**Group Differential Privacy-preserving Disclosure of Multi-level Association Graphs**
Balaji Palanisamy (University of Pittsburgh), Chao Li (University of Pittsburgh), Prashant Krishnamurthy (University of Pittsburgh)

**Tracking Information Flow in Cyber-Physical Systems**
Stefan Gries (University of Duisburg-Essen), Marc Hesenius (University of Duisburg-Essen), Volker Gruhn (University of Duisburg-Essen)

**Privacy-preserving Matchmaking in Geosocial Networks with Untrusted Servers**
Qiuxiang Dong (Arizona State University), Dijiang Huang (Arizona State University)

**You’ve Been Tricked! A User Study of the Effectiveness of Typosquatting Techniques**
Jeffrey Spaulding (SUNY Buffalo), Shambhu Upadhyaya (SUNY Buffalo), Aziz Mohaisen (SUNY Buffalo)

**Real-time Detection of Illegal File Transfers in the Cloud**
Adam Bowers (Missouri University of Science and Technology), Dan Lin (Missouri University of Science and Technology), Anna Squicciarini (The Pennsylvania State University), Ali Hurson (Missouri University of Science and Technology)

**Eyes of the Swarm: Streamers’ Detection in BitTorrent**
Daniel Silva (Fluminense Federal University), Antonio Rocha (Fluminense Federal University)

**Poster 3: Clouds and Virtualization Cluster**

**Load prediction for energy-aware scheduling for Clouds computing platforms**
Alexandre Dambreville (LRI), Joanna Tomasik (CentraleSupélec), Johanne Cohen (LRI-CNRS), Fabien Dufoulon (LRI)

**Learn-as-you-go with Megh: Efficient Live Migration of Virtual Machines**
Debabrota Basu (National University of Singapore), Xiayang Wang (Institute of Parallel and Distributed Systems, Shanghai Jiao Tong University), Yang Hong (Shanghai Jiao Tong University), Haibo Chen (Shanghai Jiao Tong University), Stephane Bressan (National University of Singapore)

**Machine-Learning Based Performance Estimation for Distributed Parallel Applications in Virtualized Heterogeneous Clusters**
Seonte Kim (UNIST), Nguyen Pham (UNIST), Woongki Baek (UNIST), Young-Ri Choi (UNIST)

**Incremental elasticity for NoSQL data stores**
Antonis Papaioannou (ICS-FORTH and University of Crete), Konstantis Magoutis (ICS-FORTH and University of Ioannina)

**A Framework for Efficient Energy Scheduling of Spark Workloads**
Stathis Maroulis (Athens University of Economics and Business), Nikos Zacheilas (Athens University of Economics and Business), Vana Kalogeraki (Athens University of Economics and Business)

**Towards a Complete Virtual Data Center Embedding Algorithm using Hybrid Strategy**
M P Giles (National Institute of Technology Calicut), S D Madhu Kumar (National Institute of Technology Calicut), Lillykutty Jacob (National Institute of Technology Calicut), Umesh Bellur (Indian Institute of Technology Bombay)
Federating Consistency for Partition-Prone Networks
Benjamin Bengfort (University of Maryland), Pete Keleher (University of Maryland)

Mitigating nesting-agnostic hypervisor policies in derivative clouds
Chandra Prakash (IIT Bombay), Prashanth (IIT Bombay), Purushottam Kulkarni (IIT Bombay), Umesh Bellur (IIT Bombay)

A Novel Architecture for Efficient Fog to Cloud Data Management in Smart Cities
Amir Sinaeepourfard (UPC), Jordi Garcia (UPC), Xavier Masip-Bruin (UPC), Eva Marin-Tordera (UPC)

Networklet: Concept and Deployment
Sheng Zhang (Nanjing University), Yu Liang (Nanjing University of Posts and Telecommunications), Zhuzhong Qian (Nanjing University), Mingjun Xiao (University of Science and Technology of China), Jie Wu (Temple University), Fanyu Kong (Ant Financial), Sanglu Lu (Nanjing University)

Optimistic Causal Consistency for Geo-Replicated Key-Value Stores
Kristina Spirovskka (EPFL), Diego Didona (EPFL), Willy Zwaenepoel (EPFL)

Automated Performance Evaluation for Multi-Tier Cloud Service Systems Subject to Mixed Workloads
Xudong Zhao (Shandong University), Lizhen Cui (Shandong University), Jiwei Huang (Beijing University of Posts and Telecommunications), Shijun Liu (Shandong University), Lei Liu (Shandong University), Calvin Pu (Georgia Tech)

Decentralised Runtime Monitoring for Access Control Systems in Cloud Federations
Md Sadek Ferdous (University of Southampton), Andrea Margheri (University of Southampton), Federica Paci (University of Southampton), Mu Yang, Vladimiro Sassone (University of Southampton)

Poster 4: Distributed Systems and Networking Cluster

DuoFS: An Attempt at Energy-Saving and Retaining Reliability of Storage Systems
Shu Yin (Hunan University)

A Proposal of an Efficient Traffic Matrix Estimation under Packet Drops
Kohei Watabe (Nagako University of Technology), Toru Mano (NTT Network Innovation Laboratories), Kimihiro Mizutani (NTT Network Innovation Laboratories), Osamu Akashi (NTT Network Innovation Laboratories), Kenji Nakagawa (Nagaoka University of Technology), Takeru Inoue (NTT Network Innovation Laboratories)

Straggler Mitigation for Distributed Behavioral Simulation
Eman Bin Khunayn (University of Melbourne), Shanika Karunasekera (University of Melbourne), Hairuo Xie (University of Melbourne), Kotagiri Ramamohanarao (University of Melbourne)

Supporting Resource Control for Actor Systems in Akka
Ahmed Abdel Moamen (University of Saskatchewan), Dezhong Wang (University of Saskatchewan), Nadeem Jamali (University of Saskatchewan)

A Distributed Operating System Network Stack and Device Driver for Multicores
B M Saif Ansary (ECE, Virginia Tech), Antonio Barbalace (ECE, Virginia Tech), Binoy Ravindran (ECE, Virginia Tech), Thomas Lazor (ECE, Virginia Tech), Ho-Ren Chuang (ECE, Virginia Tech)

Cache Potentiality of MONs: A Prime
Peiyuan Yuan (Henan Normal University), Honghai Wu (Henan University of Science and Technology), Xiaoyan Zhao (Henan Normal University), Zhengnan Dong (Henan Normal University)

Oak: User-Targeted Web Performance
Marcel Flores(Northwestern University), Alexander Wenzel(Northwestern University), Aleksandar Kuzmanovic (Northwestern University)

Ctrl-A: A Self-* Distributed and In-band SDN Control Plane
Marco Canini (Université catholique de Louvain), Iosif Salem (Chalmers University of Technology), Liron Schiff (Tel Aviv University), Elad Michael Schiller (Chalmers University of Technology), Stefan Schmid (Aalborg University & TU Berlin)

18:00-20:00 Tuesday, June 6, 2017
Reception
Location: Phoenix Ballroom
Day 3 – Wednesday, June 7, 2017

7:30-8:30 Wednesday, June 7, 2017

Continental Breakfast
Location: Foyer

8:30-9:30 Wednesday, June 7, 2017

Keynote 2 by M. Tamer Özsu (University of Waterloo)
Location: Phoenix Ballroom
Session Chair: Karl Aberer (EPFL)

9:30-10:00 Wednesday, June 7, 2017

Coffee Break
Location: Foyer

10:00-12:00 Wednesday, June 7, 2017

Research 7: Internet of Things, Smart Cities, and Cyber-Physical Systems
Location: Salon I
Session Chair: Joao Eduardo Ferreira (University of Sao Paulo)

Persistent Traffic Measurement Through Vehicle-to-Infrastructure Communications
He Huang (Soochow University), Yu-E Sun (Soochow University), Shigang Chen (University of Florida), Hongli Xu (University of Science and Technology of China), Yuan Zhou (Google)

TagBreathe: Monitor Breathing with Commodity RFID Systems
Yuxiao Hou (The Hong Kong Polytechnic University), Yanwen Wang (The Hong Kong Polytechnic University), Yuanqing Zheng (The Hong Kong Polytechnic University)

Double-Edged Sword: Incentivized Verifiable Product Path Query for RFID-enabled Supply Chain
Saiyu Qi (Xidian University), Yuanqing Zheng (The Hong Kong Polytechnic University), Xiaofeng Chen (Xidian University), Jianfeng Ma (Xidian University), Yong Qi (Xian Jiaotong University)

Towards Accurate Corruption Estimation in ZigBee Under Cross-Technology Interference
Gong Long Chen (Zhejiang University), Wei Dong (Zhejiang University), Zhiwei Zhao (University of Electronic Science and Technology of China), Tao Gu (RMIT University)

Unseen Activity Recognition: A Hierarchical Active Transfer Learning Approach
Mohammad Arif Ul Alam (University of Maryland Baltimore County), Nirmalya Roy (University of Maryland Baltimore County)

RFIPad: Enabling Cost-efficient and Device-free In-air Handwriting using Passive Tags
Han Ding (Xi’an Jiaotong University), Chen Qian (University of California Santa Cruz), Jinsong Han (Xi’an Jiaotong University), Ge Wang (Xi’an Jiaotong University), Wei Xi (Xi’an Jiaotong University), Kun Zhao (Xi’an Jiaotong University), Jizhong Zhao (Xi’an Jiaotong University)

Research 8: Mobile and Wireless Computing Systems I
Location: Salon II
Session Chair: Karthik Sundaresan (NEC Laboratories America)

Robust Incentive Tree Design for Mobile Crowdsensing
Xiang Zhang (Arizona State University), Guoliang Xue (Arizona State University), Ruozhou Yu (Arizona State University), Dejun Yang (Colorado School of Mines), Jian Tang (Syracuse University)

WearLock: Unlocking Your Phone via Acoustics using Smartwatch
Shanhe Yi (College of William and Mary), Zhengrui Qin (Northwest Missouri State University), Nancy Carter (College of William and Mary), Qun Li (College of William and Mary)

Modeling Mobile Code Acceleration in the Cloud
Huber Flores (University of Oulu), Xiang Su (University of Oulu), Vassilis Kostakos (University of Oulu), Jukka Riekki (University of Oulu), Eemil Lagerspetz (University of Helsinki), Sasu Tarkoma (Helsinki University of Technology), Pan Hui (HKUST), Yong Li (Tsinghua University), Jukka Manner (Aalto University)

E-Android: A New Energy Profiling Tool for Smartphones
Xing Gao (College of William and Mary), Dachuan Liu (College of William and Mary), Daiping Liu (University of Delaware), Haining Wang (University of Delaware), Angelos Stavrou (George Mason University)

Local and Low-Cost White Space Detection
Ahmed Saeed (Georgia Institute of Technology), Khaled Harras (Carnegie Mellon University), Ellen Zegura (Georgia Institute of Technology), Mostafa Ammar (Georgia Institute of Technology)

General Analysis of Incentive Mechanisms for Peer-to-Peer Transmissions: A Quantum Game Perspective
Weiman Sun (Beijing Normal University), Shengling Wang (Beijing Normal University)

Vision 4: Security and Trust in Future Systems
Location: Atlanta

Session Chair: Ling Liu (Georgia Institute of Technology)

How Computer Science Risks to Lose Its Innocence, and Should Attempt to Take Responsibility
Karl Aberer (EPFL)

A Cognitive Policy Framework for Next-Generation Distributed Federated Systems - Concepts and Research Directions
Elisa Bertino (Purdue University), Seraphin Calo (IBM), Maroum Touma (IBM), Dinesh Verma (IBM), Christopher Williams (UK DSTL), Brian Rivera (Army Research Labs)

Machine to Machine Trust in Smart Cities
Margaret Loper (Georgia Tech Research Institute), Brian Swenson (Georgia Institute of Technology)

Lateral Thinking for Trustworthy Apps
Hermann Härtig (Technische Universität Dresden), Michael Roitzsch (Technische Universität Dresden), Carsten Weinhold (Technische Universität Dresden), Adam Lackorzynski (Technische Universität Dresden)

Rumor Initiator Detection in Infected Signed Networks
Jiawei Zhang (University of Illinois at Chicago), Charu C. Aggarwal (IBM T. J. Watson Research Center), Philip S. Yu (University of Illinois at Chicago)

Addressing Smartphone-based Multi-factor Authentication via Hardware-rooted Technologies
Zhongjie Ba (The State University of New York at Buffalo), Kui Ren (The State University of New York at Buffalo)

Application 5: Cloud Computing and Data Center Systems
Location: Columbia

Session Chair: Yuanyuan Yang (Stony Brook University)

Multi-Resource Load Balancing for Virtual Network Functions
Tao Wang (Huazhong University of Science & Technology), Hong Xu (City University of Hong Kong), Fangming Liu (Huazhong University of Science and Technology)

Learning from failure across multiple clusters: A trace-driven approach to understanding, predicting, and mitigating job terminations
Nosayba El-Sayed (MIT), Hongyu Zhu (University of Toronto), Bianca Schroeder (University of Toronto)

RBAY: A Scalable and Extensible Information Plane for Federating Distributed Datacenter Resources
Xin Chen (Georgia Institute of Technology), Liting Hu (Florida International University), Douglas M. Blough (Georgia Institute of Technology), Michael A. Kozuch (Intel Labs Pittsburgh), Matthew Wolf (Oak Ridge National Laboratory)

Task-aware TCP in Data Center Networks
Sen Liu (Central South University), Jiawei Huang (Central South University), Yutao Zhou (Central South University), Jianxin Wang (Central South University), Tian He (University of Minnesota)

Limitations of Load Balancing Mechanisms for N-Tier Systems in the Presence of Millibottlenecks
Tao Zhu (Georgia Institute of Technology), Jack Li (Georgia Institute of Technology), Josh Kimball (Georgia Institute of Technology), Junhee Park (Indiana University), Chien-An Lai (Georgia Institute of Technology), Calton Pu (Georgia Institute of Technology), Qingyang Wang (Louisiana State University)

Xiulin Li (Shandong University), Li Pan (Shandong University), Jiwei Huang (Beijing University of Posts and Telecommunications), Shijun Liu (Shandong University), Yuliang Shi (Shandong University), Calton Pu (Georgia Institute of Technology)

**Application 6: Big Data Systems and Distributed Data Management and Analytics**

**Location:** Nashville

**Session Chair:** Zhengrui Qin (Northwest Missouri State University)

**Evaluation of Deep Learning Frameworks over Different HPC Architectures**
Shayan Shams (Louisiana State University), Richard Platania (Louisiana State university), Kisung Lee (Louisiana State University), Seung-Jong Park (Louisiana State University)

**On Achieving Efficient Data Transfer for Graph Processing in Geo-Distributed Datacenters**
Amelie Chi Zhou (Inria Rennes), Shadi Ibrahim (Inria Rennes), Bingsheng He (National University of Singapore)

**GBBooster: Towards Acceleration of GPU-intensive Mobile Applications**
Elliott Wen (Victoria University of Wellington), Bryan Ng (Victoria University of Wellington), Winston Seah (Victoria University of Wellington), Xue Liu (McGill University), Jiannong Cao (The Hong Kong Polytechnic University), Xuefeng Liu (Huangzhong University of Science and Technology)

**Scaling K-Nearest Neighbors Queries (The right way)**
Atoshum Samuel Cahnai (University Of Glasgow), Nikos Ntarmos (University Of Glasgow), Christos Anagnostopoulos (University of Glasgow), Peter Triantafillou (University Of Glasgow)

**Parallelizing Big De Bruijn Graph Construction on Heterogeneous Processors**
Shuang Qiu (The Hong Kong University of Science and Technology), Qiong Luo (The Hong Kong University of Science and Technology)

**Private, yet Practical, Multiparty Deep Learning**
Xinyang Zhang (Lehigh University), Shouling Ji (Zhejiang University), Hui Wang (Stevens Institute of Technology), Ting Wang (Lehigh University)

**Industry 2: Mobile Computing and Internet of Things**

**Location:** Charleston 1

**Session Chair:** Robert Birke (IBM Research Zurich)

**On the Limits of Subsampling of Location Traces**
Mudhakar Srivatsa (IBM T.J. Watson Research Center), Raghu Ganti (IBM T.J. Watson Research Center), Prasant Mohapatra (UC Davis)

**SOM-TC: Self-organizing map for Hierarchical Trajectory Clustering**
Pranita Dewan (IBM T J Watson Research Center), Raghu Ganti (IBM T J Watson Research Center), Mudhakar Srivatsa (IBM T J Watson Research Center)

**Processing Encrypted and Compressed Time-Series Data**
Matúš Harvan (Enovos Luxembourg S.A.), Samuel Kimoto (Open Systems), Thomas Locher (ABB Corporate Research), Yvonne-Anne Pignolet (ABB Corporate Research), Johannes Schneider (University of Liechtenstein)

**Calvin Constrained - A Framework for IoT Applications in Heterogeneous Environments**
Amardeep Mehta (Umeå University), Rami Baddour (Università della Svizzera italiana), Fredrik Svensson (Ericsson Research), Harald Gustafsson (Ericsson Research), Erik Elmroth (Umeå University)

**12:00-13:30 Wednesday, June 7, 2017**

**Conference Luncheon**

**Location:** Phoenix Ballroom

**13:30-15:30 Wednesday, June 7, 2017**

**Research 9: Distributed Big Data Systems**

**Location:** Salon I

**Session Chair:** Kisung Lee (Louisiana State University)

**High-Performance and Resilient Key-Value Store with Online Erasure Coding for Big Data Workloads**
Dipti Shankar (The Ohio State University), Xiaoyi Lu (The Ohio State University), Dhabaleswar Panda (The Ohio State University)

**Modeling and Analyzing Latency in the Memcached system**
Wenxue Cheng (Tsinghua University), Fengyuan Ren (Tsinghua University), Wanchun Jiang (Central South University), Tong Zhang (Tsinghua University)
Speculative Slot Reservation: Enforcing Service Isolation for Dependent Data-Parallel Computations
Chen Chen (HKUST), Wei Wang (HKUST), Bo Li (HKUST)

Optimizing Shuffle in Wide-Area Data Analytics
Shuhao Liu (University of Toronto), Hao Wang (University of Toronto), Baochun Li (University of Toronto)

Job Scheduling without Prior Information in Big Data Processing Systems
Zhiming Hu (University of Toronto), Baochun Li (University of Toronto), Zheng Qin (Institute of High Performance Computing), Rick Siow Mong Goh (Institute of High Performance Computing)

Distributed Load Balancing in Key-Value Networked Caches
Sikder Huq (The University of Iowa), Zubair Shafiq (The University of Iowa), Sukumar Ghosh (The University of Iowa), Amir Khakpour (Verizon Digital Media Services), Harkeerat Bedi (Verizon Digital Media Services)

Research 10: Distributed Algorithms and Theory I

Session Chair: Haiying Shen (University of Virginia)

Dong Han (Oakland University), Ye Yan (Oakland University), Tao Shu (Auburn University), Liuqing Yang (Colorado State University), Shuguang Cui (University of California, Davis)

Fair Caching Algorithms for Peer Data Sharing in Pervasive Edge Computing Environments
Yaodong Huang (Stony Brook University), Xintong Song (Peking University), Fan Ye (Stony Brook University), Yuanyuan Yang (Stony Brook University), Xiaoming Li (Peking University)

Latency-Driven Cooperative Task Computing in Multi-User Fog-Radio Access Networks
Ai-Chun Pang (National Taiwan University), Wei-Ho Chung (Academia Sinica), Te-Chuan Chiu (National Taiwan University), Junshan Zhang (Arizona State University)

Approximation and Online Algorithms for NFV-Enabled Multicasting in SDNs
Zichuan Xu (University College London), Weifa Liang (The Australian National University), Meitian Huang (The Australian National University), Mike Jia (The Australian National University), Song Guo (The Hong Kong Polytechnic University), Alex Galis (University College London)

Distributed Auctions for Task Assignment and Scheduling in Mobile Crowdsensing Systems
Zhuojun Duan (Georgia State University), Wei Li (Georgia State University), Zhipeng Cai (Georgia State University)

Effective Mobile Data Trading in Secondary Ad-hoc Market with Heterogeneous and Dynamic Environment
Hengky Susanto (Huawei Future Network Theory Lab), Honggang Zhang (University of Massachusetts Boston), Shing Yip Ho (Share Media), Benyuan Liu (University of Massachusetts Lowell)

Vision 5: Future Distributed Systems

Session Chair: Manish Parashar (Rutgers University)

Enabling wide area analytics with Collaborative Distributed Processing Pipes (CDPPs)
Anja Feldmann (TU Berlin), Manfred Hauswirth (TU Berlin), Volker Markl (TU Berlin)

The Millibottleneck Theory of Performance Bugs, and Its Experimental Verification
Calton Pu (Georgia Institute of Technology), Joshua Kimball (Georgia Institute of Technology), Chien-An Lai (Georgia Institute of Technology), Tao Zhu (Georgia Institute of Technology), Jack Li, Junhee Park, Qingyang Wang, Deepal Jayasinghe, Pengcheng Xiong, Simon Malkowski, Qinyi Wu, Gueyoung Jung, Younggun Koh, Galen Swint

Execution: Enhancing Scientific Data Management for Exascale
Scott Klaskey (Oak Ridge National Laboratory), Eric Suchyta (Oak Ridge National Lab), Mark Ainsworth (Brown University), Qing Liu (New Jersey Institute of Technology), Ben Whitney (Brown University), Matthew Wolf (Oak Ridge National Laboratory), Jong Choi (Oak Ridge National Laboratory), Ian Foster (Argonne National Laboratory), Mark Kim (Oak Ridge National Laboratory), Jeremy Logan (University Of Tennessee Knoxville), Kshitij Mehta (Oak Ridge National Laboratory), Todd Munson (Argonne National Laboratory), George Ostrouchov (Oak Ridge National Laboratory), Manish Parashar (Rutgers University), Norbert Podhorszcz (Oak Ridge National Laboratory), David Pugmire (Oak Ridge National Laboratory), Lipeng Wan (Oak Ridge National Laboratory)

Hardware Acceleration Landscape for Distributed Real-time Analytics: Virtues and Limitations
Mohammadreza Najafi (Technische Universitat Munchen), Kaiwen Zhang (Technische Universitat Munchen), Hans-Arno Jacobsen (University of Toronto), Mohammad Sadoghi (Purdue University)
Coordinating Distributed Speaking Objects
Marco Lippi (DISMI – Università di Modena e Reggio Emilia), Marco Mamei (DISMI – Università di Modena e Reggio Emilia), Stefano Mariani (DISMI – Università di Modena e Reggio Emilia), Franco Zambonelli (DISMI – Università di Modena e Reggio Emilia)

Model-Driven Domain-Specific Middleware
Fabio Costa (Federal University of Goias), Karl Morris (Temple University), Fabio Kon (University of São Paulo), Peter Clarke (Florida International University)

Application 7: Distributed Middleware Systems
Location: Columbia

Session Chair: Qingyang Wang (Louisiana State University)

Fast and Flexible Networking for Message-oriented Middleware
Lars Kroll (KTH Royal Institute of Technology), Alexandru A. Ormenisan (KTH Royal Institute of Technology), Jim Dowling (KTH Royal Institute of Technology)

TailCut: Power Reduction under Quality and Latency Constraints in Distributed Search Systems
Chih-Hsun Chou (University of California, Riverside), Laxmi Bhuyan (University of California, Riverside), Shaolei Ren (University of California, Riverside)

StoArranger: Enabling Efficient Usage of Cloud Storage Services on Mobile Devices
Yongshu Bai (SUNY Binghamton), Yifan Zhang (SUNY Binghamton)

Characterizing Performance and Energy-efficiency of The RAMCloud Storage System
Yacine Taleb (Inria), Shadi Ibrahim (Inria), Gabriel Antoniu (Inria), Toni Cortes (Barcelona Supercomputing Center)

Proactively Secure Cloud-Enabled Storage
Karim Eldefrawy (Hughes Research Lab), Tyler Kaczmarek (University of California, Irvine), Sky Faber (University of California, Irvine)

BEES: Bandwidth- and Energy- Efficient Image Sharing for Real-time Situation Awareness
Pengfei Zuo (Huazhong University of Science and Technology), Yu Hua (Huazhong University of Science and Technology), Xue Liu (McGill University), Dan Feng (Huazhong University of Science and Technology), Wen Xia (Huazhong University of Science and Technology), Shunde Cao (Huazhong University of Science and Technology), Jie Wu (Huazhong University of Science and Technology), Yuanyuan Sun (Huazhong University of Science and Technology), Yuncheng Guo (Huazhong University of Science and Technology)

Application 8: Distributed Systems and Optimizations
Location: Nashville

Session Chair: Aziz Mohaisen (State University of New York at Buffalo)

Transparent Fault-Tolerance using Intra-Machine Full-Software-Stack Replication
Giuliano Losa (Virginia Tech), Antonio Barbalace (Virginia Tech), Yuzhong Wen (Virginia Tech), Marina Sadini (Virginia Tech), Ho-Ren Chuang (Virginia Tech), Binoy Ravindran (Virginia Tech)

A preventive auto-parallelization approach for elastic stream processing
Roland Kotto Kombi (University Claude Bernard), Nicolas Lumineau (Université de Lyon), Philippe Lamarre (INSA Lyon)

Dependable Cloud Resources with Guardian
Bara Abusalah (Purdue University), Derek Schatzlein (Purdue University), Julian James Stephen (Purdue University), Masoud Saeida Ardekani (Purdue University), Patrick Eugster (Purdue University)

A Communication-aware Container Re-distribution Approach for High Performance VNFs
Yuchao Zhang (Tsinghua University), Yusen Li (Nankai University), Ke Xu (Tsinghua University), Dan Wang (Hong Kong Polytechnic University), Minghui Li (Baidu), Xuan Cao (Baidu), Qingqing Liang (Baidu)

Minimizing Cost in IaaS Clouds via Scheduled Instance Reservation
Qiushi Wang (Nanyang Technological University), Ming Ming Tan (Nanyang Technological University), Xueyan Tang (Nanyang Technological University), Wentong Cai (Nanyang Technological University)

Efficient Distributed Coordination at WAN-scale
Ailidani Ailijiang (SUNY Buffalo), Aleksey Charapko (SUNY Buffalo), Murat Demirbas (SUNY Buffalo), Bekir Oguz Turkkan (SUNY Buffalo), Tevfik Kosar (SUNY Buffalo)

Short Paper 4: Mobile, Wireless, Edge, and Crowd Computing
Location: Charleston 1
Session Chair: Lakshmish Ramaswamy (University of Georgia)

On efficient offloading control in cloud radio access network with mobile edge computing
Tong Li (Tsinghua University), Chathura Sarathchandra Magurawalage (University of Essex), Kezhi Wang (University of Essex), Ke Xu (Tsinghua University), Kun Yang (University of Essex), Haiyang Wang (University of Minnesota at Duluth)

Location Privacy in Mobile Edge Clouds
Ting He (Pennsylvania State University), Ertugrul Ciftcioglu (Army Research Laboratory), Shiqiang Wang (IBM), Kevin Chan (Army Research Laboratory)

Approximation Design for Cooperative Relay Deployment in Wireless Networks
Haotian Wang (Shanghai Jiao Tong University), Shilei Tian (Shanghai Jiao Tong University), Xiaofeng Gao (Shanghai Jiao Tong University), Lidong Wu (University of Texas at Tyler), Guihai Chen (Shanghai Jiao Tong University)

Dispersing Social Content in Mobile Crowd through Opportunistic Contacts
Lei Zhang (Simon Fraser University), Feng Wang (The University of Mississippi), Jiangchuan Liu (South China Agricultural University)

Making Smartphone Smart on Demand for Longer Battery Life
Marco Brocanelli (The Ohio State University), Xiaorui Wang (The Ohio State University)

FADEWICH: Fast Deauthentication over the Wireless Channel
Giulio Lovisotto (University of Oxford), Mauro Conti (University of Padua), Ivan Martinovic (University of Oxford), Gene Tsudik (University of California, Irvine)

Cognitive Wireless Charger: Sensing-Based Real-Time Frequency Control For Near-Field Wireless Charging
Sang-Yoon Chang (University of Colorado Colorado Springs), Sristi Lakshmi Sravana Kumar (Advanced Digital Sciences Center), Yih-Chun Hu (University of Illinois at Urbana-Champaign)

Density and Mobility-driven Evaluation of Broadcast Algorithms for MANETs
Raziel Carvajal Gómez (University of Neuchatel), Inti Gonzalez-Herrera (LaBRI/University of Bordeaux), Yérom-David Bromberg (University of Rennes 1), Laurent Réveillère (University of Bordeaux), Etienne Rivière (University of Neuchatel)

Energy-Aware CPU Frequency Scaling for Mobile Video Streaming
Wenjie Hu (The Pennsylvania State University), Guohong Cao (The Pennsylvania State University)

Crazy Crowd Sourcing to Mitigate Resource Scarcity
Nova Ahmed (North South University), Md Mahfuzur Rahman Siddiquee (Independent Researcher), Refaya Karim (North South University), Mohsina Zaman (Independent Researcher), Syed Mahmudul Alam (North South University), Syed Fahim Asraf (North South University)

Detecting Rogue AP with the Crowd Wisdom
Tongqing Zhou (National University of Defense Technology), Zhiping Cai (National University of Defense Technology), Bin Xiao (The Hong Kong Polytechnic University), Yueyue Chen (National University of Defense Technology), Ming Xu (National University of Defense Technology)

15:30-16:00 Wednesday, June 7, 2017

Coffee Break

Location: Foyer

16:00-18:00 Wednesday, June 7, 2017

Research 11: Security and Privacy in Distributed Systems II

Location: Salon I

Session Chair: Kui Ren (State University of New York at Buffalo)

Kalis - A System for Knowledge-driven Adaptable Intrusion Detection for the Internet of Things
Daniele Midi (Purdue University), Antonino Rullo (University of Calabria), Anand Mudgerikar (Purdue University), Elisa Bertino (Purdue University)

Fuzzy Extractors for Biometric Identification
Nan Li (CSIRO), Fuchun Guo (University of Wollongong), Yi Mu (University of Wollongong), Willy Susilo (University of Wollongong), Surya Nepal (CSIRO)

Smartphone Privacy Leakage of Social Relationships and Demographics from Surrounding Access Points
**Chen Wang** (Stevens Institute of Technology), **Chuyu Wang** (Stevens Institute of Technology), **Yingying Chen** (Stevens Institute of Technology), **Lei Xie** (Nanjing University), **Sanglu Lu** (Nanjing University)

**Research 12: Cloud Computing and Distributed Data Analytics**

**Location:** Salon II

**Session Chair:** Keke Chen (Wright State University)

**Service Overlay Forest Embedding for Software-Defined Cloud Networks**
Jian-Jhih Kuo (Academia Sinica), Shan-Hsiang Shen (National Taiwan University of Science and Technology), Ming-Hong Yang (University of Minnesota), De-Nian Yang (Academia Sinica), Ming-Jer Tsai (National Tsing Hua University), Wen-Tsuen Chen (Academia Sinica)

**Join Optimization of Chain Placement and Request Scheduling for Network Function Virtualization**
Qixia Zhang (Huazhong University of Science & Technology), Yikai Xiao (Huazhong University of Science & Technology), Fangming Liu (Huazhong University of Science and Technology), John Chi Shing Lui (Chinese University of Hong Kong), Jian Guo (Huazhong University of Science & Technology), Tao Wang (Huazhong University of Science & Technology)

**BIG Cache Abstraction for Cache Networks**
Eman Ramadan (University of Minnesota), Arvind Narayanan (University of Minnesota), Zhi-Li Zhang (University of Minnesota), Runhui Li (Huawei Future Network Theory Lab), Gong Zhang (Huawei Future Network Theory Lab)

**Distributed QR decomposition framework for training Support Vector Machines**
Jyotikrishna Dass (Texas A&M University), V. N. S. Prithvi Sakuru (Texas A&M University), Vivek Sarin (Texas A&M University), Rabi N. Mahapatra (Texas A&M University)

**Distributively Computing Random Walk Betweenness Centrality in Linear Time**
Qiang-Sheng Hua (Huazhong University of Science and Technology), Ming Ai (Huazhong University of Science and Technology), Hai Jin (Huazhong University of Science and Technology), Dongxiao Yu (Huazhong University of Science and Technology), Xuanhua Shi (Huazhong University of Science and Technology)

**DeGPar: Large Scale Topic Detection using Node-Cut Partitioning on Dense Weighted Graphs**
Kambiz Ghoorchian (Royal Institute of Technology (KTH)), Sarunas Girdzijauskas (Royal Institute of Technology (KTH)), Fatemeh Rahimian (Swedish Institute of Computer Science (SICS))

**Vision 6: Innovation in Big Data Systems**

**Location:** Atlanta

**Session Chair:** Manfred Hauswirth (TU Berlin)

**On the Design of a Blockchain Platform for Clinical Trial and Precision Medicine**
Zonyin Shae (ASIA University, Taiwan), Jeffrey Tsai (ASIA University, Taiwan)

**Towards Dataflow-based Graph Accelerator**
Hai Jin (Huazhong University of Science and Technology), Pengcheng Yao (Huazhong University of Science and Technology), Xiaofei Liao (Huazhong University of Science and Technology), Xianliang Li (Huazhong University of Science and Technology)

**Towards a RISC Framework for Efficient Contextualization in IoT**
Dimitrios Georgakopoulos (Swinburne University), Ali Yavari (RMIT University), Prem Prakash Jayaraman (Swinburne University), Rajiv Ranjan (Newcastle University)

**The Future of the Semantic Web: Prototypes on a Global Distributed Filesystem**
Michael Cochez (Fraunhofer - FIT), Dominik H"usser (RWTH Aachen University), Stefan Decker (RWTH Aachen)

**On Broad Big Data**
Steffen Staab (Institut WeST, University Koblenz-Landau and WAIS, University of Southampton)
Research 13: Distributed Algorithms and Theory II
Location: Salon II

Session Chair: Aziz Mohaisen (State University of New York at Buffalo)

Networked Stochastic Multi-Armed Bandits with Combinatorial Strategies
Shaojie Tang (University of Texas at Dallas), Yaqin Zhou (SUTD), Kai Han (University of Science and Technology of China), Zhao Zhang (Zhejiang Normal University), Jing Yuan (University of Texas at Dallas), Weili Wu (University of Texas at Dallas)

Computability of Perpetual Exploration in Highly Dynamic Rings
Marjorie Bournat (UPMC Sorbonne Universités), Swan Dubois (UPMC Sorbonne Universités), Franck Petit (UPMC Sorbonne Universités)

Locally Self-Adjusting Skip Graphs
Sikder Huq (The University of Iowa), Sukumar Ghosh (The University of Iowa)

Online to Offline Business: Urban Taxi Dispatching with Passenger-Driver Matching Stability
Huanyang Zheng (Temple University), Jie Wu (Temple University)

An Optimization Framework For Online Ride-sharing Markets
Yongzheng Jia (Tsinghua University), Wei Xu (Tsinghua University), Xue Liu (McGill University)

Fast and Accurate Tracking of Population Dynamics in RFID Systems
Muhammad Shahzad (North Carolina State University), Alex Liu (Michigan State University)

Short Paper 5: Distributed Big Data Systems and Analytics
Location: Nashville

Session Chair: Varun Soundararajan (Google)

Towards Multilingual Automated Classification Systems
Aibek Musaev (University of Alabama), Calton Pu (Georgia Institute of Technology)

The Joint Effects of Tweet Content Similarity and Tweet Interactions for Topic Derivation
Robertus Nugroho (Macquarie University), Weiliang Zhao (Macquarie University), Jian Yang (Macquarie University), Cecile Paris (CSIRO – ICT Centre), Surya Nepal (CSIRO)

Timed-release of Self-emerging Data using Distributed Hash Tables
Chao Li (University of Pittsburgh), Balaji Palanisamy (University of Pittsburgh)

Caching for Pattern Matching Queries in Time Evolving Graphs: Challenges and Approaches
Muhammad Nisar (University of Georgia), Sahar Voghoei (University of Georgia), Lak shmish Ramaswamy (University of Georgia)

GraphA: Adaptive Partitioning for Natural Graphs
Dongsheng Li (National University of Defense Technology), Chengfei Zhang (National University of Defense Technology), Jinyan Wang (National University of Defense Technology), Zhaoning Zhang (National University of Defense Technology), Yiming Zhang (National University of Defense Technology)

Parallel Algorithm for Core Maintenance in Dynamic Graphs
Na Wang (Huazhong University of Science and Technology), Dongxiao Yu (Huazhong University of Science and Technology), Hai Jin (Huazhong University of Science and Technology), Chen Qian (Huazhong University of Science and Technology), Xia Xie (Huazhong University of Science and Technology), Qiang-Sheng Hua (Huazhong University of Science and Technology)

DHCRF: A Distributed Conditional Random Field Algorithm on Heterogeneous CPU-GPU Cluster for Big Data
Ai Wei (Hunan University), Li Kenli (Hunan University), Chen Cen (Hunan University), Peng Jiwu (Hunan University), Li Keqin (Hunan University)

Towards New Abstractions for Implementing Quorum-based Systems
Tormod Erevik Lea (University of Stavanger), Leander Jehl (University of Stavanger), Hein Meling (University of Stavanger)

Selective Traffic Offloading On the Fly: a Machine Learning Approach
Zaiyang Tang (Huazhong University of Science and Technology), Peng Li (The University of Aizu), Song Guo (The Hong Kong Polytechnic University), Xiaofei Liao (Huazhong University of Science and Technology), Hai Jin (Huazhong University of Science and Technology), Daqing Zhang (Institut Mines-Telecom, Telecom SudParis)

A Fast Heuristic Attribute Reduction Algorithm using Spark
Mincheng Chen (Wuhan University of Technology), Jingling Yuan (Wuhan University of Technology), Lin Li (Wuhan University of Technology), Dongling Liu (Wuhan University of Technology), Tao Li (University of Florida)

Profiling Users by Modeling Web Transactions
JeCache: Just-Enough Data Caching with Just-in-Time Prefetching for Big Data Applications
Yifeng Luo (Fudan University), Jia Shi (Fudan University), Shuigeng Zhou (Fudan University)

Demo 1 - 4
Location: Charleston 1 and 2

Session Chairs: Gerald F Lofstead (Sandia National Lab) and Balaji Palanisamy (University of Pittsburg)

Demo 1: Distributed Applications Cluster
LITMUS: Towards Multilingual Reporting of Landslides
Aibek Musaev (University of Alabama), Qixuan Hou (Georgia Institute of Technology), Yang Yang (Georgia Institute of Technology), Calton Pu (Georgia Institute of Technology)

Pythia: A System for Online Topic Discovery of Social Media Posts
Iouliana Litou (Athens University of Economics and Business), Vana Kalogera (Athens University of Economics and Business)

Data-driven Serendipity Navigation in Urban Places
Xiaoyu Ge (University of Pittsburgh), Ameya Daphalapurkar (University of Pittsburgh), Manali Shimpi (University of Pittsburgh), Kohli Darpun (University of Pittsburgh), Konstantinos Pelechrinis (University of Pittsburgh), Panos Chrysanthis (University of Pittsburgh), Demetrios Zeinalipour-Yazti (Max Planck Institute for Informatics and University of Cyprus)

Toward An Integrated Approach to Localizing Failures in Community Water Networks (DEMO)
Qing Han (University of California Irvine), Phu Nguyen (University of California Irvine), Ronald T. Eguchi (ImageCat, Inc.), Kuo-Lin Hsu (University of California Irvine), Nalini Venkatasubramanian (University of California Irvine)

Demo 2: Security and Privacy Cluster
PrivateGraph: A Cloud-Centric System for Privacy-Preserving Spectral Analysis of Large Encrypted Graphs
Sagar Sharma (Wright State University), Keke Chen (Wright State University)

IoT Sentinel Demo: Automated Device-Type Identification for Security Enforcement in IoT
Markus Miettinen (Technische Universität Darmstadt), Samuel Marchal (Aalto University), Ibbad Hafeez (University of Helsinki), Tommaso Frassetto (Technische Universität Darmstadt), N. Asokan (Aalto University), Ahmad-Reza Sadeghi (Technische Universität Darmstadt), Susu Tarkoma (University of Helsinki)

Rogue Access Point Detector Using Characteristics of Channel Overlapping in 802.11n
Rhongho Jang (INHA University of Korea), Jeonil Kang (INHA university), Aziz Mohaisen (SUNY Buffalo), Daehun Nyang (Department of Computer and Information Engineering, INHA University, Incheon, Korea)

ReverseCloak: A Reversible Multi-level Location Privacy Protection System
Chao Li (University of Pittsburgh), Balaji Palanisamy (University of Pittsburgh), Aravind Kalaivanan (University of Pittsburgh), Sriram Raghunathan (University of Pittsburgh)

Demo 3: Clouds and Virtualization Cluster
Hopworks: Improving User Experience and Development on Hadoop with Scalable, Strongly Consistent Metadata
Mahmoud Ismail (KTH - Royal Institute of Technology), Ermias Gebremeskel (RISE SICS), Theofilos Kakountouis (RISE SICS), Gautier Berthou (RISE SICS), Jim Dowling (KTH - Royal Institute of Technology)

Isolation in Docker through Layer Encryption
Ioannis Giannakopoulos (National Technical University of Athens), Konstantinos Papazafeiropoulos (National Technical University of Athens), Katerina Doka (National Technical University of Athens), Nectarios Koziiris (National Technical University of Athens)

Dela - Sharing Large Datasets between Hadoop Clusters
Alexandru A. Ormenisan (KTH Royal Institute of Technology), Jim Dowling (KTH Royal Institute of Technology)

In Vivo Evaluation of the Secure Opportunistic Schemes Middleware using a Delay Tolerant Social Network
Corey E. Baker (University of California San Diego), Allen Starke (University of Florida), Tanisha G. Hill-Jarrett (University of Florida), Janise McNair (University of Florida)

Demo 4: Distributed Systems and Networking Cluster
Scaling and Load Testing Location-based Publish and Subscribe
Bertil Chapuis (University of Lausanne), BENOÎT Garbinato (University of Lausanne)
A Distributed Event-centric Collaborative Workflows Development System for IoT Application
Yongyang Cheng (BUPT), Shuai Zhao (BUPT), Bo Cheng (BUPT), Shoulu Hou (BUPT), Xiulei Zhang (BUPT), Junliang Chen (BUPT)

Incentive Mechanism for Data-Centric Message Delivery in Delay Tolerant Networks
Himanshu Jethawa (Missouri University of Science and Technology), Sanjay Madria (Missouri University of Science and Technology)

Performance Of Cognitive Wireless Charger For Near-Field Wireless Charging
Sang-Yoon Chang (University of Colorado, Colorado Springs and Advanced Digital Sciences Center), Sristi Lakshmi Sravana Kumar (Advanced Digital Sciences Center), Yih-Chun Hu (University of Illinois at Urbana-Champaign)

19:00-21:00 Wednesday, June 7, 2017

Organization Event (Invitation Only)
Day 4 – Thursday, June 8, 2017

7:30-8:30 Thursday, June 8, 2017
Continental Breakfast
Location: Foyer

8:30-9:30 Thursday, June 8, 2017
Keynote 3 by Kenneth Calvert (National Science Foundation)
Location: Phoenix Ballroom
Session Chair: Calton Pu (Georgia Institute of Technology)

9:30-10:00 Thursday, June 8, 2017
Coffee Break
Location: Foyer

10:00-12:00 Thursday, June 8, 2017
Tutorial 2: Sensor Cloud: A Cloud of Sensor Networks
Location: Charleston I
Sanjay Madria (Missouri University of Science and Technology)

Research 14: Mobile and Wireless Computing Systems II
Location: Salon I
Session Chair: Carlee Joe-Wong (Carnegie Mellon University)

Robust Indoor Wireless Localization Using Sparse Recovery
Wei Gong (Simon Fraser University), Jianguan Liu (Simon Fraser University)

Max-Min Fair Resource Allocation in HetNets: Distributed Algorithms and Hybrid Architecture
Ehsan Aryafar (Portland State University), Alireza Keshavarz-Haddad (Shiraz University), Carlee Joe-Wong (Carnegie Mellon University), Mung Chiang (Princeton University)

Optimization of Full-View Barrier Coverage with Rotatable Camera Sensors
Xiaofeng Gao (Shanghai Jiao Tong University), Rui Yang (University of Illinois Urbana-Champaign), Fan Wu (Shanghai Jiao Tong University), Guihai Chen (Shanghai Jiao Tong University), Jingguang Zhou (Shanghai Jiao Tong University)

Communication through Symbol Silence: Towards Free Control Messages in Indoor WLANs
Bing Feng (University of Science and Technology of China), Jianqing Liu (University of Florida), Chi Zhang (University of Science and Technology of China), Yuguang Fang (University of Florida)

Secure connectivity of wireless sensor networks under key predistribution with on/off channels
Jun Zhao (Carnegie Mellon University)

iUpdater: Low Cost RSS Fingerprints Updating for Device-free Localization
Liqiong Chang (Northwest University), Jie Xiong (Singapore Management University), Yu Wang (University of North Carolina at Charlotte), Xiaojiang Chen (Northwest University), Junhao Hu (Northwest University), Fang Dingyi (Northwest University)

Research 15: Social Networks and Crowdsourcing
Location: Columbia
Session Chair: Ting Wang (Lehigh University)

Influence Maximization in a Many Cascades World
Iouliana Litou (AUEB), Vana Kalogeraki (AUEB), Dimitrios Gunopulos (UoA)

Expertise-Aware Truth Analysis and Task Allocation in Mobile Crowdsourcing
Xiaomei Zhang (University of South Carolina Beaufort), Yibo Wu (Pennsylvania State University), Lifu Huang (Rensselaer Polytechnic Institute), Heng Ji (Rensselaer Polytechnic Institute), Guohong Cao (Pennsylvania State University)
MeLoDy: A Long-term Dynamic Quality-aware Incentive Mechanism for Crowdsourcing
Hongwei Wang (Shanghai Jiao Tong University), Song Guo (The Hong Kong Polytechnic University), Jiannong Cao (The Hong Kong Polytechnic University), Minyi Guo (Shanghai Jiao Tong University)

The Strong Link Graph for Enhancing Sybil Defenses
Suhendry Effendy (National University of Singapore), Roland Yap (National University of Singapore)

Mechanism Design for Mobile Crowdsensing with Execution Uncertainty
Zhenzhe Zheng (Shanghai Jiao Tong University), Zhaoxiong Yang (Shanghai Jiao Tong University), Fan Wu (Shanghai Jiao Tong University), Guihai Chen (Shanghai Jiao Tong University)

Towards Scalable and Dynamic Social Sensing Using A Distributed Computing Framework
Daniel Zhang (University of Notre Dame), Chao Zheng (University of Notre Dame), Dong Wang (University of Notre Dame), Doug Thain (University of Notre Dame), Xin Mu (University of Notre Dame), Greg Madey (University of Notre Dame), Chao Huang (University of Notre Dame)

Application 9: Distributed Systems and Applications
Location: Atlanta

Session Chair: Xueyan Tang (Nanyang Technological University)

Specifying a Distributed Snapshot Algorithm as a Meta-program and Model Checking it at Meta-level
Ha Thi Thu Doan (Japan Advanced Institute of Science and Technology), Francois Bonnet (Osaka University), Kazuhiro Ogata (Japan Advanced Institute of Science and Technology)

Self-Evolving Subscriptions for Content-Based Publish/Subscribe Systems
Cesar Cañas (McGill University), Kaiwen Zhang (Technical University of Munich), Bettina Kemme (McGill University), Jörg Kienzle (McGill University), Hans-Arno Jacobsen (Technical University of Munich)

Scalable Routing for Topic-based Publish/Subscribe Systems under Fluctuations
Volker Turau (Hamburg University of Technology), Gerry Siegemund (Hamburg University of Technology)

OPPay: Design and Implementation of A Payment System for Opportunistic Data Services
Fengrui Shi (Imperial College London), Zhijin Qin (Imperial College London), Julie McCann (Imperial College London)

Optimal Resource Allocation for Multi-user Video Streaming over mmWave Networks
Zhifeng He (Auburn University), Shiwen Mao (Auburn University)

A Multi-Agent Parallel Apporach to Analyzing Large Climate Data Sets
Jason Woodring (University of Washington Bothell), Matthew Sell (University of Washington Bothell), Munehiro Fukuda (University of Washington Bothell), Hazeline Asuncion (University of Washington Bothell), Eric Salathe (University of Washington Bothell)

Application 10: Distributed Systems and Services
Location: Columbia

Session Chair: Sangeetha Seshadri (IBM Almaden Research Center)

Energy Proportional Servers: Where Are We in 2016?
Congfeng Jiang (Hangzhou Dianzi University), Yumei Wang (Hangzhou Dianzi University), Dongyang Ou (Hangzhou Dianzi University), Bing Luo (Wayne State University), Weisong Shi (Wayne State University)

Are HTTP/2 Servers Ready Yet?
Muhui Jiang (The Hong Kong Polytechnic University), Xiapu Luo (The Hong Kong Polytechnic University), Tungngai Miu (Nexsguard Limited), Shengtuo Hu (The Hong Kong Polytechnic University), Weixiong Rao (Tongji University)

Data Integrity for Collaborative Applications over Hosted Services
Ertem Esiner (Nanyang Technological University), Anwitaman Datta (Nanyang Technological University)

Virtual Machine Power Accounting with Shapley Value
Weixiang Jiang (Huazhong University of Science & Technology), Fangming Liu (Huazhong University of Science and Technology), Guoming Tang (University of Victoria), Kui Wu (University of Victoria), Hai Jin (Huazhong University of Science & Technology)

A Versatile Platform for Mobile Data Gathering Experiments in Wireless Sensor Networks
Ji Li (Stony Brook University), Cong Wang (Stony Brook University), Yuanyuan Yang (Stony Brook University)

On Directional Neighbor Discovery in mmWave Networks
Yu Wang (Auburn University), Shiwen Mao (Auburn University), Theodore S. Rappaport (New York University)
Short Paper 6: Security, Privacy, Trust, and Fault Tolerance in Distributed Systems

Location: Nashville

Session Chair: Balaji Palanisamy (University of Pittsburgh)

Proximity Awareness Approach to Enhance Propagation Delay on the Bitcoin Peer-to-Peer Network
Muntadher Fadhil Sallal (University of Portsmouth), Gareth Owenson (University of Portsmouth), Mo Adda (University of Portsmouth)

Catch Me If You Can: Detecting Compromised Users Through Partial Observation on Networks
Derek Wang (Deakin University), Sheng Wen (Deakin University), Jun Zhang (Deakin University), Surya Nepal (Data61), Yang Xiang (Deakin University), Wanlei Zhou (Deakin University)

Location Privacy Breach: Apps Are Watching You in Background
Dachuan Liu (College of William & Mary), Xing Gao (College of William & Mary), Haining Wang (University of Delaware)

Android Malware Detection using Complex-Flows
Feng Shen (SUNY Buffalo), Justin Del Vecchio (SUNY Buffalo), Aziz Mohaisen (SUNY Buffalo), Steven Y. Ko (SUNY Buffalo), Lukasz Ziarek (SUNY Buffalo)

Privacy Implications of DNSSEC Look-aside Validation
Aziz Mohaisen (SUNY Buffalo), Zhongshu Gu (IBM Research), Kui Ren (SUNY Buffalo)

FlipNet: Modeling Covert and Persistent Attacks on Networked Resources
Sudip Saha (Virginia Polytechnic Institute and State University), Anil Vullikanti (Virginia Polytechnic Institute and State University), Mahantesh Halappanavar (Pacific Northwest National Lab)

Understanding the Market-level and Network-level Behaviors of the Android Malware Ecosystem
Chao Yang (Niara, Inc.), Jialong Zhang (IBM Research), Guofei Gu (Texas A&M University)

EnGarde: Mutually-Trusted Inspection of SGX Enclaves.
Hai Nguyen (Rutgers University), Vinod Ganapathy (Rutgers University)

Truthful Online Auction for Cloud Instance Subletting
Yifei Zhu (Simon Fraser University), Silvery Fu (Simon Fraser University), Jiangchuan Liu (Simon Fraser University), Yong Cui (Tsinghua University)

Giuseppe Antonio Di Luna (La Sapienza), Paola Flocchini (University of Ottawa), Taisuke Izumi (Nagoya Institute of Technology), Tomoko Izumi (College of Information Science and Engineering), Nicola Santoro (Carleton University), Giovanni Viglietta (University of Ottawa)

Distributed Fault Tolerant Linear System Solvers based on Erasure Coding
Xuejiao Kang (Purdue University--West Lafayette), David F. Gleich (Purdue University--West Lafayette), Ahmed Sameh (Purdue University--West Lafayette), Ananth Grama (Purdue University--West Lafayette)

Preserving Incumbent Users’ Privacy in Exclusion-Zone-Based Spectrum Access Systems
Yanzhi Dou (Virginia Tech), He Li (Virginia Tech), Kexiong Zeng (Virginia Tech), Jinshan Liu (Virginia Tech), Yaling Yang (Virginia Tech), Bo Gao (Chinese Academy of Sciences), Kui Ren (SUNY Buffalo)

12:00-13:30 Thursday, June 8, 2017

Business Lunch including Awards and ICDCS 2018 Announcements
Location: Phoenix Ballroom

13:30-15:30 Thursday, June 8, 2017

Tutorial 2: Sensor Cloud: A Cloud of Sensor Networks (until 14:30)
Location: Charleston 1

Sanjay Madria (Missouri University of Science and Technology)

Plenary Panel on the Convergence of Big Data, IoT/CPS, and SCC (Smart & Connected Communities)
Location: Phoenix Ballroom

The keywords of Big Data, Internet of Things (IoT), Cyber-Physical Systems (CPS), and Smart & Connected Communities (a.k.a. Smart Cities and Smart Planet) have been around for quite a few years. They started from different disciplines:
• Big data originated from scientific sensors (e.g., satellites) and enterprise applications (e.g., Walmart cash registers).
• IoT/CPS started from wireless sensor networks and real-time systems (e.g., the CPSweek series of conferences)
• Smart Planet, Smart Cities, and SCC started from Autonomic Computing (with these keywords popularized initially by IBM)

These research fields and application areas have been expanding tremendously in recent years, with significant and growing overlaps among them. We believe these overlaps represent huge opportunities for innovative research and potential societal impact. At the same time, they also create unprecedented research challenges that surpass the traditional confines of each original discipline.

As simple examples, big data analytics and real-time IoT sensor-based decision making (individually) have been the front runner smart applications showcased by Smart City projects. However, their combination has seen limited integration of techniques from both fields. An example of overlapping areas is streaming analytics of real-time IoT sensors, which typically use big data tools at fine time granularity (e.g., Apache Spark and Storm) with lingering limitations in real-time guarantees and machine learning capabilities needed for smart applications. A concrete example of challenge applications is the automated real-time tracking of moving entities across networks of video cameras. Although such tracking is done routinely by humans, its automation requires significant advances in the integration of vision/machine learning tools (object recognition from video images) with streaming analytics (parallel processing of video images from related cameras).

The panel will discuss the overlapping areas among big data, IoT/CPS, and SCC/Smart Cities, with emphasis on the research opportunities and technical challenges.

Panel Moderator: Calton Pu

Calton Pu
Calton’s research interests are in the areas of service computing, distributed and cloud computing, integration and veracity of big data. His current projects include cloud computing (Elba) and big data (GRAIT-DM) research. Using experimental data from realistic benchmarks, the Elba project studies the interesting phenomena such as very short bottlenecks that have large impact on n-tier system response time. The GRAIT-DM project collects real world data from social sensors (e.g., Twitter and YouTube) and physical sensors (e.g., USGS GSN and NASA TRMM) to detect physical events and manage real-time information on them. The sponsors for Calton Pu’s research include both government funding agencies such as NSF, and companies from industry such as HP, Fujitsu, IBM, and Intel. He is a co-director of Center for Experimental Research in Computer Systems (CERCS), and affiliate faculty of Institute for Information Security and Privacy (IISP) at Georgia Tech. He is also the director of RCN on Big Data for Smart Cities, with collaborations around the world. Positions available: Georgia Tech is recruiting good graduate students.

Panelists
Karl Aberer
Karl Aberer received his PhD in mathematics in 1991 from the ETH Zürich. From 1991 to 1992 he was postdoctoral fellow at the International Computer Science Institute (ICSI) at the University of California, Berkeley. In 1992, he joined the Integrated Publication and Information Systems institute (IPSI) of GMD in Germany, where he was leading the research division Open Adaptive Information Management Systems. In 2000 he joined EPFL as full professor. Since 2005 he is the director of the Swiss National Research Center for Mobile Information and Communication Systems (NCCR-MICS, www.mics.ch). He is member of the editorial boards of VLDB Journal, ACM Transaction on Autonomous and Adaptive Systems and World Wide Web Journal. He has been consulting for the Swiss government in research and science policy as a member of the Swiss Research and Technology Council (SWTR) from 2003 - 2011.

Srinivas Aluru
Srinivas Aluru is a professor in the School of Computational Science and Engineering within the College of Computing at Georgia Institute of Technology. He co-leads the Georgia Tech Strategic Initiative in Data Engineering and Science. He conducts research in high performance computing, bioinformatics and systems biology, combinatorial scientific computing, and applied algorithms. He pioneered the development of parallel methods in computational biology, and contributed to the assembly and analysis of complex plant genomes. His group is currently focused on developing bioinformatics methods for high-throughput DNA sequencing, particularly error correction and genome assembly. In systems biology, his group is working on network inference methods using mutual information and Bayesian approaches, and network analysis techniques to further the knowledge of partially characterized pathways. His contributions in scientific computing lie in parallel Fast Multipole Method, domain decomposition methods, spatial data structures, and applications in computational electromagnetics and materials informatics. Aluru is a Fellow of the American Association for the Advancement of Science (AAAS) and the Institute for Electrical and Electronic Engineers (IEEE). He is a recipient of the NSF Career award (1997), IBM faculty award (2002), and Swarnajayanti fellowship from the Government of India (2007). He serves on the editorial boards of the IEEE Transactions on Parallel and Distributed Systems, the Journal of Parallel and Distributed Computing, and the International Journal of Data Mining and Bioinformatics.

Kenneth Calvert
Ken Calvert is Division Director for Computer and Network Systems in the Computer and Information Science and Engineering (CISE) Directorate at the National Science Foundation. He is on rotation from the University of Kentucky, where he is Gartner Group Professor in Network Engineering in the Department of Computer Science. His research deals with the design and implementation of advanced network protocols and services, with particular interest in routing and incentives in future network architectures. He received his Ph.D. in computer science from the University of Texas at Austin. He holds a M.S. in computer science from Stanford University and a B.S. in computer science and engineering from the Massachusetts Institute of Technology. Prior to his appointment at the University of Kentucky, he was a Member of the Technical Staff at Bell Laboratories in Holmdel, NJ, and served on the faculty in the College of Computing.
at the Georgia Institute of Technology. He is an IEEE Fellow and a member of the ACM.

**C. Mohan**

Dr. C. Mohan has been an IBM researcher for 35 years in the database area, impacting numerous IBM and non-IBM products, the research and academic communities, and standards, especially with his invention of the ARIES family of database locking and recovery algorithms, and the Presumed Abort commit protocol. This IBM (1997), and ACM/IEEE (2002) Fellow has also served as the IBM India Chief Scientist for 3 years (2006-2009). In addition to receiving the ACM SIGMOD Innovation Award (1996), the VLDB 10 Year Best Paper Award (1999) and numerous IBM awards, Mohan was elected to the US and Indian National Academies of Engineering (2009), and was named an IBM Master Inventor (1997). This Distinguished Alumnus of IIT Madras (1977) received his PhD at the University of Texas at Austin (1981). He is an inventor of 50 patents. He is currently focused on Big Data, HTAP and Blockchain technologies. In 2016, he was named a Distinguished Visiting Professor of China’s prestigious Tsinghua University. He has served on the advisory board of IEEE Spectrum, and on numerous conference and journal boards. Mohan is a frequent speaker in North America, Europe and India, and has given talks in 40 countries. He is very active on social media and has a huge network of followers. More information could be found in the Wikipedia page at http://bit.ly/CMwIkP

**Manish Parashar**

Manish Parashar is Distinguished Professor of Computer Science at Rutgers, The State University of New Jersey University. He is also the founding Director of the Rutgers Discovery Informatics Institute (RDI2) and The Applied Software Systems Laboratory (TASSL), Full Member (Clinical Investigations and Precision Therapeutics Program) of the Rutgers Cancer Institute of New Jersey, and is Associate Director at the Rutgers Center for Information Assurance (RUCIA). He also has a Joint Faculty Appointment with Oak Ridge National Laboratory (ORNL), and is Visiting Professor in the Faculty of Business, Computing & Law, University of Derby, UK. He co-founded and was Co-Director of the Cloud and Autonomic Computing Center (CAC) NSF IUCRC at Rutgers (CAC@Rutgers) between 2008 and 2013. At Rutgers, he led (with Prof. H. Berman) the strategic planning efforts in Research Computing and served as the Interim Associate Vice President of Research Computing between 2015 – 2016 to oversee the establishment of the Rutgers Office of Advanced Research Computing (OARC). He is also currently the Lead PI for Cyberinfrastructure for the NSF Ocean Observatories Initiative.
Research 1: Distributed Fault Tolerance and Dependability

Timely, Reliable, and Cost-Effective Internet Transport Service using Dissemination Graphs

Amy Babay (Johns Hopkins University), Emily Wagner (Johns Hopkins University, LTN Global Communications), Michael Dinitz (Johns Hopkins University), Yair Amir (Johns Hopkins University, LTN Global Communications)

Emerging applications such as remote manipulation and remote robotic surgery require communication that is both timely and reliable, but the Internet natively supports only communication that is either completely reliable with no timeliness guarantees (e.g. TCP) or timely with best-effort reliability (e.g. UDP). We present an overlay transport service that can provide highly reliable communication while meeting stringent timeliness guarantees (e.g. 130ms round-trip latency across the US) over the Internet. To enable routing schemes that can support the necessary timeliness and reliability, we introduce dissemination graphs, providing a unified framework for specifying routing schemes ranging from a single path, to multiple disjoint paths, to arbitrary graphs. We conduct an extensive analysis of realworld network data, finding that a routing approach using two disjoint paths performs well in most cases, and that cases where two disjoint paths do not perform well typically involve problems around a source or destination. Based on this analysis, we develop a timely dissemination-graph-based routing method that can add targeted redundancy in problematic areas of the network. This approach can cover over 99% of the performance gap between a traditional single-path approach and an optimal (but prohibitively expensive) scheme, while two dynamic disjoint paths cover about 70% of this gap, and two static disjoint paths cover about 45%. This performance improvement is obtained at a cost increase of about 2% over two disjoint paths.

Pronto: Efficient Test Packet Generation for Dynamic Network Data Planes

Yu Zhao (University of Kentucky), Huazhe Wang (University of California at Santa Cruz), Xin Lin (University of California at Santa Cruz), Tingting Yu (University of Kentucky), Chen Qian (University of California at Santa Cruz)

Computer networks are becoming increasingly complex today and thus prone to various network faults. Traditional testing tools (e.g., ping, traceroute) that often involve substantial manual effort to uncover faults are inefficient. This paper focuses on fault detection of the network data plane using test packets. Existing solutions of test packet generation either take very long time (e.g., more than one hour) to complete or generate too many test packets that may hurt regular traffic. In this paper, we present Pronto, an automated test packet generation tool that generates test packets to exercise data plane rules in the entire network in a short time (e.g., several seconds) and can quickly react to rule changes due to network dynamics. In addition, Pronto minimizes the number of test packets by allowing a packet to test multiple rules at different switches. The performance evaluation using two real network data plane rule sets shows that Pronto is faster than a recently developed tool by more than two orders of magnitude. Pronto can update the probes for rule changes using less than 1ms while existing methods have no such update function.

Agar: A Caching System for Erasure-Coded Data

Raluca Halalai (University of Neuchâtel), Pascal Felber (University of Neuchâtel), Anne-Marie Kermarrec (INRIA), François Taiani (IRISA)

Erasure coding is an established data protection mechanism. It provides high resiliency with low storage overhead, which makes it very attractive to storage systems developers. Unfortunately, when used in a distributed setting, erasure coding hampers a storage systems performance, because it requires clients to contact several, possibly remote sites in order to retrieve their data. This has hindered the adoption of erasure coding in practice, limiting its use to cold, archival data. Recent research showed that it is feasible to use erasure coding for hot data as well, thus opening up new perspectives for improving erasure coded storage systems. In this paper, we address the problem of minimizing access latency in erasure coded storage. We propose Agara novel caching system tailored for erasure-coded content. Agar optimizes the contents of the cache based on live information regarding data popularity and access latency to different data storage sites. Our system adapts a dynamic programming algorithm to optimize the choice of data blocks that are cached, using an approach akin to Knapsack algorithms. We compare Agar to the classical Least Recently Used and Least Frequently Used cache eviction policies, while varying the amount of data cached between a data chunk and a whole replica of the object. We show that Agar can achieve 16% to 41% lower latency than systems that use classical caching policies.

High performance recovery for parallel state machine replication

Odorico Mendizabal (FURG), Fernando Luis Dotti (PUCRS), Fernando Pedone (University of Lugano)

State machine replication is a fundamental approach to high availability. Despite the vast literature on the topic, relatively few studies have considered the issues involved in recovering faulty replicas. Recovering a replica requires (a) retrieving and installing an up-to-date replica checkpoint, and (b) restoring and re-executing the log of commands not reflected in the checkpoint. Parallel techniques to state machine replication render recovery particularly challenging since throughput under normal execution (i.e., in the absence of failures) is very high. Consequently, the log of commands that need to be applied until the replica is available is typically large, which delays recovery. In this paper, we present two techniques to optimize recovery in parallel state machine replication. The first technique allows new commands to execute concurrently with the execution of logged commands, before replicas are completely updated. The second technique introduces on-demand state recovery, which allows segments of a checkpoint to be recovered concurrently.

On Data Parallelism of Erasure Coding in Distributed Storage Systems

Jun Li (University of Toronto), Baohun Li (University of Toronto)

Deployed in various distributed storage systems, erasure coding has demonstrated its advantages of low storage overhead and high failure tolerance. Typically in an erasure coded distributed storage system, systematic maximum distance separable (MDS) codes are chosen since the optimal storage overhead can be achieved and meanwhile data can be read directly without decoding operations. However, data parallelism of existing MDS codes is limited, because we can only read data from some specific servers in parallel without decoding operations. In this paper, we propose Carousel codes, designed to allow data to be read from an arbitrary number of servers in parallel without decoding, while preserving the optimal storage overhead of MDS codes. Furthermore, Carousel codes can achieve the optimal network traffic to reconstruct an unavailable block. We have implemented a prototype of Carousel codes on Apache Hadoop. Our experimental results have demonstrated that Carousel codes can make MapReduce jobs finish with almost 50% less time and reduce data access latency significantly, with a comparable throughput in the encoding and decoding operations and no additional sacrifice of failure tolerance or the network overhead to reconstruct unavailable data.

MeteorShower: Minimizing Request Latency for Majority Quorum-based Data Consistency Algorithms in Multiple Data Centers
Ying Liu (KTH Royal Institute of Technology), Xi Guan (KTH Royal Institute of Technology), Vladimir Vlassov (KTH Royal Institute of Technology), Seif Haridi (KTH Royal Institute of Technology)

With the increasing popularity of serving and storing data in multiple data centers, we investigate the efficiency of majority quorum-based data consistency algorithms under this scenario. Because of the failure-prone nature of distributed storage systems, majority quorum-based data consistency algorithms become one of the most widely adopted approaches. In this paper, we propose the MeteorShower framework, which provides fault-tolerant read/write key-value storage service across multiple data centers with sequential consistency guarantees. A major feature is that most read operations are executed locally within a single data center. This results in lowering read latency from hundreds of milliseconds to tens of milliseconds. The data consistency algorithm in MeteorShower augments majority quorum-based algorithms. Thus, it keeps all the desirable properties of majority quorums, such as fault tolerance, balanced load, etc. An implementation of MeteorShower on top of Cassandra is deployed and evaluated in multiple data centers using the Google Cloud Platform. Evaluations of MeteorShower framework have shown that it can consistently serve read requests without paying the communication delays among replicas maintained in multiple data centers. As a result, we are able to improve the latency of read requests from hundreds of milliseconds to tens of milliseconds while achieving the same latency on write requests and the same fault tolerance guarantee. Thus, MeteorShower is optimized for read intensive workloads.

**Research 2: Distributed Operating Systems and Middleware**

**LSbM-tree: Re-enabling high-speed caching in Data Management for Mixed Reads and Writes**

Dejun Teng (The Ohio State University), Lei Guo (Google), Rubao Lee (The Ohio State University), Feng Chen (Louisiana State University), Siyuan Ma (The Ohio State University), Xiaodong Zhang (The Ohio State University), Yanfeng Zhang (Northeastern University)

LSM-tree has been widely used in data management production systems for write-intensive workloads. However, as read and write workloads co-exist under LSM-tree, data accesses can experience long latency and low throughput due to the interferences to buffer caching from the compaction, a major and frequent operation in LSM-tree. After a compaction, the existing data blocks are reorganized and written to other locations on disks. As a result, the related data blocks that have been loaded in the buffer cache are invalidated since their referencing addresses are changed, causing serious performance degradations. In order to re-enable high-speed buffer caching during intensive writes, we propose Log-Structured buffered-Merge tree (simplyified as LSbM-tree) by adding a compaction buffer on disks, to minimize the cache invalidations on buffer cache caused by compactions. The compaction buffer efficiently and adaptively maintains the frequently visited data sets. In LSbM, strong locality objects can be effectively kept in the buffer cache with minimum or without harmful invalidations. With the help of a small on-disk compaction buffer, LSbM achieves a high query performance by enabling effective buffer caching, while retaining all the merits of LSM-tree for write-intensive data processing, and providing high bandwidth of disks for range queries. We have implemented LSbM based on LevelDB. We show that with a standard buffer cache and a hard disk, LSbM can achieve 2x performance improvement over LevelDB. We have also compared LSbM with other existing solutions to show its strong effectiveness.

**Incremental Topology Transformation for Publish/Subscribe Systems Using Integer Programming**

Pooya Salehi (Technical University of Munich), Kaiwen Zhang (Technical University of Munich), Hans-Arno Jacobsen (University of Toronto)

Distributed overlay-based publish/subscribe systems provide a selective, scalable, and decentralized approach to data dissemination. Due to the dynamic communication flows between data producers and consumers, the overlay topology of such systems can become inefficient over time and therefore requires adaptation to the existing load. Existing studies propose algorithms to design overlay topologies which are optimized for specific workloads. However, the problem of generating a plan to incrementally transform the current topology to an optimized one has been largely ignored. In this paper, we present IPITT, an approach based on integer programming for the incremental topology transformation (ITT) problem. Given the current topology and a target topology, IPITT generates a transformation plan with a minimal number of steps in order to lessen service disruption. Furthermore, we introduce a plan execution mechanism and evaluate our approach on an existing publish/subscribe system. Based on our evaluation, IPITT can reduce plan computation time by a factor of 10 and generates plans with an execution time up to 55% shorter than those of existing approaches.

**milliScope: a Fine-Grained Monitoring Framework for Performance Debugging of n-Tier Web Services**

Chien-An Lai (Georgia Institute of Technology), Josh Kimball (Georgia Institute of Technology), Tao Zhu (Georgia Institute of Technology), Qingyang Wang (Louisiana State University), Calton Pu (Georgia Institute of Technology)

Modern distributed systems are often considered to be black-boxes that greatly limit the potential to understand behaviors at the level of detail necessary to diagnose some of the most important types of performance problems. Recently researchers have found abnormal response time delay, one to two order of magnitude longer than the average response time, exists in short period and causes economical loss for service providers. These very short bottlenecks are hard to detect due to its short live span and its variety of possible reasons. In this paper, we propose milliScope (mScope), the first millisecond-granularity software-based resource and event monitoring for distributed systems that achieves both performance, low overhead at high frequency, and high accuracy matched with other software monitoring tool. More specifically, milliScope is a fine-grained monitoring framework to collaborate multiple mScopeMonitors for event and resource monitoring to reconstruct the flow of each client request and profile execution performance in a distributed system. We utilize the resource mScopeMonitors for system resource monitoring, and we develop our own event mScopeMonitors to identify the execution boundary in a lightweight, precise and systematic methodology. The semantic and syntactic of these monitoring logs with arbitrary formats are enriched by our multi-stage data transformation tool, mScopeDataTransformer, which unifies the diverse monitoring logs into a dynamic data warehouse, mScopeDB, for advanced analysis. We conduct several illustrative scenarios in which milliScope successfully diagnoses the response time anomalies caused by very short bottlenecks using a representative web application benchmark (RUBBoS). Besides, we validate the accuracy of our event mScopeMonitors and demonstrate availability and flexibility of milliScope through several evaluations.

**Stark: Optimizing In-Memory Computing For Dynamic Dataset Collections**

Shen Li (IBM Research), Md Tanvir Al Amin (UIUC), Raghu Ganti (IBM Research), Mudhakar Srvatsa (IBM Research), Shaohan Hu (IBM Research), Yiran Zhao (UIUC), Tarek Abdelzaher (UIUC)

Emerging distributed in-memory computing frameworks, such as Apache Spark, can process a huge amount of cached data within seconds. This remarkably high efficiency requires the system to well balance data across tasks and ensure data locality. However, it is challenging to satisfy these requirements for applications that operate on a collection of dynamically loaded and evicted datasets. The dynamics may lead to time-varying data volume and distribution, which would frequently invoke expensive data re-partition and transfer operations, resulting in high overhead and large delay. To address this problem, we present Stark, a
system specifically designed for optimizing in-memory computing on dynamic dataset collections. Stark enforces data locality for transformations spanning multiple datasets (e.g., join and cogroup) to avoid unnecessary data replications and shuffles. Moreover, to accommodate fluctuating data volume and skewed data distribution, Stark delivers elasticity into partitions to balance task execution time and reduce job makespan. Finally, Stark achieves bounded failure recovery latency by optimizing the data checkpointing strategy. Evaluations on a 50-server cluster show that Stark reduces the job makespan by 4X and improves system throughput by 6X compared to Spark.

CRESON: Callable and Replicated Shared Objects over NoSQL
Pieter Sutre (Télécom SudParis, CNRS, Université Paris-Saclay, France), Etienne Rivière (University of Neuchatel), Cristian Cotes (Universitat Rovira i Virgili), Marc Sánchez Artigas (Universitat Rovira i Virgili), Pedro García Lopez (Universitat Rovira i Virgili), Emmanuel Bernard (Red Hat), William Burns (Red Hat), Galder Zamarrano (Red Hat)

The ability to share and persist objects simplifies the design of applications in Cloud environments. Storing objects on a NoSQL database ensures availability and scalability. When Object-NoSQL Mapping is performed at the client side, objects that are accessed concurrently are repeatedly converted between their in-memory and serialized representations. This negatively impacts performance and increases replication costs. We describe in this paper the design of CRESON, a system supporting callable objects over NoSQL in which application objects are mapped and instantiated directly on the storage nodes. CRESON supports composition by reference and ensures strong consistency. Objects are replicated and maintained coherent using State Machine Replication. The implementation of CRESON leverages the support of a listenable key-value store (LKVS), a novel NoSQL storage abstraction that we introduce in this paper. We discuss the performance and complexity of using CRESON with the example of the portage of a personal cloud storage service, initially developed using object-relational mapping over a sharded PostgreSQL database. Our results show that CRESON offers a simpler programming experience both in terms of learning time and lines of code, while performing better on average and being more scalable.

Virtualized Network Coding Functions on the Internet
Linquan Zhang (University of Calgary), Shangqi Lai (The University of Hong Kong), Chuan Wu (The University of Hong Kong), Zongpeng Li (University of Calgary), Chuaxiong Guo (Microsoft Research)

Network coding is a fundamental tool that enables higher network capacity and lower complexity in routing algorithms, by encouraging the mixing of information flows in the middle of a network. Implementing network coding in the core network is subject to practical concerns, since Internet routers are often overwhelmed by packet forwarding tasks, leaving little processing capacity for coding operations. Inspired by the recent paradigm of network function virtualization, we propose implementing network coding as a new network function, and deploying such coding functions in geo-distributed cloud data centers, to practically enable network coding on the Internet. We target multicast sessions (including unicast flows as special cases), strategically deploy relay nodes (network coding functions) in selected data centers between senders and receivers, and embrace high bandwidth efficiency brought by network coding with dynamic coding function deployment. We design and implement the network coding function on typical virtual machines, featuring efficient packet processing. We propose an efficient algorithm for coding function deployment, scaling in and out, in the presence of system dynamics. Real-world implementation on Amazon EC2 and Linode demonstrates significant throughput improvement and higher robustness of multicast via coding functions as well as efficiency of the dynamic deployment and scaling algorithm.

Research 3: Security and Privacy in Distributed Systems I

Consensus Robustness and Transaction De-Anonymization in the Ripple Currency Exchange System
Adriano Di Luzio (Sapienza University of Rome), Alessandro Mei (Sapienza University of Rome), Julinda Stefa (Sapienza University of Rome)

Distributed financial systems are radically changing the way we do business and spend our money. Ripple, in particular, is unique in its kind. It is built on consensus and trust among its peers and, differently from many other systems, it allows exchanging both fiat currencies and goods. It does so by storing the accounts of its users, their balances, and all the transactions in a distributed ledger, publicly accessible. In this paper we perform for the first time an in-depth study of the Ripple exchange system and its public distributed ledger. We analyze payments, the structure of payment paths, and the role of important peers in the system such as Gateways (the equivalent of Banks) and Market Makers that allow cross-currency exchange among users. To complete the study of the ecosystem we analyze the internal stream of events in Ripple and show that the whole system relies on a surprisingly small number of active validators, raising several concerns on the robustness and on the actual fairness of the system. Finally, we show how distributed financial systems can jeopardize the privacy of their users. By examining the first 3 years of Ripple history (more than 500 GB of data), we show that even approximate information on a single payment can uncover, with incredible accuracy, the whole financial life of the user. For example, this allows anyone who overhears our order for a Latte at our favourite bar to gain complete and unlimited access to our balance, our previous and future payments, our monthly income, as well as the places where we shop and the people we trust.

Learning privacy habits of PDS owners
Bikash Singh (University of Insubria), Barbara Carminati (University of Insubria), Elena Ferrari (University of Insubria)

The concept of Personal Data Storage (PDS) has recently emerged as an alternative and innovative way of managing personal data w.r.t. the service-centric one commonly used today. The PDS offers a unique logical repository, allowing individuals to collect, store, and give access to their data to third parties. The research on PDS has so far mainly focused on the enforcement mechanisms, that is, on how user privacy preferences can be enforced. In contrast, the fundamental issue of preference specification has been so far not deeply investigated. In this paper, we do a step in this direction by proposing different learning algorithms that allow a fine-grained learning of the privacy aptitudes of PDS owners. The learned models are then used to answer third party access requests. The extensive user studies we have performed show the effectiveness of the proposed approach.

City-Hunter: Hunting Smartphones in Urban Areas
Xuefeng Liu (Hong Kong Polytechnic University), Jiaqi Wen (Hong Kong Polytechnic University), Shaojie Tang (University of Texas at Dallas), Jiannong Cao (Hong Kong Polytechnic University), Jiaxing Shen (Hong Kong Polytechnic University)

The security issue of public WiFi is gaining more and more concern. By listening to probe requests, an adversary can obtain the SSID list of the APs to which a smartphone previously connected, and utilizes this information to trick the smartphone into associating to it. However, with the enhancement of security level, most smartphones now do not proactively disclose their SSID lists, making these attacks obsolete. In this paper, we propose City-Hunter, an attacker that can lure nearby smartphones without knowing their SSID information. City-Hunter establishes and maintains an SSID database by integrating both offline and online information. Meanwhile, it smartly chooses some SSIDs to hit a smartphone according to the past record and freshness. We evaluate the performance of City-
failures. Towards this goal, we collect failures data along with many parameters that might influence failures from two large hardware, workloads, support facilities, and even the environment. One has to rely on failure data from the field to quantify the influence of these factors on failures. Towards this goal, we collect failures data along with many parameters that might influence failures from two large production datacenters with very high utilization levels as high as 83%, despite the same millibottlenecks.

Cloud datacenters must ensure high availability for the hosted applications and failures can be the bane of datacenter operations. Understanding the what, when and why of failures can help tremendously to mitigate their occurrence and impact. Failures can, however, depend on numerous spatial and temporal factors spanning hardware, workloads, support facilities, and even the environment. One has to rely on failure data from the field to quantify the influence of these factors on failures. Towards this goal, we collect failures data along with many parameters that might influence failures from two large production datacenters with very high utilization levels as high as 83%, despite the same millibottlenecks.

Network tomography is a vital tool to estimate link qualities from end-to-end network measurements. An implicit assumption in network tomography is that observed measurements indeed reflect the aggregate of link performance (i.e., seeing is believing). However, it is not guaranteed today that there exists no anomaly (e.g., malicious autonomous systems and insider threats) in large-scale networks. Malicious nodes can intentionally manipulate link metrics via delaying or dropping packets to affect measurements. Will such an assumption render a vulnerability when facing attackers? The problem is of essential importance in that network tomography is developed towards effective network diagnostics and failure recovery. In this paper, we demonstrate that the vulnerability is real and propose a new attack strategy, called scapegoating, in which malicious nodes can substantially damage a network (e.g., delaying packets) and at the same time maliciously manipulate end-to-end measurement results so that a legitimate node is misleadingly identified as the root cause of the damage (thereby becoming a scapegoat) under network tomography. We formulate three basic scapegoating approaches and show under what conditions attacks can be successful. We also reveal conditions to detect such attacks. Our theoretical and experimental results show that simply trusting measurements leads to scapegoating vulnerabilities. Thus, existing methods should be revisited accordingly for security in various applications.

You Can Hear But You Cannot Steal: Defending against Voice Impersonation Attacks on Smartphones
Si Chen (University at Buffalo / West Chester University), Kui Ren (University at Buffalo), Sixu Piao (University at Buffalo), Cong Wang (City University of Hong Kong), Qian Wang (Wuhan University), Jian Weng (Jinan University), Lu Su (University at Buffalo), Aziz Mohaisen (University at Buffalo)

Voice, as a convenient and efficient way of information delivery, has a significant advantage over the conventional keyboard-based input methods, especially on small mobile devices such as smartphones and smartwatches. However, the human voice could often be exposed to the public, which allows an attacker to quickly collect sound samples of targeted victims and further launch voice impersonation attacks to spoof those voice-based applications. In this paper, we propose the design and implementation of a robust software-only voice impersonation defense system, which is tailored for mobile platforms and can be easily integrated with existing off-the-shelf smart devices. In our system, we explore magnetic field emitted from loudspeakers as the essential characteristic for detecting machine-based voice impersonation attacks. Furthermore, we use a state-of-the-art automatic speaker verification system to defend against human imitation attacks. Our advanced sensory data processing technique achieves fast authentication speed (6.1 s) which makes it suitable for mobile platforms. Finally, our evaluation results show that our system achieves significantly high accuracy (100%) and low (0%) equal error rates (EERs) in detecting the machine-based voice impersonation attack on smartphones.

Flow Reconnaissance via Timing Attacks on SDN Switches
Sheng Liu (University of North Carolina at Chapel Hill), Michael Reiter (University of North Carolina at Chapel Hill), Vyas Sekar (Carnegie Mellon University)

When encountering a packet flow for which it has no covering rule, a software-defined networking (SDN) switch requests an appropriate rule from its controller; this request delays the routing of the flow until the controller responds. We show that this delay gives rise to a timing side channel in which an attacker can test for the recent occurrence of a target flow by judiciously probing the switch with forged flows and using the delays they suffer to discern whether covering rules were previously installed in the switch. We develop a Markov model of an SDN switch to permit the attacker to select the best probe (or probes) to infer whether a target flow has recently occurred. Our model captures complexities related to rule evictions to make room for other rules; rule timeouts due to inactivity; the presence of multiple rules that apply to overlapping sets of flows; and rule priorities. We show that our model permits detection of target flows with considerable accuracy in many cases.

Research 4: Cloud Computing and Data Center Systems
A Study of Long-Tail Latency in n-Tier Systems: RPC vs. Asynchronous Invocations
Qingyang Wang (Louisiana State University), Chien-An Lai (Georgia Tech), Yasuhiro Kanemasa (Fujitsu Laboratories Ltd.), Shungeng Zhang (Louisiana State University), Calton Pu (Georgia Tech)

Long-tail latency of web-facing applications continues to be a serious problem. Most of the previously published research addresses two classes of long latency problems: uneven workloads such as web search, and resource saturation in single nodes. We describe an experimental study of a third class of long tail latency problems that are specific to distributed systems: Cross-Tier Queue Overflow (CTQO) due to a combination of millibottlenecks (with sub-second duration) and tightly-coupled servers in n-tier systems (e.g., Apache, Tomcat, and MySQL) using RPC-style request-response communications. Our experiments show that the appearance of millibottlenecks (e.g., created by short workload bursts) in one server often causes another server (which has no saturated resources) in the synchronous invocation chain to fill up its queues (CTQO) and drop packets, creating very long response time queries. CTQO can be reduced or avoided by replacing the server dropping packets with an asynchronous server. In synchronous n-tier system experiments, long tail latency due to CTQO can be reproduced consistently at utilization as low as 43%. In contrast, when all n-tier servers are replaced by asynchronous versions, CTQO and consequent dropped packets remain absent at utilization levels as high as 83%, despite the same millibottlenecks.

Rain or Shine? - Making Sense of Cloudy Reliability Data
Iysswarya Narayanan (The Pennsylvania State University), Bikash Sharma (Microsoft), Di Wang (Microsoft), Sriram Govindan (Microsoft), Laura Caulfield (Microsoft), Anand Sivasubramaniam (The Pennsylvania State University), Aman Kansal (Microsoft), Jie Liu (Microsoft), Badrriddine Khesib (Microsoft), Kushagra Vaid (Microsoft)

Cloud datacenters must ensure high availability for the hosted applications and failures can be the bane of datacenter operators. Understanding the what, when and why of failures can help tremendously to mitigate their occurrence and impact. Failures can, however, depend on numerous spatial and temporal factors spanning hardware, workloads, support facilities, and even the environment. One has to rely on failure data from the field to quantify the influence of these factors on failures. Towards this goal, we collect failures data along with many parameters that might influence failures from two large production datacenters with very high utilization levels as high as 83%, despite the same millibottlenecks.
diverse characteristics. We show that multiple factors simultaneously affect failures, and these factors may interact in non-trivial ways. This makes conventional approaches that study aggregate characteristics or single parameter influences, rather inaccurate. Instead, we build a multi-factor analysis framework to systematically identify influencing factors, quantify their relative impact, and help in more accurate decision making for failure mitigation. We demonstrate this approach for three important decisions: spare capacity provisioning, comparing the reliability of hardware for vendor selection, and quantifying flexibility in datacenter climate control for cost-reliability trade-offs.

Right-sizing Geo-distributed Data Centers for Availability and Latency
Ilyswarya Narayanan (The Pennsylvania State University), Aman Kansal (Microsoft), Anand Sivasubramaniam (The Pennsylvania State University)

We show cloud developers how to right size data center (DC) capacity for geo-distributed applications deployed on several multi-megawatt DCs, possibly also using many smaller edge DCs. Note that capacity considerations for a geo-distributed infrastructure do not decompose into individual DC capacity planning. When edge DCs are used, heterogeneous availability and costs affect the capacity split between the edge and core DCs. Non-uniform spatial distribution of clients and interdependence between latency and availability constraints make it non-trivial to provision the right capacity at each DC. We develop a geo-distributed capacity planning framework to capture the key factors that influence capacity, ranging from application demand patterns, latency and availability requirements, DC cost-availability trade-offs, and data replication overheads. We apply our framework to a realistic application and DC infrastructure setting to gather insights into how capacity should be provisioned and allocated across DCs for a representative set of requirements and costs.

Performance Driven Resource Sharing Markets for the Small Cloud
Sung-Han Lin (University of Southern California), Ranjan Pal (University of Southern California), Marco Paolieri (University of Southern California), Leana Golubchik (University of Southern California)

Small-scale clouds (SCs) often suffer from resource under-provisioning during peak demand, leading to inability to satisfy service level agreements (SLAs) and consequent loss of customers. One approach to address this problem is for a set of autonomous SCs to share resources among themselves in a costinduced cooperative fashion, thereby increasing their individual capacities (when needed) without having to significantly invest in more resources. A central problem in this context is how to properly share resources (for a price) to achieve profitable service while maintaining customer SLAs. To address this problem, in this paper, we propose the SC-Share framework that utilizes two interacting models: (i) a stochastic performance model that estimates the achieved performance characteristics under given SLA requirements, and (ii) a market-based game-theoretic model that (as shown empirically) converges to efficient resource sharing decisions at market equilibrium. Our results include extensive evaluations that illustrate the utility of the proposed framework.

Fault-scalable Virtualized Infrastructure Management
Mukil Kesavan (VMware Inc.), Ada Gavriloavskia (Georgia Institute of Technology), Karsten Schwan (Georgia Institute of Technology)

Large-scale virtualized datacenters require considerable automation in infrastructure management in order to operate efficiently. Automation is impaired, however, by the fact that deployments are prone to multiple types of subtle faults due to hardware failures, software bugs, misconfiguration, crashes, performance degraded hardware, etc. Existing Infrastructure-as-a-Service (IaaS) management stacks incorporate little to no resilience measures to shield end users from such cloud provider-level failures and poor performance. This paper proposes and evaluates extensions to IaaS stacks that mask faults in a fault-agnostic manner while ensuring that the overheads can be proportional to observed failure rates. We also demonstrate that infrastructure automation services and end-user applications can use service-specific knowledge, together with our new interface, to achieve better outcomes.

DeltaCFS: Boosting Delta Sync for Cloud Storage Services by Learning from NFS
Quanlu Zhang (Peking University), Zhenhua Li (Tsinghua University), Zhi Yang (Peking University), Shenglong Li (Peking University), Yangze Guo (Peking University), Yafei Dai (Peking University), Shouyang Li (Peking University)

Cloud storage services, such as Dropbox, iCloud Drive, Google Drive, and Microsoft OneDrive, have greatly facilitated users synchronizing files across heterogeneous devices. Among them, Dropbox-like services are particularly beneficial owing to the delta sync functionality that strives towards greater network-level efficiency. However, when delta sync trades computation overhead for network-traffic saving, the tradeoff could be highly unfavorable under some typical workloads. We refer to this problem as the abuse of delta sync. To address this problem, we propose DeltaCFS, a novel file sync framework for cloud storage services by learning from the design of conventional NFS (Network File System). Specifically, we combine delta sync with NFS-like file RPC in an adaptive manner, thus significantly cutting computation overhead on both the client and server sides while preserving the network-level efficiency. DeltaCFS also enables a neat design for guaranteeing causal consistency and fine-grained version control of files. In our FUSE-based prototype system (which is open-source), DeltaCFS outperforms Dropbox by generating up to 11.6 less data transfer and up to 100.2 less computation overhead under concerned workloads.

Research 5: Edge and Fog Computing
Cachier: Edge-caching for recognition applications
Utsav Drolia (Carnegie Mellon University), Katherine Guo (Bell Labs), Iiaq Tan (Nokia), Rajeev Gandhi (Carnegie Mellon University), Priya Narasimhan (Carnegie Mellon University)

Recognition and perception-based mobile applications, on the premise, are on the rise. These applications recognize the users surroundings and augment it with information and/or media. These applications are latency-sensitive. They have a soft-real-time nature - late results are potentially meaningless. On the one hand, given the compute-intensive nature of the tasks performed by such applications, execution is typically offloaded to the cloud. On the other hand, offloading such applications to the cloud incurs network latency, which can increase the user-perceived latency. Consequently, edge-computing has been proposed to let devices offload intensive tasks to edge-servers instead of the cloud, to reduce latency. In this paper, we propose a different model for using edge-servers. We propose to use the edge as a specialized cache for recognition applications and formulate the expected latency for such a cache. We show that using an edge-server like a typical web-cache, for recognition applications, can lead to higher latencies. We propose Cachier, a system that uses the caching model along with novel optimizations to minimize latency by adaptively balancing load between the edge and the cloud by leveraging spatiotemporal locality of requests, using offline analysis of applications, and online estimates of network conditions. We evaluate Cachier for image-recognition applications and show that our techniques yield 3x speed-up in responsiveness, and perform accurately over a range of operating conditions. To the best of our knowledge, this is the first work that models edge-servers as caches for compute-intensive recognition applications, and Cachier is the first system that uses this model to minimize latency for these applications.
Content Centric Peer Data Sharing in Pervasive Edge Computing Environments

Xintong Song (Peking University), Yaodong Huang (Stony Brook University), Qian Zhou (Stony Brook University), Fan Ye (Stony Brook University), Yuanyuan Yang (Stony Brook University), Xiaoming Li (Peking University)

The proliferation and daily aggregation of modern mobile devices have created abundant opportunities for peer edge devices to share valuable data with each other. The short contact durations, relatively small sharing sizes, and uncertain data availability, demand agile, light weight peer based data sharing. In this paper, we propose Peer Data Sharing (PDS) that enables edge devices to discover which data exist in nearby peers, and retrieve interested data robustly and efficiently. PDS uses novel lingering queries, mixedcast and en-route message rewriting techniques to minimize redundant transmissions and maximize opportunistic overhearing thus caching in data discovery and retrieval. Extensive evaluations based on an Android prototype show that PDS discovers and retrieves almost 100% data in tens of seconds, and remains robust despite wireless contention, simultaneous consumer requests and user mobility.

FLARE: Coordinated Rate Adaptation for HTTP Adaptive Streaming in Cellular Networks

Youngbin Im (University of Colorado at Boulder), Jinyoung Han (Hanyang University), Ji Hoon Lee (Juni Korea), Yoon Kwon (Kakao), Carlee Joe-Wong (Carnegie Mellon University), Taekyoung Kwon (Seoul National University), Sangtae Ha (University of Colorado at Boulder)

Fog computing is an emerging architecture that aims to run applications on multiple devices that lie on a continuum from centralized cloud servers to personal user devices. These architectures allow applications to optimize over the information stored at each type of device and divide their functionalities based on the device capabilities. We demonstrate the benefits of this approach for mobile video streaming. Existing HAS (HTTP adaptive streaming) techniques, used by popular video service providers, often suffer from problems like unstable video quality and suboptimal resource utilization. We find that a lack of coordination prevents both client- and network-side HAS techniques from solving them. However, our fog approach can exploit existing telecommunication APIs, which expose network capabilities to applications, in order to coordinate between the client and network. Our coordinated HAS solution, FLARE, optimizes the total utility of all clients in a cell while maintaining stable video quality and supporting user- and device-specific needs. We implement FLARE on a commodity LTE femtocell and use the implementation to conduct the first comparison of HAS players on an LTE femtocell. By conducting extensive experiments using the ns-3 simulator, we also demonstrate that FLARE (i) enhances the average video bitrate, (ii) achieves stable video quality, and (iii) balances the throughput of simultaneous video and data flows, compared to other representative HAS solutions.

Networked Drone Cameras for Sports Streaming

Xiaoli Wang (Princeton University), Aakanksha Chowdhery (Princeton University), Mung Chiang (Princeton University)

A network of drone cameras can be deployed to cover live events, such as high-action sports game played on a large field, but managing networked drone cameras in real-time is challenging. Distributed approaches yield suboptimal solutions from lack of coordination but coordination with a centralized controller incurs round-trip latencies of several hundreds of milliseconds over a wireless channel. We propose a fog-networking based system architecture to automatically coordinate a network of drones equipped with cameras to capture and broadcast the dynamically changing scenes of interest in a sports game. We design both optimal and practical algorithms to balance the tradeoff between two metrics: coverage of the most important scenes and streaming bitrate. To compensate for network round-trip latencies, the centralized controller uses a predictive approach to predict which locations the drones should cover next. The controller maximizes video bitrate by associating each drone to an optimally matched server and dynamically re-assigning drones as relay nodes to boost the throughput in low-throughput scenarios. This dynamic assignment at the centralized controller occurs at slower time-scale permitted by round-trip latencies, while the predictive approach and drones local decision ensures that the system works in real-time. Experimental results over tens of flights on the field suggest our system can achieve really good performance, for example, 8 drones can achieve a tradeoff of 94% coverage and (on average) 2K video support at 20 Mbps by optimizing between coverage and throughput. By dynamically allocating drones to cover the game or act as relays, our system also demonstrates a 2x gain over systems maximizing static coverage alone that achieves only 9 Mbps video throughput.

Chronus: Consistent Data Plane Updates in Timed SDNs

Jiaqi Zheng (Nanjing University), Guihai Chen (Nanjing University), Stefan Schmid (Aalborg University), Haipeng Dai (Nanjing University), Jie Wu (Temple University)

Software-Defined Networks (SDNs) introduce interesting new opportunities in how network routes can be defined, verified, and changed over time. Yet despite the logically centralized perspective offered, an SDN still needs to be considered a distributed system: rule updates communicated from the controller to the individual switches traverse an asynchronous network and may arrive out-of-order, and hence lead to (temporary or permanent) inconsistencies. Accordingly, the consistent network update problem has recently received much attention. Motivated by the advent of tightly synchronized SDNs, we in this paper initiate the study of algorithms for consistent network updates in timed SDNs, in which individual node updates can be scheduled at specific times. This paper presents Chronus, which is based on provably congestion- and loop-free update scheduling algorithms, and avoids the flow table space headroom required by existing two-phase update approaches. We formulate the Minimum Update Time Problem (MUTP) as an optimization program. We propose a tree algorithm to check the feasibility and a greedy algorithm to find a update sequence in polynomial time. Extensive experiments on Mininet and numerical simulations show that Chronus can substantially reduce transient congestion by 75% and save over 60% of the rules compared to the state of the art.

Distributed Deep Neural Networks over the Cloud, the Edge and End Devices

Surat Teerapittayanon (Harvard University), Bradley McDaniel (Harvard University), H.T. Kung (Harvard University)

We propose distributed deep neural networks (DDNNs) over distributed computing hierarchies, consisting of the cloud, the edge (fog) and end devices. While being able to accommodate inference of a deep neural network (DNN) in the cloud, a DDNN also allows fast and localized inference using shallow portions of the neural network at the edge and end devices. Moreover, via distributed computing, DDNNs enhance data privacy and system fault tolerance for DNN applications. When supported by a scalable distributed computing hierarchy, a DDNN can scale up in neural network size and scale out in geographical span. In implementing a DDNN, we map sections of a DNN onto a distributed computing hierarchy. By jointly training these sections, we minimize communication and resource usage for devices and maximize usefulness of extracted features which are utilized in the cloud. As a proof of concept, we show a DDNN can exploit geographical diversity of sensors to improve recognition accuracy and reduce communication cost. In our experiment, compared with the traditional method of offloading raw sensor data to be processed in the cloud, DDNN locally processes most sensor data on end devices and is able to reduce the communication cost by a factor of over 20x.

Research 6: Distributed Green Computing and Energy Management

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Dynamic Control of Flow Completion Time For Power Efficient Data Center Networks
Kuangyu Zheng (The Ohio State University), Xiaorui Wang (The Ohio State University)

Data center network (DCN) can consume a significant amount of power (e.g., 10% to 20%) in large-scale data centers. To reduce the power consumption of DCN, traffic consolidation has been recently proposed as an effective approach to reduce the number of DCN devices in use. However, existing consolidation approaches do not sufficiently consider the flow completion time (FCT) requirement. On one hand, missing the FCT deadlines can cause serious violation of service-level agreement, especially for delay-sensitive networking services, such as web search and E-commerce. On the other hand, keeping all the devices on to make FCTs much shorter than the desired requirements is unnecessary because 1) users may not be able to perceive the difference, and 2) such a greedy strategy can lead to unnecessarily high DCN power consumption and thus more electricity costs. In this paper, we propose FCTcon, a dynamic FCT control strategy for DCN power optimization. FCTcon is designed rigorously based on control theory to dynamically control the FCT of delay-sensitive traffic flows exactly to requirements, such that the desired FCT performance is guaranteed while the maximum amount of DCN power savings can be achieved. Results from both hardware experiments and simulation evaluations demonstrate that, compared to the state-of-the-art DCN power optimization schemes, FCTcon can improve the DCN FCT performance, while achieving nearly the same or even more power savings. Consequently, FCTcon can result in more than 22.0% to 62.2% extra net profits for a data center with 50K servers.

On Energy-Efficient Congestion Control for Multipath TCP
Jia Zhao (Simon Fraser University), Jiangchuan Liu (Simon Fraser University), Haiyang Wang (University of Minnesota Duluth)

Multipath transport protocols, e.g. Multipath TCP (MPTCP), enable transmission via multiple routes between an end-to-end connection to improve resource usage of regular TCP. Due to the increasing concern in green computing, there has been significant interest in designing energy-efficient multipath transport. For existing MPTCP congestion control algorithms, the research community still lacks a comprehensive understanding of which components in such an algorithm play the fundamental role in energy efficiency, how various algorithms compare against each other from energy-consuming perspective, or whether there exist potentially better solutions for energy saving. In this paper, we take a first step to answer these questions. Based on the MPTCP Linux kernel experiments, we first summarize that the energy consumption is related to three aspects: average throughput, path delay and different network scenarios. In order to bridge congestion control to the three aspects, we analyze the existing algorithms and capture the essential parameters of multipath congestion control model related to MPTCPs energy efficiency. Then we design a window increase factor to shift traffic to low-delay energy-efficient paths. We further extend this design by using an energy-aware compensative parameter to fit the general hierarchical Internet topology. We evaluate the performance of existing multipath congestion control algorithms and our proposed algorithm in different network scenarios. The results show energy efficiency of our design.

A Mechanism for Cooperative Demand-Side Management
Guangchao Yuan (Microsoft), Chung-Wei Hang (IBM), Michael Huhns (University of South Carolina), Munindar Singh (North Carolina State University)

Demand-side management (DSM) is an important theme in the Smart Grid and offers the possibility of leveling power consumption with its attendant benefits of reducing capital expenses. This paper develops an algorithmic mechanism that reduces peak total consumption and encourages prosocial behavior, such as expressing flexibility in ones power consumption and reporting preferences truthfully. Our objective is to provide a tractable, budget-balanced mechanism that promotes truthfulness from households. The resulting mechanism is theoretically and empirically proven to be ex ante budget-balanced, weakly Pareto-efficient, and weakly Bayesian incentive-compatible. A simulation study verifies that the mechanism could largely reduce the computational complexity that the optimal allocation requires, while maintaining approximately the same performance. A user study with 20 subjects further shows the effectiveness of the mechanism in preventing participants from defecting and incentivizing them to reveal flexible preferences.

Ning Liu (Syracuse University), Zhe Li (Syracuse University), Zhiyuan Xu (Syracuse University), Jielong Xu (Syracuse University), Sheng Lin (Syracuse University), Qinru Qiu (Syracuse University), Jian Tang (Syracuse University), Yanzhi Wang (Syracuse University)

Automatic decision-making approaches, such as reinforcement learning (RL), have been applied to (partially) solve the resource allocation problem adaptively in the cloud computing system. However, a complete cloud resource allocation framework exhibits high dimensions in state and action spaces, which prohibit the usefulness of traditional RL techniques. In addition, high power consumption has become one of the critical concerns in design and control of cloud computing systems, which degrades system reliability and increases cooling cost. An effective dynamic power management (DPM) policy should minimize power consumption while maintaining performance degradation within an acceptable level. Thus, a joint virtual machine (VM) resource allocation and power management framework are critical to the overall cloud computing system. Moreover, novel solution framework is necessary to address the even higher dimensions in state and action spaces. In this paper, we propose a novel hierarchical framework for solving the overall resource allocation and power management problem in cloud computing systems. The proposed hierarchical framework comprises a global tier for VM resource allocation to the servers and a local tier for distributed power management of local servers. The emerging deep reinforcement learning (DRL) technique, which can deal with complicated control problems with large state space, is adopted to solve the global tier problem. Furthermore, an autoencoder and a novel weight sharing structure are adopted to handle the high-dimensional state space and accelerate the convergence speed. On the other hand, the local tier of distributed server power managed comprises an LSTM based workload predictor and a model-free RL based power manager, operating in a distributed manner. Experiment results using actual Google cluster traces show that our proposed hierarchical framework significantly saves the power consumption and energy usage than the baseline while achieving no severe latency degradation. Meanwhile, the proposed framework can achieve the best trade-off between latency and power/energy consumption in a server cluster.

SunChase: Energy-Efficient Route Planning for Solar-Powered EVs.
Landu Jiang (McGill University), Yu Hua (Huazhong University of Science and Technology), Chen Ma (McGill University), Xue Liu (McGill University)

Electric vehicles (EVs) play a significant role in the current transportation systems. The main factor that affects acceptance of existing EV models is the range anxiety problem caused by limited charging stations and long recharge times. Recently, the solar-powered EV has drawn many attentions due to being free of charging limitations. However, the solar-powered EVs may still struggle with the limited use because of unpredictable solar availability. For example, shadings caused by buildings and trees also possibly decrease the solar panel cell efficiency. To address this, we propose a route planning method for solar-powered EVs to balance the energy harvesting and consumption subject to time constraint. The idea behind our solution is to offer power-aware optimal routing, which maximizes the on-road energy input given solar availability on each road segment. We first build a solar access estimation model using 3D geographic data and then employ a multi-criteria
search method to generate a set of Pareto candidate routes. In order to reduce the size of the set, we leverage the bisect kmeans clustering algorithm to extract the most representative Pareto routes with better solar availability. In the evaluation, we developed a validation platform on the vehicle and leveraged mobile sensing techniques to examine our proposed model in real road environments. We conducted simulations to evaluate our proposed route planning algorithm using real life scenarios. Experimental results demonstrate that our solar input model is robust to real road scenarios, and the routing algorithm has great potential to provide efficient services for solar-powered EV in the future.

**Research 7: Internet of Things, Smart Cities, and Cyber-Physical Systems**

**Persistent Traffic Measurement Through Vehicle-to-Infrastructure Communications**

He Huang (Soochow University), Yu-E Sun (Soochow University), Shigang Chen (University of Florida), Hongli Xu (University of Science and Technology of China), Yian Zhou (Google)

Measuring point traffic volume and point-to-point traffic volume in a road system has important applications in transportation engineering. The connected vehicle technologies integrate wireless communications and computers into transportation systems, allowing wireless data exchanges between vehicles and road-side equipment, and enabling large-scale, sophisticated traffic measurement. This paper investigates the problems of persistent point traffic measurement and persistent point-to-point traffic measurement, which were not adequately studied in the prior art, particularly in the context of intelligent vehicular networks. We propose two novel estimators for privacy-preserving persistent traffic measurement: one for point traffic and the other for point-to-point traffic. The estimators are mathematically derived from the join result of traffic records, which are produced by the electronic roadside units with privacy-preserving data structures. We evaluate our estimation methods using simulations based on both real transportation traffic data and synthetic data. The numerical results demonstrate the effectiveness of the proposed methods in producing high measurement accuracy and allowing accuracy-privacy tradeoff through parameter setting.

**TagBreathe: Monitor Breathing with Commodity RFID Systems**

Yuxiao Hou (The Hong Kong Polytechnic University), Yanwen Wang (The Hong Kong Polytechnic University), Yuanqing Zheng (The Hong Kong Polytechnic University)

Breath monitoring helps assess the general personal health and gives clues to chronic diseases. Yet current breath monitoring technologies are inconvenient and intrusive. For instance, typical breath monitoring devices need to attach nasal probes or chest bands to users. Wireless sensing technologies have been applied to monitor breathing using radio waves without physical contact. Those wireless sensing technologies however require customized radios which are not readily available. More importantly, due to interference, such technologies do not work well with multiple users. With multiple users in presence, the detection accuracy of existing systems decreases dramatically. In this paper, we propose to monitor users breathing using commercial-off-the-shelf (COTS) RFID systems. In our system, passive lightweight RFID tags are attached to users clothes and backscatter radio waves, and commodity RFID readers report low level data (e.g., phase values). We track periodic body movement due to inhaling and exhaling by analyzing the low level data reported by commodity readers. To enhance the measurement robustness, we synthesize data streams from an array of multiple tags to improve the monitoring accuracy. Our design follows the standard EPC protocol which arbitrates collisions in the presence of multiple tags. We implement a prototype the breath monitoring system with commodity RFID systems. The experiment results show that the prototype system can simultaneously monitor breathing with high accuracy even with the presence of multiple users.

**Double-Edged Sword: Incentivized Verifiable Product Path Query for RFID-enabled Supply Chain**

Saiyu Qi (XiDian University), Yuanqing Zheng (The Hong Kong Polytechnic University), Xiaofeng Chen (XiDian University), Jianfeng Ma (XiDian University), Yong Qi (Xian Jiaotong University)

Querying the path information of individual products in a supply chain is key to many applications. RFID (RadioFrequency IDENTification) is a main technology to enable product path information query today. With RFID technology, supply chain participants can efficiently track products in transit and record their states in databases. In this paper, we investigate the following question: how can we conduct privacy-preserving product path information query with verifiability on an RFID-enabled distributed supply chain? We address this question with Double Edged(DE)-Sword, an incentivized verifiable query system. DE-Sword introduces a novel double-edged reputation incentive mechanism to encourage supply chain participants to behave; and couples it with cryptographic primitives and careful protocol design. We evaluate DE-Sword through security analysis and performance experiments. The security analysis shows that DE-Sword guarantees both verifiability and privacy. The experiment results show that DE-Sword achieves low overhead in RFID-enabled supply chain applications.

**Towards Accurate Corruption Estimation in ZigBee Under Cross-Technology Interference**

Gong Long Chen (Zhejiang University), Wei Dong (Zhejiang University), Zhiwei Zhao (University of Electronic Science and Technology of China), Tao Gu (RMIT University)

Cross-Technology Interference affects the operation of low-power ZigBee networks, especially under severe WiFi interference. Accurate corruption estimation is very important to improve the resilience of ZigBee transmissions. However, there are many limitations in existing approaches such as low accuracy, high overhead, and requiring hardware modification. In this paper, we propose an accurate corruption estimation approach, AccuEst, which utilizes per-byte SINR (Signal-to-Interference-and-Noise Ratio) to detect corruption. We combine the use of pilot symbols with per-byte SINR to improve corruption detection accuracy, especially in highly noisy environments (i.e., noise and interference are at the same level). In addition, we design an adaptive pilot instrumentation scheme to strike a good balance between accuracy and overhead. We implement AccuEst on the TinyOS 2.1.1/TeosB platform and evaluate its performance through extensive experiments. Results show that AccuEst improves corruption detection accuracy by 78.6% on average compared with state-of-the-art approach (i.e., CARE) in highly noisy environments. In addition, AccuEst reduces pilot overhead by 53.7% on average compared to the traditional pilot-based approach. We implement AccuEst in a coding-based transmission protocol, and results show that with AccuEst, the packet delivery ratio is improved by 20.3% on average.

**Unseen Activity Recognition: A Hierarchical Active Transfer Learning Approach**

Mohammad Arif Ul Alam (University of Maryland Baltimore County), Nirmalya Roy (University of Maryland Baltimore County)

Human activity recognition (AR) is an essential element for user-centric and context-aware applications. While previous studies showed promising results using various machine learning algorithms, most of them can only recognize the activities that were previously seen in the training data. We investigate the challenges of improving the recognition of unseen daily activities in smart home environment, by better exploiting the hierarchical taxonomy of complex daily activities. We first (a) design a hierarchical representation of complex activity taxonomy in terms of human-readable semantic attributes, and (b) develop a hierarchy of classifiers which incorporates a cluster tree built on the domain knowledge from training samples. Though this model is rich in recognizing complex activities that are
previously seen in training data, it is not well versed to recognize unseen complex activities without new training samples. To tackle this challenge, we extend Hierarchical Active Transfer Learning (HATL) approach that exploits semantic attribute cluster structure of complex activities shared between seen (source) and unseen (target) activity domains. Our approach employs transfer and active learning to help label target domain unlabeled data by spawning the most effective queries. We evaluated our approach with two real-time smart home systems (IRB #00064387) which corroborates radical improvements in recognizing unseen complex activities.

**RFIPad: Enabling Cost-efficient and Device-free In-air Handwriting using Passive Tags**
Han Ding (Xi'an Jiaotong University), Chen Qian (University of California Santa Cruz), Jinsong Han (Xi'an Jiaotong University), Ge Wang (Xi'an Jiaotong University), Wei Xi (Xi'an Jiaotong University), Kun Zhao (Xi'an Jiaotong University), Jizhong Zhao (Xi'an Jiaotong University)

An important function of smart environments is the ubiquitous access of computing devices. In public areas such as hospitals, libraries, and airports, people may want to interact with nearby computing systems to get information, such as directions to a hospital room, locations of books, and flight departure/arrival information. Touch screen based displays and kiosks, which are commonly used today, may incur extra hardware cost or even possible germ and bacteria infection. This work provides a new solution: users can make queries and inputs by performing in-air handwriting to an array of passive RFID tags, named RFIPad. This input method does not require human hands to carry any device and hence is convenient for applications in public areas. Besides the mobile and contactless property, this system is a cost-efficient extension to current RFID systems: an existing reader can monitor multiple RFIPads while performing its regular applications such as identification and tracking. We implement a prototype of RFIPad using commercial off-the-shelf UHF RFID devices. Experimental results show that RFIPad achieves >91% accuracy in recognizing basic touchscreen operations and English letters.

**Research 8: Mobile and Wireless Computing Systems I**

**Robust Incentive Tree Design for Mobile Crowdsensing**
Xiang Zhang (Arizona State University), Guoliang Xue (Arizona State University), Ruozhou Yu (Arizona State University), Dejun Yang (Colorado School of Mines), Jian Tang (Syracuse University)

With the proliferation of smart mobile devices such as smart phones, tablets, and wearable, mobile crowdsensing becomes a powerful sensing and computation paradigm which has been applied in many fields, such as spectrum sensing, environmental monitoring, healthcare, and so on. Driven by promising incentives, the power of the crowd grants crowdsensing an advantage in mobilizing users who perform sensing tasks with the embedded sensors on the smart devices. Auction is one of the commonly adopted crowdsensing incentive mechanisms to incentivize users for participation. However, auction does not consider the incentive for user solicitation where in crowdsensing, a large number of users is often needed. To deal with this issue, we aim to design an auction-based incentive tree to offer rewards to users for both participation and solicitation. Meanwhile, we want the incentive mechanism to be robust against dishonest behavior such as untruthful bidding and sybil attacks, to eliminate the malicious price manipulation. We design an incentive mechanism RIT, which combines the advantages of auctions and incentive trees. We prove that RIT is truthful and sybil-proof with probability at least H, for any given H _ (0, 1). We also prove that RIT satisfies individual rationality, computational efficiency, and solicitation incentive. Simulation results of RIT further confirm our analysis.

**WearLock: Unlocking Your Phone via Acoustics using Smartwatch**
Shanhe Yi (College of William and Mary), Zhengrui Qin (Northwest Missouri State University), Nancy Carter (College of William and Mary), Qun Li (College of William and Mary)

Smartphone lock screens are implemented to reduce the risk of data loss or compromise given the fact that increasing amount of person data are accessible on smartphones nowadays. Unfortunately, many smartphone users abandon lock screens due to the inconvenience of unlocking their phones many times a day. With the wide adoption of wearables, token-based approaches have gained popularity in simplifying unlocking and retaining security at the same time. To this end, we propose to take advantage of the smartwatch for easy smartphone unlocking. In this paper, we have designed WearLock, a system that uses acoustic tones as tokens to automate the unlocking securely. We build a sub-channel selection and an adaptive modulation in the acoustic modem to maximize unlocking success rate against ambient noise only when those two devices are nearby. We leverage the motion sensor on the smartphone to reduce the unlock frequency. We offload smartphone tasks to the smartphone to speed up computation and save energy. We have implemented the WearLock prototype and conducted extensive evaluations. Results achieved a low average bit error rate (BER) as 8% in various experiments. Compared to traditional manual personal identification numbers (PINs) entry, WearLock achieves at least 18% unlock speedup without any manual effort.

**Modeling Mobile Code Acceleration in the Cloud**
Huber Flores (University of Oulu), Xiang Su (University of Oulu), Vassilis Kostakos (University of Oulu), Jukka Riekkki (University of Oulu), Eemil Lagerspetz (University of Helsinki), Sasu Tarkoma (Helsinki University of Technology), Pan Hui (HKUST), Yong Li (Tsinghua University), Jukka Manner (Aalto University)

Tuning the quality of service of a mobile application is critical in order to ensure users satisfaction. Techniques have been proposed to accomplish adaptation of quality of service dynamically. However, there is still a limited understanding about how to provide an utility model for code execution. One key challenge is to model the level of quality in the code execution that can be provisioned by the cloud. Since the allocation of cloud resources has a cost, it is important to optimize cloud usage. We propose a software-defined networking approach that allows modeling and controlling code acceleration of a mobile application deployed across multiple type of devices. By segmenting the computational requirements of the mobile application into groups, we were able to define the acceleration needed by each group of devices. As the computational requirements of a device can change across time, a mobile device can be re-assigned to another group based on demand. Our SDN approach implements a model that allows the system to predict workload based on acceleration groups. Evaluating our system in a real testbed showed that it is possible to predict workload and allocate optimal resources to handle that workload with 87.5% of accuracy.

**E-Android: A New Energy Profiling Tool for Smartphones**
Xing Gao (College of William and Mary), Dachuan Liu (College of William and Mary), Daiping Liu (University of Delaware), Haining Wang (University of Delaware), Angelos Stavrou (George Mason University)

Smartphones have become an indispensable part of our daily lives. As the limited battery lifetime remains a major factor restricting the applicability of a smartphone, significant research efforts have been devoted to understand the energy consumption in smartphones. Existing energy modeling methods can account energy drain in a fine-grained manner and provide well designed human-battery interfaces for users to characterize energy usage of every app in smartphones.
However, in this paper, we demonstrate that there are still pitfalls in current Android energy modeling approaches, making Android vulnerable to malicious attacks. In particular, we present a set of new collateral energy attacks, which can deplete battery life but sidestep the supervision of current energy accounting. To defend against collateral energy attacks, we propose E-Android to accurately profile energy consumption of a smartphone in a comprehensive manner. E-Android monitors collateral energy related events and maintains energy consumption maps for relevant apps. We evaluate the effectiveness of E-Android under six different collateral energy attacks and two normal scenarios, and compare the results with those of Android. While Android fails to disclose all collateral energy attacks, E-Android can accurately profile energy consumption and reveal the existence of energy malware. Our evaluation results also show that the overhead induced by E-Android is minor.

**Local and Low-Cost White Space Detection**

Ahmed Saeed (Georgia Institute of Technology), Khaled Harras (Carnegie Mellon University), Ellen Zegura (Georgia Institute of Technology), Mostafa Ammar (Georgia Institute of Technology)

White spaces are portions of the TV spectrum that are allocated but not used locally. If accurately detected, white spaces offer a valuable new opportunity for high speed wireless communications. We propose a new method for white space detection that allows a node to act locally, based on a centrally constructed model, and at low cost, while detecting more spectrum opportunities than best known approaches. We leverage two ideas: first, we demonstrate that low-cost spectrum monitoring hardware can offer good enough detection capabilities. Second, we develop a model that combines locally measured signal features and location to more efficiently detect white space availability. We incorporate these ideas into the design, implementation, and evaluation of a complete system we call Waldo. We deploy Waldo on laptop in Atlanta metropolitan area in the US covering 700 km2 showing that using signal features in addition to location can improve detection accuracy by up to 10x for some channels. We also deploy Waldo on an Android smartphone, demonstrating the feasibility of real-time white space detection with efficient use of smartphone resources.

**General Analysis of Incentive Mechanisms for Peer-to-Peer Transmissions: A Quantum Game Perspective**

Weiman Sun (Beijing Normal University), Shengling Wang (Beijing Normal University)

The peer-to-peer transmission is a main-stream in challenged network environments. Yet, the free rider phenomenon in peer-to-peer transmissions presses a need for incentive mechanisms to stimulate contributions of data transmission. As a result, it is imperative to answer the questions: whether and to what extent an incentive mechanism can invoke such contributions? To answer these questions, we employ an n-player continuous quantum game model to analyze extrinsic incentive mechanisms (promoting cooperative behaviors by offering rewards), and use the quantum prisoner’s dilemma model to analyze intrinsic incentive mechanisms (encouraging reciprocal cooperation by exploiting internal bounds). To the best of our knowledge, we are the first to analyze incentive mechanisms for peer-to-peer transmissions from a quantum game perspective. Such a perspective is adopted because the extended strategy space in the quantum game broadens the range for searching optimal strategies and the introduction of entanglement makes the proposed analytical frameworks more practical due to the consideration of the peers’ relationships in decision-making. Our proposed quantum game-based analytical frameworks are generic because they are compatible with classic game-based schemes. Our analytical results can provide straightforward insights on evaluating the potential of incentive mechanisms and can serve as important references for designing new incentive mechanisms.

**Research 9: Distributed Big Data Systems**

**High-Performance and Resilient Key-Value Store with Online Erasure Coding for Big Data Workloads**

Dipti Shankar (The Ohio State University), Xiaoyi Lu (The Ohio State University), Dhabaleswar Panda (The Ohio State University)

Distributed key-value store-based caching solutions are being increasingly used to accelerate Big Data applications on modern HPC clusters. This has necessitated incorporating faulttolerance capabilities into high-performance key-value stores such as Memcached that are otherwise volatile in nature. Inmemory replication is being used as the primary mechanism to ensure resilient data operations. However, this incurs increased network I/O with high remote memory requirements. On the other hand, erasure coding is being extensively explored for enabling data resilience, while achieving better storage efficiency. In this paper, we first perform an in-depth modeling-based analysis of the performance trade-offs of In-Memory Replication and Erasure Coding schemes for key-value stores, and explore the possibilities of employing Online Erasure Coding for enabling resilience in high-performance key-value stores for HPC clusters. We then design a non-blocking API-based engine to perform efficient Set/Get operations by overlapping the encoding/decoding involved in enabling Erasure Coding-based resilience with the request/response phases, by leveraging RDMA on high performance interconnects. Performance evaluations show that the proposed designs can outperform synchronous RDMA-based replication by about 2.8x, and can improve YCSB throughput and average read/write latencies by about 1.34x - 2.6x over asynchronous replication for larger key-value pair sizes (>16 KB). We also demonstrate its benefits by incorporating it into a hybrid and resilient key-value store-based burst-buffer system over Lustre for accelerating Big Data I/O on HPC clusters.

**Modeling and Analyzing Latency in the Memcached system**

Wenxue Cheng (Tsinghua University), Fengyuan Ren (Tsinghua University), Wanchun Jiang (Central South University), Tong Zhang (Tsinghua University)

Memcached is a widely used in-memory caching solution in large-scale searching scenarios. The most pivotal performance metric in Memcached is latency, which is affected by various factors including the workload pattern, the service rate, the unbalanced load distribution and the cache miss ratio. To quantitate the impact of each factor on latency, we establish a theoretical model for the Memcached system. Specially, we formulate the unbalanced load distribution among Memcached servers by a set of probabilities, capture the burst and concurrent key arrivals at Memcached servers in form of batching blocks, and add a cache miss processing stage. Based on this model, algebraic derivations are conducted to estimate latency in Memcached. The latency estimation is validated by intensive experiments. Moreover, we obtain a quantitative understanding of how much improvement of latency performance can be achieved by optimizing each factor and provide several useful recommendations to optimal latency in Memcached.

**Speculative Slot Reservation: Enforcing Service Isolation for Dependent Data-Parallel Computations**

Chen Chen (HKUST), Wei Wang (HKUST), Bo Li (HKUST)

Priority scheduling is a fundamental tool to provide service isolation for different jobs in shared clusters. Ideally, the performance of a high-priority job should not be dragged down by another with a lower priority. However, we show in this paper that simply assigning a high priority provides no isolation for jobs with dependent computations. A job, even receiving the highest priority, may give up compute slots to another before proceeding to the downstream computation, which is because
of barrier, i.e., that the downstream computation cannot start until all the upstream tasks have completed. Such an interruption of execution inevitably results in a significant delay. In this paper, we propose speculative slot reservation that judiciously reserves slots for downstream computations, so as to retain service isolation for high-priority jobs. To mitigate the utilization loss due to slot reservation, we analyze the trade-off between utilization and isolation, and expose a tunable knob to navigate the trade-off. We also propose a complementary straggler mitigation strategy that uses the reserved slots to run extra copies of slow tasks. We have implemented speculative slot reservation in Spark. Evaluations based on both cluster deployment and trace-driven simulations show that our approach enforces strict service isolation for high-priority jobs, without slowing down the other jobs with a lower priority.

**Optimizing Shuffle in Wide-Area Data Analytics**

Shuhao Liu (University of Toronto), Hao Wang (University of Toronto), Baochun Li (University of Toronto)

As increasingly large volumes of raw data are generated at geographically distributed datacenters, they need to be efficiently processed by data analytic jobs spanning multiple datacenters across wide-area networks. Designed for a single datacenter, existing data processing frameworks, such as Apache Spark, are not able to deliver satisfactory performance when these wide-area analytic jobs are executed. As wide-area networks interconnecting datacenters may not be congestion free, there is a compelling need for a new system framework that is optimized for wide-area data analytics. In this paper, we design and implement a new proactive data aggregation framework based on Apache Spark, with a focus on optimizing the network traffic incurred in shuffle stages of data analytic jobs. The objective of this framework is to strategically and proactively aggregate the output data of mapper tasks to a subset of worker datacenters, as a replacement to Spark's original passive fetch mechanism across datacenters. It improves the performance of wide-area analytic jobs by avoiding repetitive data transfers, which improves the utilization of inter-datacenter links. Our extensive experimental results using standard benchmarks across six Amazon EC2 regions have shown that our proposed framework is able to reduce job completion times by up to 73%, as compared to the existing baseline implementation in Spark.

**Job Scheduling without Prior Information in Big Data Processing Systems**

Zhiming Hu (University of Toronto), Baochun Li (University of Toronto), Zheng Qin (Institute of High Performance Computing), Rick Siow Mong Goh (Institute of High Performance Computing)

Job scheduling plays an important role for improving the overall system performance in big data processing frameworks. Simple job scheduling policies, such as Fair and FIFO scheduling do not consider job sizes, and may degrade the performance when jobs of varying sizes arrive. More elaborate job scheduling policies make the convenient assumption that jobs are recurring, and complete information about their sizes is available from their prior runs. In this paper, we design and implement an efficient and practical job scheduler for big data processing systems to achieve better performance even without prior information about job sizes. The superior performance of our job scheduler originates from the design of a multiple level priority queue, where jobs are demoted to lower priority queues if the amount of service consumed so far reaches a certain threshold. In this case, jobs in need of a small amount of service can finish in the topmost several levels of queues, while jobs that need a large amount of service to complete are moved to lower priority queues to avoid head-of-line blocking. Our new job scheduler can effectively mimic a shortest job first scheduling policy without knowing the job sizes in advance. To demonstrate its performance, we have implemented our new job scheduler in YARN, a popular resource manager used by Hadoop/Spark, and validated its performance with both experiments on real datasets and large-scale trace-driven simulations. Our experimental and simulation results have strongly confirmed the effectiveness of our design: our new job scheduler can reduce the average job response time of the Fair scheduler by up to 45%.

**Distributed Load Balancing in Key-Value Networked Caches**

Sikder Huq (The University of Iowa), Zubair Shafiqi (The University of Iowa), Sukumar Ghosh (The University of Iowa), Amir Khakpour (Verizon Digital Media Services), Harkeerat Bedi (Verizon Digital Media Services)

Modern web services rely on a network of distributed cache servers to efficiently deliver content to users. Load imbalance among cache servers can substantially degrade content delivery performance. Due to the skewed and dynamic nature of real-world workloads, cache servers that serve viral content experience higher load as compared to other cache servers. We propose a novel distributed load balancing protocol called Meezan to address the load imbalance among cache servers. Meezan replicates popular objects to mitigate skewness and adjusts hash space boundaries in response to load dynamics in a novel way. Our theoretical analysis shows that Meezan achieves near perfect load balancing for a wide range of operating parameters. Our trace driven simulations shows that Meezan reduces load imbalance by up to 52% as compared to prior solutions.

**Research 10: Distributed Algorithms and Theory I**

**Cognitive Context-aware Distributed Storage Optimization in Mobile Cloud Computing: A Stable Matching based Approach**

Dong Han (Oakland University), Ye Yan (Oakland University), Tao Shu (Auburn University), Liqing Yang (Colorado State University), Shuguang Cui (University of California, Davis)

Mobile cloud storage (MCS) is being extensively used nowadays to provide data access services to various mobile platforms such as smart phones and tablets. For cross-platform mobile apps, MCS is a foundation for sharing and accessing user data as well as supporting seamless user experience in a mobile cloud computing environment. However, the mobile usage of smart phones or tablets is quite different from legacy desktop computers, in the sense that each user has his/her own mobile usage pattern. Therefore, it is challenging to design an efficient MCS that is optimized for individual users. In this paper, we investigate a distributed MCS system whose performance is optimized by exploiting the fine-grained context information of every mobile user. In this distributed system, lightweight storage servers are deployed pervasively, such that data can be stored closer to its user. We systematically optimize the data access efficiency of such a distributed MCS by exploiting three types of user context information: mobility pattern, network condition, and data access pattern. We propose two optimization formulations: a centralized one based on mixed-integer linear programming (MILP), and a distributed one based on stable matching. We then develop solutions to both formulations. Comprehensive simulations are performed to evaluate the effectiveness of the proposed solutions by comparing them against their counterparts under various network and context conditions.

**Fair Caching Algorithms for Peer Data Sharing in Pervasive Edge Computing Environments**

Yaodong Huang (Stony Brook University), Xintong Song (Peking University), Fan Ye (Stony Brook University), Yuanyuan Yang (Stony Brook University), Xiaoming Li (Peking University)

Edge devices (e.g., smartphones, tablets, connected vehicles, IoT nodes) with sensing, storage and communication resources are increasingly penetrating our environments. Many novel applications can be created when nearby peer edge devices share data. Caching can greatly improve the data availability, retrieval
robustness and latency. In this paper, we study the unique issue of caching fairness in edge environment. Due to distinct ownership of peer devices, caching load balance is critical. We consider fairness metrics and formulate an integer linear programming problem, which is shown as summation of multiple Connected Facility Location (ConFL) problems. We propose an approximation algorithm leveraging an existing ConFL approximation algorithm, and prove that it preserves a 6.55 approximation ratio. We further develop a distributed algorithm where devices exchange data reachability and identity populate candidates as caching nodes. Extensive evaluation shows that compared with existing wireless network caching algorithms, our algorithms improves the 75-percentile fairness from 22.8% to 71.4%, while achieving contention thus latency similar as the best existing works.

Latency-Driven Cooperative Task Computing in Multi-User Fog-Radio Access Networks
Ai-Chun Pang (National Taiwan University), Wei-Ho Chung (Academia Sinica), Te-Chuan Chiu (National Taiwan University), Junshan Zhang (Arizona State University)

Fog computing is emerging as one promising solution to meet the increasing demand for ultra-low latency services in wireless networks. Taking a forward-looking perspective, we propose a Fog-Radio Access Network (F-RAN) model, which utilizes the existing infrastructure, e.g., small cells and macro base stations, to achieve the ultra-low latency by joint computing across multiple F-RAN nodes and near-range communications at the edge. We treat the low latency design as an optimization problem, which characterizes the tradeoff between communication and computing across multiple F-RAN nodes. Since this problem is NP-hard, we propose a latency-driven cooperative task computing algorithm with one-for-all concept for simultaneous selection of the F-RAN nodes to serve with proper heterogeneous resource allocation for multi-user services. Considering the limited heterogeneous resources shared among all users, we advocate the one-for-all strategy for every user taking others situation into consideration and seek for a winwin solution. The numerical results show that the low-latency services can be achieved by F-RAN via latency-driven cooperative task computing.

Approximation and Online Algorithms for NFV-Enabled Multicasting in SDNs
Zichuan Xu (University College London), Weifa Liang (The Australian National University), Meitian Huang (The Australian National University), Mike Jia (The Australian National University), Song Guo (The Hong Kong Polytechnic University), Alex Galis (University College London)

Multicasting is a fundamental functionality of networks for many applications including online conferencing, event monitoring, video streaming, and system monitoring in data centers. To ensure multicasting reliable, secure and scalable, a service chain consisting of network functions (e.g., firewalls, Intrusion Detection Systems (IDSs), and transcoders) usually is associated with each multicast request. Such a multicast request is referred to as an NFV-enabled multicast request. In this paper we study NFV-enabled multicasting in a Software-Defined Network (SDN) with the aims to minimize the implementation cost of each NFV-enabled multicast request or maximize the network throughput for a sequence of NFV-enabled requests, subject to network resource capacity constraints. We first formulate novel NFV-enabled multicasting and online NFV-enabled multicasting problems. We then devise the very first approximation algorithm with an approximation ratio of 2K for the NFV-enabled multicasting problem if the number of servers for implementing the network functions of each request is no more than a constant K (1). We also study dynamic admissions of NFV-enabled multicast requests without the knowledge of future request arrivals with the objective to maximize the network throughput, for which we propose an online algorithm with a competitive ratio of O(log n) when K = 1, where n is the number of nodes in the network. We finally evaluate the performance of the proposed algorithms through experimental simulations. Experimental results demonstrate that the proposed algorithms outperform other existing heuristics.

Distributed Auctions for Task Assignment and Scheduling in Mobile Crowdsensing Systems
Zhuojun Duan (Georgia State University), Wei Li (Georgia State University), Zhipeng Cai (Georgia State University)

With the emergence of Mobile Crowdsensing Systems (MCSs), many auction schemes have been proposed to incentivize mobile users to participate in sensing activities. However, in most of the existing work, the heterogeneity of MCSs has not been fully exploited. To tackle this issue, in this paper, we study the joint problem of sensing task assignment and scheduling while considering partial fulfillment, attribute diversity, and price diversity. We first elaborately model the problem as a reverse auction and design a distributed auction framework. Then, based on this framework, we propose two distributed auction schemes, costpreferred auction scheme (CPAS) and time schedule-preferred auction scheme (TPAS), which differ on the methods of task scheduling, winner determination, and payment computation. We further rigorously prove that both CPAS and TPAS can achieve computational-efficiency, individual-rationality, budgetbalance, and truthfulness. Finally, the simulation results validate the effectiveness of both CPAS and TPAS in terms of sensing tasks allocation efficiency, mobile users working time utilization and utility, and truthfulness.

Effective Mobile Data Trading in Secondary Ad-hoc Market with Heterogeneous and Dynamic Environment
Hengky Susanto (Huawei Future Network Theory Lab), Honggang Zhang (University of Massachusetts Boston), Shing Yip Ho (Share Media), Benyuan Liu (University of Massachusetts Lowell)

Advances in smartphone technologies enable mobile data subscribers to resell their data allowance to other users, creating a secondary data market. The trading environment of this secondary data market is dynamic and ad-hoc: buyers and sellers join and leave the market at all times, changing the trading landscape constantly. The amount of data demanded and offered at any point in time also vary. These conditions make determining a fair transaction price, and matching buyers to sellers difficult in practice. Prior schemes utilize global description of the network and market forces to achieve good performance, but the implementation requires a high overhead cost. In this paper, we present DataMart, a data pricing and user matching platform for trading in this dynamic, ad-hoc and heterogeneous market that works in distributed manner without needing global information. Using insights from real world traces, we demonstrate via simulation that our pricing scheme is converging and consistent with the law of demand and supply. Further, our user matching scheme achieves comparable performance to the optimal solution. We implement a prototype on Android platform, and the experiment results confirm the effectiveness of DataMart.

Research 11: Security and Privacy in Distributed Systems II
Kalis - A System for Knowledge-driven Adaptable Intrusion Detection for the Internet of Things
Daniele Midi (Purdue University), Antonino Rullo (University of Calabria), Anand Mudgerikar (Purdue University), Elisa Bertino (Purdue University)

In this paper, we introduce Kalis, a self-adapting, knowledge-driven expert Intrusion Detection System able to detect attacks in real time across a wide range of IoT systems. Kalis does not require changes to existing IoT software, can monitor a wide variety of protocols, has no performance impact on applications on IoT devices, and enables collaborative security scenarios. Kalis is the first comprehensive approach to intrusion detection for IoT that does not target individual protocols or
applications, and adapts the detection strategy to the specific network features. Extensive evaluation shows that Kalis is effective and efficient in detecting attacks to IoT systems.

**Fuzzy Extractors for Biometric Identification**
Nan Li (CSIRO), Fuchun Guo (University of Wollongong), Yi Mu (University of Wollongong), Willy Susilo (University of Wollongong), Surya Nepal (CSIRO)

Fuzzy extractor provides key generation from biometrics and other noisy data. The generated key is seamlessly usable for any cryptographic applications because its information entropy is sufficient for security. Biometric authentication offers natural and passwordless user authentication in various systems where fuzzy extractors can be used for biometric information security. Typically, a biometric system operates in two modes: verification and identification. However, existing fuzzy extractors do not support efficient user identification. In this paper, we propose a succinct fuzzy extractor scheme which enables efficient biometric identification as well as verification and it satisfies security requirements. We show that the proposed scheme can be easily used in both verification and identification modes. To the best of our knowledge, we propose the first fuzzy extractor based biometric identification protocol. The proposed protocol is able to identify a user with constant computational cost rather than linear-time computation by using other fuzzy extractor schemes. Biometric information security is an important concern of using biometric systems, so that we also provide security analysis of proposed schemes to show their security boundaries. The implementation shows that the performance of proposed identification protocol is constant and close to that of verification protocols.

**Smartphone Privacy Leakage of Social Relationships and Demographics from Surrounding Access Points**
Chen Wang (Stevens Institute of Technology), Chuyu Wang (Stevens Institute of Technology), Yingying Chen (Stevens Institute of Technology), Lei Xie (Nanjing University), Songlu Lu (Nanjing University)

While the mobile users enjoy the anytime anywhere Internet access by connecting their mobile devices through Wi-Fi services, the increasing deployment of access points (APs) have raised a number of privacy concerns. This paper explores the potential of smartphone privacy leakage caused by surrounding APs. In particular, we study to what extent the users personal information such as social relationships and demographics could be revealed leveraging simple signal information from APs without examining the Wi-Fi traffic. Our approach utilizes users activities at daily visited places derived from the surrounding APs to infer users social interactions and individual behaviors. Furthermore, we develop two new mechanisms: the Closeness-based Social Relationships Inference algorithm captures how closely people interact with each other by evaluating their physical closeness and derives fine-grained social relationships, whereas the Behavior-based Demographics Inference method differentiates various individual behaviors via the extracted activity features (e.g., activeness and time slots) at each daily place to reveal users demographics. Extensive experiments conducted with 21 participants real daily life including 257 different places in three cities over a 6-month period demonstrate that: the simple signal information from surrounding APs have a high potential to reveal peoples social relationships and infer demographics with an over 90% accuracy when using our approach.

**EV-Matching: Bridging Large Visual Data and Electronic Data for Efficient Surveillance**
Gang Li (The Ohio State University), Fan Yang (The Ohio State University), Guoxing Chen (The Ohio State University), Qiang Zhai (The Ohio State University), Xinfeng Li (The Ohio State University), Jin Teng (The Ohio State University), Junda Zhu (University of Macau), Dong Xuan (The Ohio State University), Biao Chen (University of Macau), Wei Zhao (University of Macau)

Visual (V) surveillance systems are extensively deployed and becoming the largest source of big data. On the other hand, electronic (E) data also plays an important role in surveillance and its amount increases explosively with the ubiquity of mobile devices. One of the major problems in surveillance is to determine human objects identities among different surveillance scenes. Traditional way of processing big V and E datasets separately does not serve the purpose well because V data and E data are imperfect alone for information gathering and retrieval. Matching human objects in the two datasets can merge the good of the two for efficient large-scale surveillance. Yet such matching across two heterogeneous big datasets is challenging. In this paper, we propose an efficient set of parallel algorithms, called EV-Matching, to bridge big E and V data. We match E and V data based on their spatiotemporal correlation. The EV-Matching algorithms are implemented on Apache Spark to further accelerate the whole procedure. We conduct extensive experiments on a large synthetic dataset under different settings. Results demonstrate the feasibility and efficiency of our proposed algorithms.

**Adaptive Reconnaissance Attacks with Near-Optimal Parallel Batching**
Xiang Li (University of Florida), Johnathan Smith (University of Florida), My Thai (University of Florida)

In assessing privacy on online social networks, it is important to investigate their vulnerability to reconnaissance strategies, in which attackers lure targets into being their friends by exploiting the social graph in order to extract victims sensitive information. As the network topology is only partially revealed after each successful friend request, attackers need to employ an adaptive strategy. Existing work only considered a simple strategy in which attackers sequentially acquire one friend at a time, which causes tremendous delay in waiting for responses before sending the next request, and which lack the ability to retry failed requests after the network has changed. In contrast, we investigate an adaptive and parallel strategy, of which attackers can simultaneously send multiple friend requests in batch and recover from failed requests by retrying after topology changes, thereby significantly reducing the time of reaching the targets and improving robustness. We cast this approach as an optimization problem, Max-Crawling, and show it inapproximable within $\left(1 - \frac{1}{e}\right)$. We first design our core algorithm PM-AReST which has an approximation ratio of $(1 - e/(1/e - 1))$ using adaptive monotonic submodular properties. We next provide a near-optimal solution ($(1 - 1/e)$) via a twostage stochastic programming approach. We further establish the gap bound of $(1 - e/(1 - 1/e))$ between batch strategies versus the optimal sequential one. We experimentally validate our theoretical results, finding that our algorithm performs nearoptimally in practice and that this is robust under a variety of problem settings.

**Achieving Strong Privacy in Online Survey**
You Zhou (University of Florida), Yuan Zhou (University of Florida), Shigang Chen (University of Florida), Samuel S. Wu (University of Florida)

Thanks to the proliferation of Internet access and modern digital and mobile devices, online survey has been flourishing into data collection of marketing, social, financial and medical studies. However, traditional data collection methods in online survey suffer from serious privacy issues. Existing privacy protection techniques are not adequate for online survey for lack of strong privacy. In this paper, we propose a practical strong privacy online survey scheme SPS based on a novel data collection technique called dual matrix masking (DM2), which guarantees the correctness of the tallying results with low computation overhead, and achieves universal verifiability, robustness and strong privacy. We also propose a more robust scheme RSPS, which incorporates multiple distributed survey managers. The
Research 12: Cloud Computing and Distributed Data Analytics

Service Overlay Forest Embedding for Software-Defined Cloud Networks
Jian-Jhii Kuo (Academia Sinica), Shan-Hsiang Shen (National Taiwan University of Science and Technology), Ming-Hong Yang (University of Minnesota), De-Nian Yang (Academia Sinica), Ming-Jer Tsai (National Tsing Hua University), Wen-Tsuen Chen (Academia Sinica)

Network Function Virtualization (NFV) on Software-Defined Networks (SDN) can effectively optimize the allocation of Virtual Network Functions (VNFs) and the routing of network flows simultaneously. Nevertheless, most previous studies on NFV focus on unicast service chains and thereby are not scalable to support a large number of destinations in multicast. On the other hand, the allocation of VNFs has not been supported in the current SDN multicast routing algorithms. In this paper, therefore, we make the first attempt to tackle a new challenging problem for finding a service forest with multiple service trees, where each tree contains multiple VNFs required by each destination. Specifically, we formulate a new optimization, named Service Overlay Forest (SOF), to minimize the total cost of all allocated VNFs and all multicast trees in the forest. We design a new _3_ST - approximation algorithm to solve the problem, where _ST denotes the best approximation ratio of the Steiner Tree problem, and the distributed implementation of the algorithm is also presented. Simulation results on real networks for data centers manifest that the proposed algorithm outperforms the existing ones by over 25%. Moreover, the implementation of an experimental SDN with HP OpenFlow switches indicates that SOF can significantly improve the QoE of the Youtube service.

Joint Optimization of Chain Placement and Request Scheduling for Network Function Virtualization
Qixia Zhang (Huazhong University of Science & Technology), Yikai Xiao (Huazhong University of Science & Technology), Fangming Liu (Huazhong University of Science and Technology), John Chi Shing Lui (Chinese University of Hong Kong), Jian Guo (Huazhong University of Science & Technology), Tao Wang (Huazhong University of Science & Technology)

Compared with executing Network Functions (NFs) on dedicated hardware, the recent trend of Network Function Virtualization (NFV) holds the promise for operators to flexibly deploy software-based NFs on commodity servers. However, virtual NFs (VNFs) are normally chained together to provide a specific network service. Thus, an efficient scheme is needed to place the VNF chains across the network and effectively schedule requests to service instances, which can maximize the average resource utilization of each node in service and simultaneously minimize the average response latency of each request. To this end, we formulate first VNF chains placement problem as a variant of bin-packing problem, which is NP-hard, and we model request scheduling problem based on the key concepts from open Jackson network. To jointly optimize the performance of NFV, we propose a priority-driven weighted algorithm to improve resource utilization and a heuristic algorithm to reduce response latency. Through extensive trace-driven simulations, we show that our methods can indeed enhance performance in diverse scenarios. In particular, we can improve the average resource utilization by 24.9% and can reduce the average total latency by 19.9% as compared with other state-of-the-art methods.

BIG Cache Abstraction for Cache Networks
Eman Ramadan (University of Minnesota), Arvind Narayanan (University of Minnesota), Zhi-Li Zhang (University of Minnesota), Runhui Li (Huawei Future Network Theory Lab), Gong Zhang (Huawei Future Network Theory Lab)

In this paper, we advocate the notion of BIG cache as an innovative abstraction for effectively utilizing the distributed storage and processing capacities of all servers in a cache network. The BIG cache abstraction is proposed to partly address the problem of (cascade) thrashing in a hierarchical network of cache servers, where it has been known that cache resources at intermediate servers are poorly utilized, especially under classical cache replacement policies such as LRU. We lay out the advantages of BIG cache abstraction and make a strong case both from a theoretical standpoint as well as through simulation analysis. We also develop the dCLIMB cache algorithm to minimize the overheads of moving objects across distributed cache boundaries and present a simple yet effective heuristic for addressing the cache allotment problem in the design of BIG cache abstraction.

Distributed QR decomposition framework for training Support Vector Machines
Jyotikrishna Dass (Texas A&M University), V. N. S. Prithvi Sakuru (Texas A&M University), Vivek Sarin (Texas A&M University), Rabi N. Mahapatra (Texas A&M University)

Support Vector Machines (SVM) belong to class of supervised machine learning algorithms with applications in classification and regression analysis. SVM training is modeled as a convex optimization problem that is computationally tedious and has large memory requirements. Specifically, it is a quadratic programming problem which scales rapidly with the training set size rather than the dimensionality of the feature space. In this work, we first present a novel QR decomposition framework (QRSVM) to efficiently model and solve a large scale SVM problem by capitalizing on low-rank representations of the full kernel matrix rather than solving the problem as a sequence of smaller sub-problems. The low-rank structure of the kernel matrix is leveraged to transform the dense matrix into one with a sparse and separable structure. The modified SVM problem requires significantly lesser memory and computation. Our approach scales linearly with the training set size which makes it applicable to large datasets. This motivates towards our another contribution; exploring a distributed QRSVM framework to solve large-scale SVM classification problems in parallel across a cluster of computing nodes. We also derive an optimal step size for fast convergence of the dual ascent method which is used to solve the quadratic programming problem.

Distributively Computing Random Walk Betweenness Centrality in Linear Time
Qiāng-Sheng Hu (Huazhong University of Science and Technology), Ming Ai (Huazhong University of Science and Technology), Hai Jin (Huazhong University of Science and Technology), Dongxiao Yu (Huazhong University of Science and Technology), Xuanhua Shi (Huazhong University of Science and Technology)

Betweenness centrality of a node represents its influence over the spread of information in the network. It is normally defined as the ratio of the number of shortest paths passing through the node among all shortest paths. However, the spread of information may not just pass through the shortest paths which is captured by a new measure of betweenness centrality based on random walks [1]. The random walk betweenness centrality of a node means how often it is traversed by a random walk between all pairs of other nodes. In this paper, we propose an O(n log n) time distributed randomized approximation algorithm for calculating each nodes random walk betweenness centrality with an approximation ratio (1, ) where n is the number of nodes and is an arbitrarily small constant between 0 and 1. Our distributed algorithm is designed under the widely used CON GEST model, where each edge can only transfer O(log n) bits in each round. To our best
knowledge, this is the first distributed algorithm for computing the random walk betweenness centrality. Moreover, we give a non-trivial lower bound for distributively computing the exact random walk betweenness centrality under the CON GEST model, which is \( n \log n + D \) where \( D \) is the network diameter. This means exactly computing random walk betweenness cannot be done in sublinear time.

DeGPar: Large Scale Topic Detection using Node-Cut Partitioning on Dense Weighted Graphs
Kambiz Ghoorchian (Royal Institute of Technology (KTH)), Sarunas Girdzijauskas (Royal Institute of Technology (KTH)), Fatemeh Rahimian (Swedish Institute of Computer Science (SICS))

Topic Detection (TD) refers to automatic techniques for locating topicaly relevant material in web documents [1]. Nowadays, massive amounts of documents are generated by users of Online Social Networks (OSNs), in form of very short text, tweets and snippets of news. While topic detection, in its traditional form, is applied to a few documents containing a lot of information, the problem has now changed to dealing with massive number of documents with very little information. The traditional solutions, thus, fail short either in scalability (due to huge number of input items) or sparsity (due to insufficient information per input item). In this paper we address the scalability problem by introducing an efficient and scalable graph based algorithm for TD on short texts, leveraging dimensionality reduction and clustering techniques. We first, compress the input set of documents into a dense graph, such that frequent cooccurrence patterns in the documents create multiple dense topological areas in the graph. Then, we partition the graph into multiple dense sub-graphs, each representing a topic. We compare the accuracy and scalability of our solution with two state-of-the-art solutions (including the standard LDA, and BiTerm). The results on two widely used benchmark datasets show that our algorithm not only maintains a similar or better accuracy, but also performs by an order of magnitude faster than the state-of-the-art approaches.

Research 13: Distributed Algorithms and Theory II

Networked Stochastic Multi-Armed Bandits with Combinatorial Strategies
Shaojie Tang (University of Texas at Dallas), Yaqin Zhou (SUTD), Kai Han (University of Science and Technology of China), Zhao Zhang (Zhejiang Normal University), Jing Yuan (University of Texas at Dallas), Weili Wu (University of Texas at Dallas)

In this paper, we investigate a largely extended version of classical MAB problem, called networked combinatorial bandit problems. In particular, we consider the setting of a decision maker over a networked bandits as follows: each time a combinatorial strategy, e.g., a group of arms, is chosen, and the decision maker receives a reward resulting from her strategy and also receives a side bonus resulting from that strategy for each arms neighbor. This is motivated by many real applications such as on-line social networks where friends can provide their feedback on shared content, therefore if we promote a product to a user, we can also collect feedback from her friends on that product. To this end, we consider two types of side bonus in this study: side observation and side reward. Upon the number of arms pulled at each time slot, we study two cases: single-play and combinatorial-play. Consequently, this leaves us four scenarios to investigate in the presence of side bonus: Single-play with Side Observation, Combinatorial-play with Side Observation, Single-play with Side Reward, and Combinatorial-play with Side Reward. For each case, we present and analyze a series of zero regret policies where the expect of regret over time approaches zero as time goes to infinity. Extensive simulations validate the effectiveness of our results.

Computability of Perpetual Exploration in Highly Dynamic Rings
Marjorie Bournat (UPMC Sorbonne Universités), Swan Dubois (UPMC Sorbonne Universités), Franck Petit (UPMC Sorbonne Universités)

We consider systems made of autonomous mobile robots evolving in highly dynamic discrete environment i.e., graphs where edges may appear and disappear unpredictably without any recurrence, stability, nor periodicity assumption. Robots are uniform (they execute the same algorithm), they are anonymous (they are devoid of any observable ID), they have no means allowing them to communicate together, they share no common sense of direction, and they have no global knowledge related to the size of the environment. However, each of them is endowed with persistent memory and is able to detect whether it stands alone at its current location. A highly dynamic environment is modeled by a graph such that its topology keeps continuously changing over time. In this paper, we consider only dynamic graphs in which nodes are anonymous, each of them is infinitely often reachable from any other one, and such that its underlying graph (i.e., the static graph made of the same set of nodes and that includes all edges that are present at least once over time) forms a ring of arbitrary size. In this context, we consider the fundamental problem of perpetual exploration: each node is required to be infinitely often visited by a robot. This paper analyzes the computability of this problem in (fully) synchronous settings, i.e., we study the deterministic solvability of the problem with respect to the number of robots. We provide three algorithms and two impossibility results that characterize, for any ring size, the necessary and sufficient number of robots to perform perpetual exploration of highly dynamic rings.

Locally Self-Adjusting Skip Graphs
Sikder Huq (The University of Iowa), Sukumar Ghosh (The University of Iowa)

We present a distributed self-adjusting algorithm for skip graphs that minimizes the average routing costs between arbitrary communication pairs by performing topological adaptation to the communication pattern. Our algorithm is fully decentralized, conforms to the CON GEST model (i.e. O(log n) bit messages), and requires O(log n) bits of memory for each node, where n is the total number of nodes. Upon each communication request, our algorithm first establishes communication by using the standard skip graph routing, and then locally and partially reconstructs the skip graph topology to perform topological adaptation. We propose a computational model for such algorithms, as well as a yardstick (working set property) to evaluate them. Our working set property can be also used to evaluate self-adjusting algorithms for other graph classes where multiple tree-like subgraphs overlap (e.g. hypercube networks). We derive a lower bound of the amortized routing cost for any algorithm that follows our model and serves an unknown sequence of communication requests. We show that the routing cost of our algorithm is at most a constant factor more than the amortized routing cost of any algorithm conforming to our computational model. We also show that the expected transformation cost for our algorithm is at most a logarithmic factor more than the amortized routing cost of any algorithm conforming to our computational model.

Online to Offline Business: Urban Taxi Dispatching with Passenger-Driver Matching Stability
Huanyang Zheng (Temple University), Jie Wu (Temple University)

In the Online to Offline (O2O) taxi business (e.g., Uber), the interests of passengers, taxi drivers, and the company may not align with each other, since taxis do not belong to the company. To balance those interests, this paper studies the taxi dispatch problem for the O2O taxi business. The interests of passengers and taxi drivers are modeled. For non-sharing taxi dispatches (multiple passenger requests cannot share a taxi), a stable marriage approach is proposed. It can deal with unequal numbers of passenger requests and taxis through matching them to dummy partners. The existence of stable matchings with dummy partners is proved.
Three rules are presented to find out all possible stable matchings. For sharing taxi dispatches (multiple passenger requests could share a taxi), passenger requests are packed through solving a maximum set packing problem. Packed passenger requests are regarded as a single request for matching taxis. Extensive real data-driven experiments demonstrate the performance of our approach. The proposed algorithms have a limited performance gap to the literature in terms of the dispatch delay and the passenger satisfactory, but significantly improves the existing algorithms in terms of the taxi satisfactory. Index Terms Taxi dispatch schedule, passenger requests, taxi drivers, matching stability, sharing and non-sharing.

**An Optimization Framework For Online Ride-sharing Markets**
Yongzheng Jia (Tsinghua University), Wei Xu (Tsinghua University), Xue Liu (McGill University)

Taxi services and product delivery services are instrumental for our modern society. Thanks to the emergence of sharing economy, ride-sharing services such as Uber, Didi, Lyft and Google’s Waze Rider are becoming more ubiquitous and grow into an integral part of our everyday lives. However, the efficiency of these services are severely limited by the optimal and suboptimal matching between the supply and demand. We need a generalized framework and corresponding efficient algorithms to address the efficient matching, and hence optimize the performance of these markets. Existing studies for taxi and delivery services are only applicable in scenarios of the one-sided market. In contrast, this work investigates a highly generalized model for the taxi and delivery services in the market economy (abbreviated as taxi and delivery market) that can be widely used in two-sided markets. Further, we present efficient online and offline algorithms for different applications. We verify our algorithm with theoretical analysis and trace-driven simulations under realistic settings.

**Fast and Accurate Tracking of Population Dynamics in RFID Systems**
Muhammad Shahzad (North Carolina State University), Alex Liu (Michigan State University)

RFID systems have been widely deployed for various applications such as supply chain management, indoor localization, inventory control, and access control. This paper deals with the fundamental problem of estimating the number of arriving and departing tags between any two time instants in dynamically changing RFID tag populations, which is needed in many applications such as warehouse monitoring and privacy sensitive RFID systems. In this paper, we propose a dynamic tag estimation scheme, namely DTE, that can achieve arbitrarily high required reliability, is compliant with the C1G2 standard, and works in single as well as multiple-reader environment. DTE uses the standardized frame slotted Aloha protocol and utilizes the number of slots that change their values in corresponding Aloha frames at the two time instants to estimate the number of arriving and departing tags. It is easy to deploy because it neither requires modification to tags nor to the communication protocol between tags and readers. We have extensively evaluated and compared DTE with the only prior scheme, ZDE, that can estimate the number of arriving and departing tags. Unfortunately, ZDE cannot achieve arbitrarily high required reliability. In contrast, our proposed scheme always achieves the required reliability. For example, for a tag population containing 104 tags, a required reliability of 95%, and a required confidence interval of 5%, DTE takes 5.12 seconds to achieve the required reliability whereas ZDE achieves a reliability of only 66% in the same amount of time.

**Research 14: Mobile and Wireless Computing Systems II**

**Robust Indoor Wireless Localization Using Sparse Recovery**
Wei Gong (Simon Fraser University), Jiangchuan Liu (Simon Fraser University)

With the multi-antenna design of WiFi interfaces, phased array has become a promising mechanism for accurate WiFi localization. State-of-the-art WiFi-based solutions using AoA (Angle-of-Arrival), however, face a number of critical challenges. First, their localization accuracy degrades dramatically when the Signal-to-Noise Ratio (SNR) becomes low. Second, they do not fully utilize coherent processing across all available domains. In this paper, we present ROArray, a Robust Array based system that accurately localizes a target even with low SNRs. First, in the spatial domain, ROArray can produce sharp AoA spectrums by parameterizing the steering vector based on a sparse grid. Then, to expand into the frequency domain, it jointly estimates the ToAs (Time-of-Arrival) and AoAs of all the paths using multi-subcarrier OFDM measurements. Furthermore, through multi-packet fusion, ROArray is enabled to perform coherent estimation across the spatial, frequency, and time domains. Such coherent processing not only increases the virtual aperture size, which enlarges the number of maximum resolvable paths, but also improves the system robustness to noises. Our implementation using off-the-shelf WiFi cards demonstrates that, with low SNRs, ROArray significantly outperforms state-of-the-art solutions in localization accuracy; when medium or high SNRs are present, it achieves comparable accuracy.

**Max-Min Fair Resource Allocation in HetNets: Distributed Algorithms and Hybrid Architecture**
Ehsan Aryafar (Portland State University), Alireza Keshavarz-Haddad (Shiraz University), Carlee Joe-Wong (Carnegie Mellon University), Mung Chiang (Princeton University)

We study the resource allocation problem in RANlevel integrated HetNets. This emerging HetNets paradigm allows for dynamic traffic splitting across radio access technologies for each client, and then for aggregating the traffic inside the network to improve the overall resource utilization. We focus on the maxmin fair service rate allocation across the clients, and study the properties of the optimal solution. Based on the analysis, we design a low complexity distributed algorithm that tries to achieve max-min fairness. We also design a hybrid network architecture that leverages opportunistic centralized network supervision to augment the distributed solution. We analyze the performance of our proposed algorithms and prove their convergence. We also derive conditions under which the outcome is optimal. When the conditions are not satisfied, we provide constant upper and lower bounds on the optimality gap. Finally, we study the convergence time of our distributed solution and show that leveraging appropriate policies in its design significantly reduces the convergence time.

**Optimization of Full-View Barrier Coverage with Rotatable Camera Sensors**
Xiaofeng Gao (Shanghai Jiao Tong University), Rui Yang (University of Illinois Urbana-Champaign), Fan Wu (Shanghai Jiao Tong University), Guihai Chen (Shanghai Jiao Tong University), Jingguang Zhou (Shanghai Jiao Tong University)

In all the researches in wireless sensor networks, cameras are increasingly utilized for their surveillance capabilities. In this paper, we elaborately discuss about the problem of Full-View Barrier Coverage with Rotatable Camera Sensors (FVBCR), including weakly and strongly connected versions. FBCR is proven to be NP-hard in this paper by reducing Group Steiner Tree problem to it. Our goal is to reduce sensor number when guaranteeing the surveillance capabilities at the same time. Correspondingly, we introduce a novel weighed graph structure called Full-View Barrier Graph. We transform weak version problem into a pseudo one-dimension one and propose WGrapProj algorithm with the help of dynamic programming; in strong version problem, we introduce two centralized algorithms (S-Dijkstra, S-Thorup), respectively aiming to save sensor number and to reduce time complexity. Moreover, we rigorously analyze the correctness and time complexity for each algorithm. In addition, the mass number of experiments are conducted to validate the efficiency of all algorithms, which prove that our structures and algorithms can construct a full-view barrier with fewer camera sensors compared with previous researches.
Communication through Symbol Silence: Towards Free Control Messages in Indoor WLANs
Bing Feng (University of Science and Technology of China), Jianqing Liu (University of Florida), Chi Zhang (University of Science and Technology of China), Yuguang Fang (University of Florida)

Efficient design of wireless networks benefits from the exchange of control messages. However, control message itself consumes scarce channel resources. In this paper, we propose CoS (Communication through Symbol Silence), a novel communication strategy that conveys control messages for free without consuming extra channel resources. CoS inserts silence symbols in data packets and leverages the intervals between inserted silence symbols to encode information. The silence symbols can be located by energy detection at the granularity of symbols and the intervals are interpreted into transmitted control messages. Based on our key insights that the channel code is under-utilized in current wireless networks and the distribution of symbol errors within a data packet is predictable in indoor wireless transmissions, the symbols erased by silence symbols are recovered by the coding redundancy that is originally used to correct symbol errors. A rate adaptation scheme is designed to dynamically adjust the rate of free control messages according to channel conditions so that the transmission of free control messages does not harm the original data throughput. We implement CoS on our software defined radio platform to validate the feasibility of CoS. The extensive results show that the control messages are delivered with close to 100% accuracy in a large SNR range. In addition, we measure the achievable capacity of free control messages in various channel conditions.

Secure connectivity of wireless sensor networks under key predistribution with on/off channels
Jun Zhao (Carnegie Mellon University)

The q-composite key predistribution scheme [1] is used prevalently for secure communications in large-scale wireless sensor networks (WSNs). Prior work [2][4] explores secure connectivity in WSNs employing the q-composite scheme for q = 1 with unreliable communication links modeled as independent on/off channels. In this paper, we investigate secure connectivity in WSNs operating under the q-composite scheme for general q and under the on/off channel model. We present conditions on how to scale the model parameters so that the network is securely connected with high probability when the number of sensors becomes large. The results are given in the form of zero-one laws. Numerical experiments confirm the validity of our analytical results.

iUpdater: Low Cost RSS Fingerprints Updating for Device-free Localization
Liqiong Chang (Northwest University), Jie Xiong (Singapore Management University), Yu Wang (University of North Carolina at Charlotte), Xiaojiang Chen (Northwest University), Junhao Hu (Northwest University), Fang Dingyi (Northwest University)

While most existing indoor localization techniques are device-based, many emerging applications such as intruder detection and elderly care drive the needs of device-free localization, in which the target can be localized without any device attached. Among the diverse techniques, received signal strength (RSS) fingerprint-based methods are popular because of the wide availability of RSS readings in most commodity hardware. However, current fingerprint-based systems suffer from high human labor costs to update the fingerprint database and low accuracy due to large degree of RSS variations. In this paper, we propose a fingerprint-based device-free localization system named iUpdater to significantly reduce the labor cost and increase the accuracy. We present a novel selfaugmented regularized singular value decomposition (RSVD) method integrating the sparse attribute with unique properties of the fingerprint database. iUpdater is able to accurately update the whole database with RSS measurements at a small number of reference locations, thus reducing the human labor cost. Furthermore, iUpdater observes that although the RSS readings vary a lot, the RSS differences between both the neighboring locations and adjacent wireless links are relatively stable. This unique observation is applied to overcome the short-term RSS variations to improve the localization accuracy. Extensive experiments in three different environments over 3 months demonstrate the effectiveness and robustness of iUpdater.

Research 15: Social Networks and Crowdsourcing

Influence Maximization in a Many Cascades World
Iouliana Litou (AUEB), Vana Kalogeraki (AUEB), Dimitrios Gunopulos (UoA)

Online Social Networks (OSNs) are widely utilized in viral marketing campaigns exploiting the word-of-mouth effect. Various propagation models have been proposed to describe the way cascades unfold in OSNs. Based on the existing propagation models, several studies address the problem of influence maximization, where the objective is to identify an appropriate subset of users to initiate the spread of a contagion. However, existing approaches ignore an important factor in the propagation process, i.e., the correlation of multiple contagions simultaneously cascading in the social network and how these affect the users decisions regarding the adoption of a contagion. Although recent works look into either the competition or the complementarity among a pair of contagions, a uniform model that describes the propagation of multiple cascades with varying types and degrees of correlations is lacking. This work constitutes the first attempt to fill this gap. We formulate a novel propagation model, the Correlated Contagions Dynamic Linear Threshold (CCDLT), that considers the correlation of many contagions in either competitive or complementary manner. Our proposed model allows for different degrees of competition/complementarity among cascades. We further consider that users may dynamically switch states regarding the contagion they promote during the propagation process, based on the influence of their neighborhoods. We then design a greedy seed selection algorithm that identifies the appropriate subset of users to participate in a specific contagion in order to maximize its spread and we formally prove that it approximates the best solution at a ratio of 1 _ 1/e. Through an extensive experimental evaluation we demonstrate the superiority of our approach over existing schemes.

Expertise-Aware Truth Analysis and Task Allocation in Mobile Crowdsourcing
Xiaomei Zhang (University of South Carolina Beaufort), Yibo Wu (Pennsylvania State University), Lifu Huang (Rensselaer Polytechnic Institute), Heng Ji (Rensselaer Polytechnic Institute), Guohong Cao (Pennsylvania State University)

Mobile crowdsourcing has received considerable attention as it enables people to collect and share large volume of data through their mobile devices. Since the accuracy of the collected data is usually hard to ensure, researchers have proposed techniques to identify truth from noisy data by inferring and utilizing the reliability of users, and allocate tasks to users with higher reliability. However, they neglect the fact that a user may only have expertise on some problems (in some domains), but not others. Neglecting this expertise diversity may cause two problems: low estimation accuracy in truth analysis and ineffective task allocation. To address these problems, we propose an Expertise-aware Truth Analysis and Task Allocation (ETA2) approach, which can effectively infer user expertise and then allocate tasks and estimate truth based on the inferred expertise. ETA2 relies on a novel semantic analysis method to identify the expertise domains of the tasks and user expertise, an expertise-aware truth analysis solution to estimate truth and learn user expertise, and an expertise-aware task allocation method to maximize the
probability that tasks are allocated to users with the right expertise while ensuring the work load does not exceed the processing capability at each user. Experimental results based on two real-world datasets demonstrate that ETA2 significantly outperforms existing solutions.

**MeLoDy: A Long-term Dynamic Quality-aware Incentive Mechanism for Crowdsourcing**

Hongwei Wang (Shanghai Jiao Tong University), Song Guo (The Hong Kong Polytechnic University), Jiannong Cao (The Hong Kong Polytechnic University), Minyi Guo (Shanghai Jiao Tong University)

Crowdsourcing allows requesters to allocate tasks to a group of workers on the Internet to make use of their collective intelligence. Quality control is a key design objective in incentive mechanisms for crowdsourcing as requesters aim at obtaining answers of high quality under a given budget. However, when measuring workers long-term quality, existing mechanisms either fail to utilize workers historical information, or treat workers quality as stable and ignore its temporal characteristics, hence performing poorly in a long run. In this paper we propose MELODY, a long-term dynamic quality-aware incentive mechanism for crowdsourcing. MELODY models interaction between requesters and workers as reverse auctions that run continuously. In each run of MELODY, we design a truthful, individual rational, budget feasible and quality-aware algorithm for task allocation with polynomial-time computation complexity and O(1) performance ratio. Moreover, taking into consideration the long-term characteristics of workers quality, we propose a novel framework in MELODY for quality inference and parameters learning based on Linear Dynamical Systems at the end of each run, which takes full advantage of workers historical information and predicts their quality accurately. Through extensive simulations, we demonstrate that MELODY outperforms existing work in terms of both quality estimation (reducing estimation error by 17.6% \_ 24.2%) and social performance (increasing requesters utility by 18.2% \_ 46.6%) in long-term scenarios.

**The Strong Link Graph for Enhancing Sybil Defenses**

Suhendry Effendy (National University of Singapore), Roland Yap (National University of Singapore)

The sybil problem is a fundamental problem in distributed systems and online social networks (OSNs). The basic problem is that an attacker can easily create multiple identities in a distributed or open online system. Popular and effective sybil defenses are usually based on properties of the network structure. However, most defenses assume that it is hard for the attacker to make many connections to honest users. However, this assumption can be invalid in real OSNs which decreases the effectiveness of many sybil defenses. We propose a graph transformation, the strong link graph, to mitigate such attacks by reducing the effect of a large number of attack edges. Our preliminary experiments show indeed that when the attacker has many attack edges, existing algorithms such as SybIlLimit, SybilRank and Gatekeeper are ineffective. After the strong link graph is applied, it deletes many of the attack edges, restoring the effectiveness of the sybil defenses.

**Mechanism Design for Mobile Crowdsensing with Execution Uncertainty**

Zhenzhe Zheng (Shanghai Jiao Tong University), Xiaoxiong Yang (Shanghai Jiao Tong University), Fan Wu (Shanghai Jiao Tong University), Guihai Chen (Shanghai Jiao Tong University)

Mobile crowdsensing has emerged as a promising paradigm for data collection due to increasingly pervasive and powerful mobile devices. There have been extensive research works that propose incentive mechanisms for crowdsensing, but they all make the assumption that the mobile user will positively complete the allocated sensing task. In this paper, we consider a new scenario of crowdsensing where a user may fail to complete the task. For example, we suppose the user continuously collect data with his device in the background, and he completes the sensing task only if he passes through the location of interest. Due to the users mobility pattern, he may succeed or fail in the task. It is an important issue for the incentive mechanism to ensure fault tolerance for each sensing task. We design reverse auctions to model the interaction between the platform and mobile users, in which users probability of success and cost to perform the tasks are private information, and we aim to guarantee the tasks to be completed with high probability, while minimizing the social cost. We prove that minimizing the social cost is an NP-hard problem, and present mechanisms that achieve truthfulness and guaranteed approximation ratio. We perform extensive simulations to validate the desirable properties of our mechanisms.

**Towards Scalable and Dynamic Social Sensing Using A Distributed Computing Framework**

Daniel Zhang (University of Notre Dame), Chao Zheng (University of Notre Dame), Dong Wang (University of Notre Dame), Doug Thain (University of Notre Dame), Xin Mu (University of Notre Dame), Greg Madey (University of Notre Dame), Chao Huang (University of Notre Dame)

With the rapid growth of online social media and ubiquitous Internet connectivity, social sensing has emerged as a new crowdsourcing application paradigm of collecting observations (often called claims) about the physical environment from humans or devices on their behalf. A fundamental problem in social sensing applications lies in effectively ascertaining the correctness of claims and the reliability of data sources without knowing either of them a priori, which is referred to as truth discovery. While significant progress has been made to solve the truth discovery problem, some important challenges have not been well addressed yet. First, existing truth discovery solutions did not fully solve the dynamic truth discovery problem where the ground truth of claims changes over time. Second, many current solutions are not scalable to large-scale social sensing events because of the centralized nature of their truth discovery algorithms. Third, the heterogeneity and unpredictability of the social sensing data traffic pose additional challenges to the resource allocation and system responsiveness. In this paper, we developed a Scalable Streaming Truth Discovery (SSTD) solution to address the above challenges. In particular, we firstly developed a dynamic truth discovery scheme based on Hidden Markov Models (HMM) to effectively infer the evolving truth of reported claims. We further developed a distributed framework to implement the dynamic truth discovery scheme using Work Queue in HTCondor system. We also integrated the SSTD scheme with an optimal workload allocation mechanism to dynamically allocate the resources (e.g., cores, memories) to the truth discovery tasks based on their computation requirements. We evaluated SSTD through real world social sensing applications using Twitter data feeds. The evaluation results on three real-world data traces (i.e., Boston Bombing, Paris Shooting and College Football) show that the SSTD scheme is scalable and outperforms the state-of-the-art truth discovery methods in terms of both effectiveness and efficiency.
Industry 1: Cloud Data Centers and Performance

Phoenix: Constraint aware scheduling for heterogeneous datacenters
Prashanth Thinakaran (Pennsylvania State University), Jashwant Raj Gunasekaran (Pennsylvania State University), Bikash Sharma (Microsoft Corp), Mahmut Kandemir (Pennsylvania State University), Chita Das (Pennsylvania State University)

Today’s datacenters are increasingly becoming diverse regarding both hardware and software architectures in order to support a myriad of applications. These applications are also heterogeneous in terms of job response times and resource requirements [eg., Number of Cores, GPUs, Network Speed] and they are expressed as task constraints. Constraints are used for ensuring task performance guarantees/Quality of Service(QoS) by enabling the application to express its specific resource requirements. While several schedulers have recently been proposed that aim to improve overall application and system performance, few of these schedulers consider resource constraints across tasks while making the scheduling decisions. Furthermore, latency-critical workloads and short-lived jobs that typically constitute about 90% of the total jobs in a datacenter have strict QoS requirements, which can be mitigated by minimizing the tail latency through effective scheduling. In this paper, we propose Phoenix, a constraint-aware hybrid scheduler to address both these problems (constraint awareness and ensuring low tail latency) by minimizing the job response times at constrained workers and proactively reordering the tasks. We use a novel Constraint Resource Vector (CRV) based scheduling, which in turn facilitates reordering of the jobs in a queue to minimize tail latency. We have used the publicly available Google traces to analyze their constraint characteristics and have embedded these constraints in Cloudera and Yahoo cluster traces for studying the impact of traces on system performance. Experiments with Google, Cloudera and Yahoo cluster traces across 15,000 worker node cluster shows that Phoenix improves the 99th percentile job response times on an average by 1.9x across all three traces when compared against a state-of-the-art hybrid scheduler. Further, in comparison to other distributed scheduler like Hawk, it improves the 90th and 99th percentile job response times by 4.5x and 5x respectively.

Dual Scaling VMs and Queries: Cost-effective Latency Curtailment
Juan Pérez (University of Melbourne), Robert Birke (IBM Research Zurich), Mathias Björkqvist (IBM Research Zurich), Lydia Y. Chen (IBM Research Zurich)

Wimpy virtual instances equipped with small numbers of cores and RAM are popular public and private cloud offerings because of their low cost for hosting applications. The challenge is how to run latency-sensitive applications using such instances, which trade off performance for cost. In this study, we analytically and experimentally show that simultaneously scaling resources at coarse granularity and workloads, i.e., submitting multiple query clones to different servers, at fine granularity can overcome the performance disadvantages of wimpy VM instances and achieve stringent latency targets that are even lower than the average execution times of wimpy servers. To such an end, we first derive a closed-form analysis for the latency under any given VM provisioning and query replication level, considering cloning policies that can (not) terminate outstanding clones with (without) an overhead. Validated on trace-driven simulations, our analysis is able to accurately predict the latency and efficiently search for the optimal number of VMs and clones. Secondly, we develop a dual elastic scaler, DuoScale, that dynamically scales VMs and clones according to the workload dynamics so as to achieve the target latency in a cost-effective manner. The effectiveness of DuoScale lies on the observation that the application performance only scales sub-linearly with increasing vertical or horizontal resource provisioning, i.e., resources per VM or number of VMs. We evaluate DuoScale against VM-only scaling strategies via extensive trace-driven simulations as well as experimental results on a cloud testbed. Our results show that DuoScale is able to achieve the stringent target latency by using clones on wimpy VMs with cost savings up to 50%, compared to scaling brawny VMs that have better performance at a higher unit cost.

A framework for enabling security services collaboration across multiple domains
Daniel Migault (Ericsson Security Research), Marcos Simplício Junior (Escola Politécnica), Bruno Barros (Escola Politécnica), Makan Pourzandi (Ericsson Security Research), Thiago Almeida (Escola Politécnica), Ewerton Andrade (Escola Politécnica), Tereza Carvalho (Escola Politécnica)

Collaboration among Security Service Functions (SSF) is expected to become as essential to SCAaaS (SECurity as a Service) systems as elasticity is to IaaS (Infrastructure as a Service). The virtualization open new era in network security as new security appliances can be created on demand in appropriate places in the network. At the same time, the increasing size and diversity of attacks make it necessary to come up with new approaches for more efficient and more resilient security mechanisms. In this paper, we propose a new framework leveraging SDN (Software Defined Networking) and SFC (Service Function Chainning) to enhance the collaboration among different SSFs to mitigate large scale attacks. We describe a framework that allows SSFs from different domains to negotiate and dynamically control the amount of resources allocated for collaboration, in what we call a “best-effort” collaboration mode. This SSF collaboration framework creates a distributed mitigation system for handling large scale attacks in a dynamic and scalable manner. The efficiency and feasibility of this framework is experimentally assessed, showing that our approach incurs low overhead, increases the amount of traffic treated by SSFs and reduces the dropped traffic due to the lack of resources from the security mechanisms.

Group Clustering Using Inter-Group Dissimilarities
Debessay Fesehay Kassa (VMware), Lenin Singaravelu (Google), Chien-Chia Chen (VMware), Xiaobo Huang (VMware), Amitabha Banerjee (VMware), Ruijin Zhou (VMware), Rajesh Somasundaran (VMware)

Various systems have natural groupings. For instance in large scale distributed system, we can have groups of virtual and/or physical devices. A system can also have groups of time series datasets collected at different time intervals. Such groups are usually characterized by multidimensional metrics (features) set. Clustering such groups using their multidimensional datasets has various applications such as identifying different performance levels for anomaly detection and load balancing. Traditional algorithms focus on clustering a single time series dataset and not on such groups with multidimensional metrics datasets. In this paper we present the design, implementation and analysis of two sets of group clustering algorithms. The first set is called one-to-many as it generates clusters of groups by comparing each group against all other groups. The second set of algorithms is called pairwise as it generates the clusters of groups using pairwise group dissimilarity matrix. Both sets of algorithms first generate group dissimilarity weights using metric ranking algorithms. We implemented the group clustering algorithms by extending a well known machine learning package and using a front-end visualizer. We validated the clustering algorithms using real world datasets on the VMware vSAN product. Experimental results show that 7 out of the 8 proposed algorithms can generate expected clusters in at least 4 out of the 6 detailed experiments. The 3 out
of 8 proposed algorithms can generate the expected clusters in 5 out of the 6 experiments. One of the pairwise algorithms can generate the expected clusters in all 6 of the 6 experiments.

**Comprehensive Measurement and Analysis of the User-Perceived I/O Performance in a Production Leadership-Class Storage System**

Lipeng Wan (Oak Ridge National Laboratory), Matthew Wolf (Oak Ridge National Laboratory), Feiyi Wang (Oak Ridge National Laboratory), Jong Youl Cho (Oak Ridge National Laboratory), George Ostrouchov (Oak Ridge National Laboratory), Scott Klasky (Oak Ridge National Laboratory)

With the increase of the scale and intensity of the parallel I/O workloads generated by those scientific applications running on high performance computing facilities, understanding the I/O dynamics, especially the root cause of the I/O performance variability and degradation in HPC environment, have become extremely critical to the HPC community. In this paper, we run extensive I/O measuring tests on a production leadership-class storage system to capture the performance variabilities of large-scale parallel I/O. Analyzing these results and its statistic correlation revealed some valuable insights into the characteristics of the storage system and the root cause of I/O performance variability. Further, we leverage these findings and propose an I/O middleware design refactoring which can improve the performance of the parallel I/O by optimizing the data stripeing and placement. Our preliminary evaluation results demonstrate the proposed approach can reduce the average per-process write latency by at least 80% and the maximum per-process write latency by at least 20%.

**Industry 2: Mobile Computing and Internet of Things**

**Location: Charleston 1**

**On the Limits of Subsampling of Location Traces**

Mudhakar Srivatsa (IBM T.J. Watson Research Center), Raghu Ganti (IBM T.J. Watson Research Center), Prasant Mohapatra (UC Davis)

Location data collection at a societal scale is increasingly becoming common - examples of this are call and data detail records in telecommunication companies, GPS samples collected by car companies, and GPS samples from mobile devices in mapping companies (e.g., Google, Microsoft). Such large scale mobility datasets have applications in urban planning, network planning, surveillance, and real-time traffic estimations. This paper addresses the problem of subsampling location traces while preserving the amount of information present in such datasets. We present a novel subsampling technique that is based on a hierarchical geographical encoding mechanism (geohash), that allows for efficient spatial cluster sampling. We analyze this subsampling technique through various information theoretic measures to quantify the total “amount” of information in a dataset from a location trace perspective and evaluate these metrics in the context of two large scale mobility datasets from telecommunication companies - one is that of call detail records and the second is that of data detail records. We show that subsampling data in both these cases by as much as 75% does not significantly reduce the total amount of information, i.e. the dataset can be used similar to the original version. This paves way for the creation of better space and CPU efficient models that can support various applications reliant on collective location traces.

**SOM-TC: Self-organizing map for Hierarchical Trajectory Clustering**

Pranita Dewan (IBM T J Watson Research Center), Raghu Ganti (IBM T J Watson Research Center), Mudhakar Srivatsa (IBM T J Watson Research Center)

Trajectory clustering techniques help discover interesting insights from moving object data, including common routes for people and vehicles, anomalous sub-trajectories, etc. Existing trajectory clustering techniques fail to take in to account the uncertainty present in location data. In this paper, we investigate the problem of clustering trajectory data and propose a novel algorithm for clustering similar full and sub-trajectories together while modeling uncertainty in this data. We describe the necessary pre-processing techniques for clustering trajectory data, namely techniques to discretize raw location data using Possible World semantics to capture the inherent uncertainty in location data, and to segment full trajectories in to meaningful sub-trajectories. As a baseline, we extend the well known K-means algorithm to cluster trajectory data. We then describe and evaluate a new trajectory clustering algorithm, SOM-TC (Self- Organizing Map Based Trajectory Clustering), that is inspired from the self-organizing map technique and is at least 4x faster than the baseline K-means and current density based clustering approaches.

**Processing Encrypted and Compressed Time-Series Data**

Matúš Harvan (Enovos Luxembourg S.A.), Samuel Kimoto (Open Systems), Thomas Locher (ABB Corporate Research), Yvonne-Anne Pignolet (ABB Corporate Research), Johannes Schneider (University of Liechtenstein)

Numerous applications, e.g., in the industrial sector, produce large amounts of time-series data, which must be stored and made available for distributed processing. While outsourcing data storage and processing to third-party service providers offers many benefits, it raises data privacy issues. In light of this problem, techniques have been proposed to share only encrypted data with the remote service provider, yet the capability to run meaningful queries over the data is preserved. However, timeseries data is typically compressed at the server to save space, which is not easily possible when dealing with encrypted data. Moreover, data must be compressed in such a way that queries can still be executed efficiently. As a first step in this direction, we present an approach that preserves data privacy, enables compression at the server, and supports querying of the stored data. Our evaluation using realworld time-series data shows that our compression mechanism can reduce the required space drastically. Moreover, the median running time of all considered queries increases marginally, implying that compression can be introduced without sacrificing performance of query execution.

**Calvin Constrained - A Framework for IoT Applications in Heterogeneous Environments**

Amardeep Mehta (Umeå University), Rami Baddour (Università della Svizzera italiana), Fredrik Svensson (Ericsson Research), Harald Gustafsson (Ericsson Research), Erik Elmoth (Umeå University)

Calvin is an IoT framework for application development, deployment and execution in heterogeneous environments, that includes clouds, edge resources, and embedded or constrained resources. Inside Calvin, all the distributed resources are viewed as one environment by the application. The framework provides multi-tenancy and simplifies development of IoT applications, which are represented using a dataflow of application components (named actors) and their communication. The idea behind Calvin poses similarity with the serverless architecture and can be seen as Actor as a Service instead of Function as a Service. This makes Calvin very powerful as it does not only scale actors quickly but also provides an easy actor migration capability. In this work, we propose Calvin Constrained, an extension to the Calvin framework to cover resource-constrained devices. Due to limited memory and processing power of embedded devices, the constrained side of the framework can only support a limited subset of the Calvin features. The current implementation of Calvin Constrained supports actors implemented in C++.
as well as Python, where the support for Python actors is enabled by using MicroPython as a statically allocated library, by this we enable the automatic management of state variables and enhance code re-usability. As would be expected, Python-coded actors demand more resources over C-coded ones. We show that the extra resources needed are manageable on current off-the-shelf micro-controller-equipped devices when using the Calvin framework.
Applications and Experiences Track Paper Abstracts

Application 1: Security, Privacy, Trust in Distributed Systems
Privacy Preserving User-based Recommender System
Shahriar Badsha (RMIT University), Xu Yi (RMIT University), Ibrahim Khalil (RMIT University), Elisa Bertino (Purdue University)

With the rapid development of the social networks, Collaborative Filtering (CF)-based recommender systems have been increasingly prevalent and become widely accepted by users. The CF-based techniques generate recommendations by collecting privacy sensitive data from users. Usually, the users are sensitive to disclosure of personal information and, consequently, there are unavoidable security concerns since private information can be easily misused by malicious third parties. In order to protect against breaches of personal information, it is necessary to obfuscate user information by means of an efficient encryption technique while simultaneously generating the recommendation by making true information inaccessible to service providers. Therefore, we propose a privacy preserving user-based CF technique based on homomorphic encryption, which is capable of determining similarities among users followed by generating recommendations without revealing any private information. We introduce different semi-honest parties to preserve privacy and to carry out intermediate computations for generating recommendations. We implement our method on publicly available datasets and show that our method is practical as well as achieves high level of security for users without compromising the recommendation accuracy.

Privacy Preserving Optimization of Participatory Sensing in Mobile Cloud Computing
Ye Yan (Oakland University), Dong Han (Oakland University), Tao Shu (Auburn University)

With the rapid growth of mobile cloud computing, participatory sensing emerges as a new paradigm to explore our physical world at an unprecedented fine granularity by recruiting the pervasive sensor-enabled smart phones. While extensive optimization has been performed in the literature to coordinate the sensing activity of the cloud-based sensing server (or platform) and the participating smart phones so as to maximize the efficiency of participatory sensing, the privacy issue in the optimization has been largely overlooked. In this paper, we propose a novel privacy-preserving optimization framework that allows both the cloud-based platform and mobile users to share data for the formulation and solution of the optimization, but without revealing sensitive information that may lead to privacy leakage of each other. Our method is built upon a privacy-preserving version of the well-known NP-hard weighted set-covering problem. To accommodate privacy requirements in this framework, our solution uses a modified bloom filter along with a Diffie-Hellman-type exchange protocol among all participants for data aggregation, sharing, and presentation. Through extensive simulation we evaluate the privacy strength of the proposed approach and also verify its effectiveness and low overhead.

SPHINX: A Password Store that Perfectly Hides Passwords from Itself
Maliheh Shirvanian (University of Alabama at Birmingham), Stanislaw Jarecki (University of California at Irvine), Hugo Krawczyk (IBM Research), Nitesh Saxena (University of Alabama at Birmingham)

Password managers (aka stores or vaults) allow a user to store and retrieve (usually high-entropy) passwords for multiple password-protected services by interacting with a “device” serving the role of the manager (e.g., a smartphone or an online third-party service) on the basis of a single memorable (low-entropy) master password. Existing password managers work well to defeat offline dictionary attacks upon web service compromise, assuming the use of high-entropy passwords is enforced. However, they are vulnerable to leakage of all passwords in the event the device is compromised, due to the need to store the passwords encrypted under the master password and/or the need to input the master password to the device (as in smartphone managers). Evidence exists that password managers can be attractive attack targets. In this paper, we introduce a novel approach to password management, called SPHINX, which remains secure even when the password manager itself has been compromised. In SPHINX, the information stored on the device is information theoretically independent of the user’s master password — an attacker breaking into the device learns no information about the master password or the user’s site-specific passwords. Moreover, an attacker with full control of the device, even at the time the user interacts with it, learns nothing about the master password — the password is not entered into the device in plaintext form or in any other way that may leak information on it. Unlike existing managers, SPHINX produces strictly high-entropy passwords and makes it compulsory for the users to register these randomized passwords with the web services, hence fully defeating offline dictionary attack upon service compromise. The design and security of SPHINX is based on the device-enhanced PAKE model of Jarecki et al. that provides the theoretical basis for this construction and is backed by rigorous cryptographic proofs of security. While SPHINX is suitable for different device and online platforms, in this paper, we report on its concrete instantiation on smartphones given their popularity and trustworthiness as password managers (or even two-factor authentication). We present the design, implementation and performance evaluation of SPHINX, offering prototype browser plugins, smartphone apps and transparent device-client communication. Based on our inspection analysis, the overall user experience of SPHINX improves upon current managers. We also report on a lab-based usability study of SPHINX, which indicates that users’ perception of SPHINX security and usability is high and satisfactory when compared to regular password-based authentication. Finally, we discuss how SPHINX may be extended to an online service for the purpose of back-up or as an independent password manager.

When Smart TV Meets CRN: Privacy-preserving Fine-grained Spectrum Access
Chaowen Guan (State University of New York at Buffalo), Aziz Mohaisen (State University of New York at Buffalo), Zhi Sun (State University of New York at Buffalo), Lu Su (State University of New York at Buffalo), Kui Ren (State University of New York at Buffalo), Yaling Yang (Virginia Tech)

Dynamic spectrum sharing techniques applied in the UHF TV band have been developed to allow secondary WiFi transmission in areas with active TV users. This technique of dynamically controlling the exclusion zone enables vastly increasing secondary spectrum re-use, compared to the “TV white space” model where TV transmitters determine the exclusion zone and only “idle” channels can be re-purposed. However, in current such dynamic spectrum sharing systems, the sensitive operation parameters of both primary TV users (PUs) and secondary users (SUs) need to be shared with the spectrum database controller (SDC) for the purpose of realizing efficient spectrum allocation. Since such SDC server is not necessarily operated by a trusted third party, those current systems might cause essential threats to the privacy requirement from both PUs and SUs. To address this privacy issue, this paper proposes a privacy-preserving spectrum sharing system between PUs and SUs, which realizes the spectrum allocation decision process using efficient multi-party computation (MPC) technique. In this design, the SDC only performs secure computation over encrypted input from PUs and SUs such that none of the PU or SU operation parameters will be revealed to SDC. The evaluation of its performance illustrates that our proposed system based on efficient MPC techniques can perform dynamic spectrum allocation process between PUs and SUs efficiently while preserving users’ privacy.

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Revisiting Security Risks of Asymmetric ScalarProduct Preserving Encryption and Its Variants
Weipeng Lin (Simon Fraser University), Ke Wang (Simon Fraser University), Zhilin Zhang (Simon Fraser University), Hong Chen (Renmin University of China)

Cloud computing has emerged as a compelling vision for managing data and delivering query answering capability over the internet. This new way of computing also poses a real risk of disclosing confidential information to the cloud. Searchable encryption addresses this issue by allowing the cloud to compute the answer to a query based on the ciphertexts of data and queries. Thanks to its inner product preservation property, the asymmetric scalar-product-preserving encryption (ASPE) has been adopted and enhanced in a growing number of works to perform a variety of queries and tasks in the cloud computing setting. However, the security property of ASPE and its enhanced schemes has not been studied carefully. In this paper, we show a complete disclosure of ASPE and several previously unknown security risks of its enhanced schemes. Meanwhile, efficient algorithms are proposed to learn the plaintext of data and queries encrypted by these schemes with little or no knowledge beyond the ciphertexts. We demonstrate these risks on real data sets.

An Adversary-Centric Behavior Modeling of DDoS Attacks
An Wang (George Mason University), Aziz Mohaisen (SUNY Buffalo), Songqing Chen (George Mason University)

Distributed Denial of Service (DDoS) attacks are some of the most persistent threats on the Internet today. The evolution of DDoS attacks calls for an in-depth analysis of those attacks. A better understanding of the attackers’ behavior can provide insights to unveil patterns and strategies utilized by attackers. The prior art on the attackers’ behavior analysis often falls in two aspects: it assumes that adversaries are static, and makes certain simplifying assumptions on their behavior, which often are not supported by real attack data. In this paper, we take a data-driven approach to designing and validating three DDoS attack models from temporal (e.g., attack magnitudes), spatial (e.g., attacker origin), and patiowtemporal (e.g., attack inter-launching time) perspectives. We design these models based on the analysis of traces consisting of more than 50,000 verified DDoS attacks from industrial mitigation operations. Each model is also validated by testing its effectiveness in accurately predicting future DDoS attacks. Comparisons against simple intuitive models further show that our models can more accurately capture the essential features of DDoS attacks.

Application 2: Social Networks and Crowdsourcing

Anti-Malicious Crowdsourcing Using the Zero-Determinant Strategy
Qin Hu (Beijing Normal University), Shengling Wang (Beijing Normal University), Liran Ma (Texas Christian University), Rongfang Bie (Beijing Normal University), Xiuzhen Cheng (George Washington University)

Crowdsourcing is a promising paradigm to accomplish a complex task via eliciting services from a large group of contributors. However, recent observations indicate that the success of crowdsourcing is being threatened by the malicious behaviors of the contributors. In this paper, we analyze the malicious attack problem using an iterated prisoner’s dilemma (IPD) game and propose a zero-determinant (ZD) strategy to solve this problem by rewarding a worker’s cooperation or penalizing the defector for enticing his final cooperation. Both theoretical analysis and simulation study indicate that the proposed algorithm has two attractive characteristics: 1) the requestor can incentivize the worker to keep on cooperating by only increasing the short-term payment; and 2) the proposed algorithm is fair, so the requestor cannot arbitrarily penalize an innocent worker to increase her payoff even though she can dominate the game. To the best of our knowledge, we are the first to use the ZD strategy to stimulate both players to cooperate in an IPD game. Moreover, our proposed algorithm is not restricted to solve the problem of the malicious crowdsourcing - it can be employed to tackle any problem that can be formulated by an IPD game.

JPR: Exploring Joint Partitioning and Replication for Traffic Minimization in Online Social Networks
Jingya Zhou (Soochow University), Jianxi Fan (Soochow University)

A scalable storage system becomes more important today for online social networks (OSNs) as the volume of user data increases rapidly. Key-value store uses consistent hashing to save data in a distributed manner. As a de facto standard, it has been widely used in production environments of many OSNs. However, the random nature of hashing always leads to high inter-server traffic. Recently, partitioning and replication are respectively proposed in many existing works where the former aims to minimize the inter-server read traffic and the latter aims to optimize the inter-server write traffic. Nevertheless, the separated manners of optimization cannot efficiently reduce the traffic. Because the inter-server read traffic is changed during replication. In this paper, we suggest that performing partitioning and replication simultaneously could provide probability to further optimize traffic. Then we formulate the problem as a revised graph partitioning with overlaps, since overlaps partitioning naturally corresponds to replication. To solve the problem, we propose a Joint Partitioning and Replication (JPR) scheme. Through extensive experiments with a real world Facebook trace, we evaluate that JPR significantly reduces inter-server traffic with slightly sacrificing storage cost compared to hashing, and preserves a good load balancing across servers as well.

Optimizing Source Selection in Social Sensing in the Presence of Influence Graphs
Huajie Shao (UIUC), Shiguang Wang (UIUC), Shen Li (UIUC), Shuochoa Yao (UIUC), Yiran Zhao (UIUC), Md Tanvir Al Amin (UIUC), Tarek Abdelzaher (UIUC), Lance Kaplan (UIUC)

This paper addresses the problem of choosing the right sources to solicit data from in sensing applications involving broadcast channels, such as those crowdsensing applications where sources share their observations on social media. The goal is to select sources such that expected fusion error is minimized. We assume that soliciting data from a source incurs a cost and that the cost budget is limited. Contrary to other formulations of this problem, we focus on the case where sources influence others. Hence, asking a source to make a claim affects the behavior of other sources as well, according to an influence model. The paper makes two contributions. First, we develop an analytic model for estimating expected fusion error, given a particular influence graph and solution to the source selection problem. Second, we use model to search for a solution that minimizes expected fusion error, formulating it as a zero-one integer non-linear programming (INLP) problem. To scale the approach, the paper further proposes a novel reliability-based pruning heuristic (RPH) and a similarity-based lossy estimation (SLE) algorithm that significantly reduce the complexity of the INLP algorithm at the cost of a modest approximation. The analytically computed expected fusion error is validated using both simulations and real-world data from Twitter, demonstrating a good match between analytic predictions and empirical measurements. It is also shown that our method outperforms baselines in terms of resulting fusion error.

Dynamic Contract Design for Heterogeneous Workers in Crowdsourcing for Quality Control
Chenxi Qiu (Pennsylvania State University), Anna Squicciarini (Pennsylvania State University), Sarah Rajtmajer (Pennsylvania State University), James Caverlee (Texas A&M University)
Crowdsourcing sites heavily rely on paid workers to ensure completion of tasks. Yet, designing a pricing strategies able to incentivize users’ quality and retention is non-trivial. Existing payment strategies either simply set a fixed payment per task without considering changes in workers’ behaviors, or rule out poor quality responses and workers based on coarse criteria. Hence, task requesters may be investing significantly in work that is inaccurate or even misleading. In this paper, we design a dynamic contract to incentivize high-quality work. Our proposed approach offers a theoretically proven algorithm to calculate the contract for each worker in a cost-efficient manner. In contrast to existing work, our contract design is not only adaptive to changes in workers’ behavior, but also adjusts pricing policy in the presence of malicious behavior. Both theoretical and experimental analysis over real Amazon review traces show that our contract design can achieve a near optimal solution. Furthermore, experimental results demonstrate that our contract design 1) can promote high-quality work and prevent malicious behavior, and 2) outperforms the intuitive strategy of excluding all malicious workers in terms of the requester’s utility.

**Joint Request Balancing and Content Aggregation in Crowdsourced CDN**

Ming Ma (Tsinghua University), Zhi Wang (Tsinghua University), Kun Yi (Tsinghua University), Jiangchuan Liu (South China Agricultural University), Lifeng Sun (Tsinghua University)

Recent years have witnessed a new content delivery paradigm named crowdsourced CDN, in which devices deployed at edge network can prefetch contents and provide content delivery service. Crowdsourced CDN offers high-quality experience to end-users by reducing their content access latency and alleviates the load of network backbone by making use of network and storage resources at millions of edge devices. In such paradigm, redirecting content requests to proper devices is critical for user experience. The uniqueness of request redirection in such crowdsourced CDN lies that: on one hand, the bandwidth capacity of the crowdsourced CDN devices is limited, hence devices located at a crowded place can be easily overwhelmed when serving nearby user requests; on the other hand, contents requested in one device can be significantly different from another one, making request redirection strategies used in conventional CDNs which only aim to balance request loads ineffective. In this paper, we explore request redirection strategies that take both workload balance of devices and content requested by users into consideration. Our contributions are as follows. First, we conduct measurement studies, covering 1.8M users watching 0.4M videos, to understand request patterns in crowdsourced CDN. We observe that the loads of nearby devices can be very different and the contents requested at nearby devices can also be significantly different. These observations lead to our design for request balancing at nearby devices. Second, we formulate the request redirection problem by taking both the content access latency and the content replication cost into consideration, and propose a request balancing and content aggregation solution. Finally, we evaluate the performance of our design using trace-driven simulations, and observe our scheme outperforms the traditional strategy in terms of many metrics, e.g., we observe a content access latency reduction by 50% over traditional mechanisms such as the Nearest/Random request routing scheme.

**Shrink: A Breast Cancer Risk Assessment Model Based on Medical Social Network**

Ali Li (University of Science and Technology Beijing), Rui Wang (University of Science and Technology Beijing), Lei Xu (University of Science and Technology Beijing)

Breast cancer risk assessment model can assess whether a person is at a high risk of developing breast cancer disease or not and confirm a breast cancer high-risk group. Because the etiology of breast cancer disease is different in different country and region, the existing risk assessment model is only adaptive to certain countries and regions. And the parameters of these models are fixed, so these models have poor generality. Aiming at these problems, the paper puts forward a new breast cancer risk assessment model named as Shrink. Using the idea of social network, Shrink constructs a medical social network to show the similarity among people, and uses group division algorithm to divide the network into breast cancer high-risk group and low-risk group. The parameters of this model can be set according to the needs of the breast census, and these parameters can be directly acquired through questionnaire, therefore Shrink has good generality. Moreover, under the uncertain classification standard, Shrink adopts a new classification method to discover breast cancer high-risk group. Based on the real data from questionnaires, we make experiments in Matlab, and obtain the evaluation index of the model. The experiment proves that the model itself has good evaluation result and is better than classic Gail model.

**Application 3: Internet of Things, Smart Cities, and Cyber-Physical Systems**

**Opportunistic Energy Sharing Between Power Grid and Electric Vehicles: A Game Theory-Based Pricing Policy**

Ankur Sarkar (University of Virginia), Zhuozhao Li (University of Virginia), William Kolodzey (Clemson University), Haiying Shen (University of Virginia)

Electric vehicles (EVs) have great potential to reduce dependency on fossil fuels. The recent surge in the development of online EV (OLEV) will help to address the drawbacks associated with current generation EVs, such as the heavy and expensive batteries. OLEVs are integrated with the smart grid of power infrastructure through a wireless power transfer system (WPT) to increase the driving range of the OLEV. However, the integration of OLEVs with the grid creates a tremendous load for the smart grid. The demand of a power grid changes over time and the price of power is not fixed throughout the day. There should be some congestion avoidance and load balancing policy implications to ensure quality of services for OLEVs. In this paper, first, we conduct an analysis to show the existence of unpredictable power load and congestion because of OLEVs. We use the Simulation for Urban MOBility tool and hourly traffic counts of a road section of the New York City to analyze the amount of energy OLEVs can receive at different times of the day. Then, we present a game theory based on a distributed power schedule framework to find the optimal schedule between OLEVs and smart grid. In the proposed framework, OLEVs receive the amount of power charging from the smart grid based on a power payment function which is updated using best response strategy. We prove that the updated power requests converge to the optimal power schedule. In this way, the smart grid maximizes the social welfare of OLEVs, which is defined as mixed consideration of total satisfaction and its power charging cost. Finally, we verify the performance of our proposed pricing policy under different scenarios in a simulation study.

**Energy Efficient Object Detection in Camera Sensor Networks**

Tuan Dao (UC Riverside), Karim Khalil (UC Riverside), Amit Roy-Chowdhury (UC Riverside), Srikanth Krishnamurthy (UC Riverside), Lance Kaplan (U.S. Army Research Laboratory)

A wireless camera network can provide situation awareness information (e.g., humans in distress) in scenarios such as disaster recovery. If such camera sensors are battery operated, sending encrypted feeds back to a central controller can be expensive in terms of energy consumption. Further, if all cameras were to use the optimal processing algorithm for object decision, they may also expend unnecessary energy. Stated otherwise, cameras that capture the same objects may not all have to use the optimal algorithm to achieve a desired accuracy, and this can save processing energy costs. In this paper, our objective is to design and implement a framework that can support coordination among cameras to deliver highly accurate detection of objects in an energy efficient way. The framework, which we call EECS (for energy efficient camera sensors), estimates the detection accuracy and energy costs incurred (both the processing and communication costs are taken into account).
account) with each detection algorithm for each camera, and comes up with a choice of cameras for sending information pertaining to the object of interest. This set of cameras and the video processing algorithms that they must use, are chosen so as to minimize the energy expenditures, given a desired detection accuracy. We implement EECS on a camera network built with smartphones, and demonstrate that it reduces the energy consumption by up to 40% while ensuring a object detection accuracy of over 86%.

**DeepOpp: Context-aware Mobile Access to Social Media Content on Underground Metro Systems**
Di Wu (Hunan University & Imperial College London), Dmitri Arkhipov (University of California Irvine), Thomas Przepioroka (Imperial College London), Qiang Liu (Dartmouth College), Julie McCann (Imperial College London), Amelia Regan (University of California Irvine)

Accessing online social media content on underground metro systems is a challenge due to the fact that passengers often lose connectivity for large parts of their commute. As the oldest metro system in the world, the London underground represents a typical transportation network with intermittent Internet connectivity. To deal with disruption in connectivity along the sub-surface and deep-level underground lines on the London underground, we have designed a context-aware mobile system called DeepOpp that enables efficient offline access to online social media by prefetching and caching content opportunistically when signal availability is detected. DeepOpp can measure, crowdsourc and predict signal characteristics such as strength, bandwidth and latency; it can use these predictions of mobile network signal to activate prefetching, and then employ an optimization routine to determine which social content should be cached in the system given real-time network conditions and device capacities. DeepOpp has been implemented as an Android application and tested on the London Underground; it shows significant improvement over existing approaches, e.g. reducing the amount of power needed to prefetch social media items by 2.5 times. While we use the London Underground to test our system, it is equally applicable in New York, Paris, Madrid, Shanghai, or any other urban underground metro system, or indeed in any situation in which users experience long breaks in connectivity.

**PhaseBeat: Exploiting CSI Phase Data for Vital Sign Monitoring with Commodity WiFi Devices**
Xuyu Wang (Auburn University), Chao Yang (Auburn University), Shiwenn Mao (Auburn University)

Vital signs, such as respiration and heartbeat, are useful to health monitoring since such signals provide important clues of medical conditions. Effective solutions are needed to provide contact-free, easy deployment, low-cost, and long-term vital sign monitoring. In this paper, we present PhaseBeat to exploit channel state information (CSI) phase difference data to monitor breathing and heartbeat with commodity WiFi devices. We provide a rigorous analysis of the CSI phase difference data with respect to its stability and periodicity. Based on the analysis, we design and implement the PhaseBeat system with off-the-shelf WiFi devices, and conduct an extensive experimental study to validate its performance. Our experimental results demonstrate the superior performance of PhaseBeat over existing approaches in various indoor environments.

**REX: Rapid Ensemble Classification System for Landslide Detection using Social Media**
Aibek Musaev (University of Alabama), De Wang (Georgia Institute of Technology), Jiateng Xie (Georgia Institute of Technology), Calton Pu (Georgia Institute of Technology)

We study the problem of using Social Media to detect natural disasters, of which we are interested in a special kind, namely landslides. Employing information from Social Media presents unique research challenges, as there exists a considerable amount of noise due to multiple meanings of the search keywords, such as ”landslide” and ”mudslide”. To tackle these challenges, we propose REX, a rapid ensemble classification system which can filter out noisy information by implementing two key ideas: (I) a new method for constructing independent classifiers that can be used for rapid ensemble classification of Social Media texts, where each classifier is built using randomized Explicit Semantic Analysis; and (II) a self-correction approach which takes advantage of the observation that the majority label assigned to Social Media texts belonging to a large event is highly accurate. We perform experiments using real data from Twitter over 1.5 years to show that REX classification achieves 0.98 in F-measure, which outperforms the standard Bag-of-Words algorithm by an average of 0.14 and the state-of-the-art Word2Vec algorithm by 0.04. We also release the annotated datasets used in the experiments as a contribution to the research community containing 2B2k labeled items.

**Toward An Integrated Approach to Localizing Failures in Community Water Networks**
Qing Han (UC Irvine), Phu Nguyen (UC Irvine), Ronald T. Eguchi (ImageCat), Kuo-Lin Hsu (UC Irvine), Nalini Venkatasubramaniam (UC Irvine)

We present a cyber-physical-human distributed computing framework, AquaSCALE, for gathering, analyzing and localizing anomalous operations of increasingly failure-prone community water services. Today, detection of pipe breaks/leaks in water networks takes hours to days. AquaSCALE leverages dynamic data from multiple information sources including IoT (Internet of Things) sensing data, geophysical data, human input, and simulation/modeling engines to create a sensor-simulation-data integration platform that can accurately and quickly identify vulnerable spots. We propose a two-phase workflow that begins with robust simulation methods using a commercial grade hydraulic simulator - EPANET, enhanced with the support for IoT sensor and pipe failure modelings. It generates a profile of anomalous events using diverse plug-and-play machine learning techniques. The profile then incorporates with external observations (NOAA weather reports and twitter feeds) to rapidly and reliably isolate broken water pipes. We evaluate the two-phase mechanism in canonical and real-world water networks under different failure scenarios. Our results indicate that the proposed approach with offline learning and online inference can locate multiple simultaneous pipe failures at fine level of granularity (individual pipeline level) with high level of accuracy with detection time reduced by orders of magnitude (from hours/days to minutes).

**Application 4: Mobile, Wireless, and Edge Computing**

**MobiQoR: Pushing the Envelope of Mobile Edge Computing via Quality-of-Result Optimization**
Yongbo Li (George Washington University), Yurong Chen (George Washington University), Tian Lan (George Washington University), Guru Venkataramani (George Washington University)

Mobile edge computing aims at improving application response time and energy efficiency by deploying data processing at the edge of the network. Due to the proliferation of Internet of Things and interactive applications, the ever-increasing demand for low latency calls for novel approaches to further pushing the envelope of mobile edge computing beyond existing task offloading and distributed processing mechanisms. In this paper, we identify a new tradeoff between Quality-of-Result (QoR) and service response time in mobile edge computing. Our key idea is motivated by the observation that a growing set of edge applications involving media processing, machine learning, and data mining can tolerate some level of quality loss in the computed result. By relaxing the need for highest QoR, significant improvement in service response time can be achieved. Toward this end, we present a novel optimization framework, MobiQoR, which minimizes service response time and app energy consumption by jointly optimizing the QoR of all edge nodes and the offloading strategy. The proposed MobiQoR is prototyped using...
Trueful Auctions for User Data Allowance Trading in Mobile Networks
Zhongxing Ming (Tsinghua University), Mingwei Xu (Tsinghua University), Ning Wang (Surrey University), Beije Gao (Tsinghua University), Qi Li (Tsinghua University)

User data allowance trading emerges as a promising practice in mobile data networks since it can help mobile networks to attract more users. However, to date, there is no study on user data allowance trading in mobile networks. In this paper, we develop a truthful framework that allows users to bid for data allowance. We focus on preventing price cheating, guaranteeing fairness, and minimizing trading maintenance cost in trading. We formulate the data trading process as a double auction problem and develop algorithms to solve the problem. In particular, we use a uniform price auction based on a competitive equilibrium to defend against price cheating and provide fairness. Meanwhile, we leverage linear programming to minimize trading maintenance cost. We conduct extensive simulations to demonstrate the performance of the proposed mechanism. The simulation results show that our trading mechanism is truthful and fair, while incurring a minimized maintenance cost.

Online Resource Allocation for Arbitrary User Mobility in Distributed Edge Clouds
Lin Wang (TU Darmstadt), Lei Jiao (University of Oregon), Jun Li (University of Oregon), Max Mühlhäuser (TU Darmstadt)

As clouds move to the network edge to facilitate mobile applications, edge cloud providers are facing new challenges on resource allocation. As users may move and resource prices may vary arbitrarily, and service delays are heterogeneous, resources in edge clouds must be allocated and adapted continuously in order to accommodate such dynamics. In this paper, we first formulate this problem with a comprehensive model that captures the key challenges, then introduce a gap-preserving transformation of the problem, and propose a novel online algorithm that optimally solves a series of subproblems with a carefully designed logarithmic objective, finally producing feasible solutions for edge cloud resource allocation over time. We further prove via rigorous analysis that our online algorithm can provide a parameterized competitive ratio, without requiring any a priori knowledge on either the resource price or the user mobility. Through extensive experiments with both real-world and synthetic data, we further confirm the effectiveness of the proposed algorithm. We show that the proposed algorithm achieves near-optimal results with an empirical competitive ratio of about 1.1, reduces the total cost by up to 4× compared to static approaches, and outperforms the online greedy one-shot optimizations by up to 70%.

Leveraging Target k-Coverage in Wireless Rechargeable Sensor Networks
Pengzhan Zhou (Stony Brook University), Cong Wang (Stony Brook University), Yuanyuan Yang (Stony Brook University)

Energy remains a major hurdle in running computation-intensive tasks on wireless sensors. Recent efforts have been made to employ a Mobile Charger (MC) to deliver wireless power to sensors, which provides a promising solution to the energy problem. Most of previous works in this area aim at maintaining perpetual network operation at the expense of high operating cost of MC. In the meanwhile, it is observed that due to low cost of wireless sensors, they are usually deployed at high density so there is abundant redundancy in their coverage in the network. For such networks, it is possible to take advantage of the redundancy to reduce the energy cost. In this paper, we relax the strictness of perpetual operation by allowing some sensors to temporarily run out of energy while still maintaining target k-coverage in the network at lower cost of MC. We first establish a theoretical model to analyze the performance improvements under this new strategy. Then we organize sensors into load-balanced clusters for target monitoring by a distributed algorithm. Next, we propose a charging algorithm named λ-GTSP Charging Algorithm to determine the optimal number of sensors to be charged in each cluster to maintain k-coverage in the network and derive the route for MC to charge them. We further generalize the algorithm to encompass mobile targets as well. Our extensive simulation results demonstrate significant improvements of network scalability and cost saving that MC can extend charging capability over 2-3 times with a reduction of 40% of moving cost without sacrificing the network performance.

Reducing Cellular Signaling Traffic for Heartbeat Messages via Energy-Efficient D2D Forwarding
Yanqi Jin (Huazhong University of Science & Technology), Fangming Liu (Huazhong University of Science and Technology), Xiaomeng Yi (Huazhong University of Science & Technology), Minghua Chen (The Chinese University of Hong Kong)

Mobile Instant Messaging (IM) apps, such as WhatsApp and WeChat, frequently send heartbeat messages to remote servers to maintain always-online status. Periodic heartbeat messages are small in size, but their transmissions incur heavy signaling traffic to frequently establish and release communication channels between base stations and smartphones, known as signaling storm. Meanwhile, smartphones also need to activate cellular data communication module frequently for transmitting short heartbeat messages, resulting in substantial energy consumption. To address these issues, we propose a Device-to-Device (D2D) based heartbeat relaying framework, in order to reduce signaling traffic and energy consumption in heartbeat transmission. The framework selects the smartphones as relays to opportunistically collect heartbeat messages from nearby smartphones using energy-efficient D2D communication. The collected heartbeat messages are transmitted to the BS in an aggregated manner to reduce cellular signaling traffic. Based on the periods and the expiration time of the collected heartbeat messages, the framework schedules the transmissions of collected heartbeat messages to minimize signaling and energy consumption while satisfying time constraints. We implement and evaluate our solution on Android smartphones. The results from real-world experiments show that our solution achieves more than 50% signaling traffic reduction and up to 36% energy saving.

k-Protected Routing Protocol in Multi-hop Cognitive Radio Networks
Chin-Jung Liu (Michigan State University), Li Xiao (Michigan State University)

In cognitive radio networks (CRNs), the established communication sessions between secondary users (SUs) may be affected or even get interrupted because the SUs need to relinquish the channel when the licensed users (PUs) appear and reclaim the spectrum/channel. On detecting PU activities, the SUs on the affected links either switch to another available idle spectrum using the same link or the SUs seek for an alternative path/link. In either approach, the ongoing session is destined to experience delay or even gets interrupted, which is intolerable to quality of service-sensitive applications such as multimedia streaming or audio/video conferencing. In this paper, we study the problem of establishing k-protected routes in CRNs. A k-protected route consists of a set of main links with preassigned backup spectrum and backup paths and is guaranteed to sustain from k PU appearances without being interrupted. For a CRN, we find a k-protected route for each session request and maximize the number of sessions that can be supported. We propose both centralized and distributed k-protected routing algorithms for this
problem. Simulation results show that our k-protected routing protocol outperforms existing opportunistic spectrum switching approaches in terms of delay and interruption rate.

**Application 5: Cloud Computing and Data Center Systems**

**Multi-Resource Load Balancing for Virtual Network Functions**

Tao Wang (Huazhong University of Science & Technology), Hong Xu (City University of Hong Kong), Fangming Liu (Huazhong University of Science and Technology)

Middleboxes are widely deployed to perform various network functions to ensure security and improve performance. The recent trend of Network Function Virtualization (NFV) makes it easy for operators to deploy software implementations of these network functions on commodity servers. However, virtual network functions consume different amounts of resources when processing packets. Thus a multi-resource load balancing (MRLB) mechanism is needed to efficiently utilize server resources. MRLB problem in the context of NFV is fundamentally different from multi-resource allocation problems, as well as traditional single-resource load balancing and multi-resource load balancing problems in task scheduling. In this paper, we tackle the MRLB problem in NFV by first proposing dominant load—the load of the most stressed resource on a server—as the load balancing metric. We then formulate the MRLB problem as an optimization to minimize the maximum dominant load of all NFV servers given the demand. Based on proximal Jacobian ADMM, we propose an efficient algorithm to solve the problem in large scale settings. Through extensive trace-driven simulations and prototype experiments on a testbed, we show that our MRLB algorithm with dominant load performs significantly better and faster than benchmarking algorithms.

**Learning from failure across multiple clusters: A trace-driven approach to understanding, predicting, and mitigating job terminations**

Nosayba El-Sayed (MIT), Hongyu Zhu (University of Toronto), Bianca Schroeder (University of Toronto)

In large-scale computing platforms, jobs are prone to interruptions and premature terminations, limiting their usability and leading to significant waste in cluster resources. In this paper, we tackle this problem in three steps. First, we provide a comprehensive study based on log data from multiple large-scale production systems to identify patterns in the behaviour of unsuccessful jobs across different clusters and investigate possible root causes behind job termination. Our results reveal several interesting properties that distinguish unsuccessful jobs from others, particularly w.r.t. resource consumption patterns and job configuration settings. Secondly, we design a machine learning-based framework for predicting job and task terminations. We show that job failures can be predicted relatively early with high precision and recall, and also identify attributes that have strong predictive power of job failure. Finally, we demonstrate in a concrete use case how our prediction framework can be used to mitigate the effect of unsuccessful execution using an effective task-cloning policy that we propose.

**RBAY: A Scalable and Extensible Information Plane for Federating Distributed Datacenter Resources**

Xin Chen (Georgia Institute of Technology), Liting Hu (Florida International University), Douglas M. Blough (Georgia Institute of Technology), Michael A. Kozuch (Intel Labs Pittsburgh), Matthew Wolf (Oak Ridge National Laboratory)

While many institutions, whether industrial, academic, or governmental, satisfy their computing needs through public cloud providers, many others still manage their own resources, often as geographically distributed datacenters. Spare capacity from these geographically distributed datacenters could be offered to others, provided there were a mechanism to discover, and then request these resources. Unfortunately, single datacenter administrators tend not to cooperate due to issues of scalability, diverse administrative policies, and site-specific monitoring infrastructure. This paper describes RBAY, an integrated information plane that enables secure and scalable sharing between geographically distributed datacenters. RBAY's key design features are twofold. First, RBAY employs a decentralized 'hierarchical aggregation tree' structure to seamlessly aggregate spare resources from geographically distributed datacenters to a global information plane. Second, RBAY attaches to each participating server a 'admin-customized' handler, which follows site-specific policy to expose, hide, add, remove resources to RBAY, and thus fulfill the task of 'which resource to expose to whom, when, and how'. An experimental evaluation on eight real-world geo-distributed sites demonstrates RBAY's rapid response to composite queries, as well as its extensible, scalable, and lightweight nature.

**Task-aware TCP in Data Center Networks**

Sen Liu (Central South University), Jiawei Huang (Central South University), Yutao Zhou (Central South University), Jianxin Wang (Central South University), Tian He (University of Minnesota)

In modern data centers, many flow-based and task-based schemes have been proposed to speed up the data transmission in order to provide fast, reliable services for millions of users. However, existing flow-based schemes treat all flows in isolation, contributing less to or even hurting user experience due to the stalled flows. Other prevalent task-based approaches, such as centralized and decentralized scheduling, are sophisticated or unable to share task information. In this work, we first reveal that relinquishing bandwidth of leading flows to the stalled ones effectively reduces the task completion time. We further present the design and implementation of a general supporting scheme that shares the flow-tardiness information through a receiver-driven coordination. Our scheme can be flexibly and widely integrated with the state-of-the-art TCP protocols designed for data centers, while making no modification on switches. Through the testbed experiments and simulations of typical data center applications, we show that our scheme reduces the task completion time by 70% and 50% compared with the flow-based protocols (e.g. DCTCP, L2DCT) and task-based scheduling (e.g. Baraat), respectively. Moreover, our scheme also outperforms other approaches by 18% to 25% in prevalent topologies of data center.

**Limitations of Load Balancing Mechanisms for N-Tier Systems in the Presence of Millibottlenecks**

Tao Zhu (Georgia Institute of Technology), Jack Li (Georgia Institute of Technology), Josh Kimball (Georgia Institute of Technology), Junhee Park (Indiana University), Chien-An Lai (Georgia Institute of Technology), Calton Pu (Georgia Institute of Technology), Qingyang Wang (Louisiana State University)

The scalability of n-tier systems relies on effective load balancing to distribute load among the servers of the same tier. We found that load balancing mechanisms (and some policies) in servers used in typical n-tier systems (e.g., Apache and Tomcat) have issues of instability when very long response time (VLRT) requests appear due to millibottlenecks, very short bottlenecks that last only tens to hundreds of milliseconds. Experiments with standard n-tier benchmarks show that during millibottlenecks, some load balancing policy/mechanism combinations make the mistake of sending new requests to the node(s) suffering from millibottlenecks, instead of the idle nodes as load balancers are supposed to do. Several of these mistakes are due to the implicit assumptions made by load balancing policies and
mechanisms on the stability of system state. Our study shows that appropriate remedies at policy and mechanism levels can avoid these mistakes during millibottlenecks and remove the VLRT requests, thus improving the average response time by a factor of 12.


Xuolin Li (Shandong University), Li Pan (Shandong University), Jiwei Huang (Beijing University of Posts and Telecommunications), Shijun Liu (Shandong University), Yuliang Shi (Shandong University), Calton Pu (Georgia Institute of Technology)

Performance analysis is crucial to the successful development of cloud computing paradigm. And it is especially important for a cloud computing center serving parallelizable application jobs, for determining a proper degree of parallelism could reduce the mean service response time and thus improve the performance of cloud computing obviously. In this paper, taking the cloud based rendering service platform as an example application, we propose an approximate analytical model for cloud computing centers serving parallelizable jobs using M/M/c/r queuing systems, by modeling the rendering service platform as a multi-station multi-server system. We solve the proposed analytical model to obtain a complete probability distribution of response time, blocking probability and other important performance metrics for given cloud system settings. Thus this model can guide cloud operators to determine a proper setting, such as the number of servers, the buffer size and the degree of parallelism, for achieving specific performance levels. Through extensive simulations based on both synthetic data and real-world workload traces, we show that our proposed analytical model can provide approximate performance prediction results for cloud computing centers serving parallelizable jobs, even those job arrivals follow different distributions.

Application 6: Big Data Systems and Distributed Data Management and Analytics

Evaluation of Deep Learning Frameworks over Different HPC Architectures

Shayan Shams (Louisiana State University), Richard Platania (Louisiana State University), Kisung Lee (Louisiana State University), Seung-Jong Park (Louisiana State University)

Recent advances in deep learning have enabled researchers across many disciplines to uncover new insights about large datasets. Deep neural networks have shown applicability to image, time-series, textual, and other data, all of which are available in a plethora of research fields. However, their computational complexity and large memory overhead requires advanced software and hardware technologies to train neural networks in a reasonable amount of time. To make this possible, there has been an influx in development of deep learning software that aim to leverage advanced hardware resources. In order to better understand the performance implications of deep learning frameworks over these different resources, we analyze the performance of three different frameworks, Caffe, TensorFlow, and Apache SINGA, over several hardware environments. This includes scaling up and out with single- and multi-node setups using different CPU and GPU technologies. Notably, we investigate the performance characteristics of NVIDIA’s state-of-the-art hardware technology, NVLink, and also Intel’s Knights Landing, the most advanced Intel product for deep learning, with respect to training time and utilization. To our best knowledge, this is the first work concerning deep learning benchmarking with NVLink and Knights Landing. Through these experiments, we provide analysis of the frameworks’ performance over different hardware environments in terms of speed and scaling. As a result of this work, better insight is given towards both using and developing deep learning tools that cater to current and upcoming hardware technologies.

On Achieving Efficient Data Transfer for Graph Processing in Geo-Distributed Datacenters

Amelie Chi Zhou (Inria Rennes), Shadi Ibrahim (Inria Rennes), Bingsheng He (National University of Singapore)

Graph partitioning is important for optimizing the performance and communication cost of large graph processing jobs. Recently, many graph applications such as social networks store their data on geo-distributed datacenters (DCs) to provide services worldwide with low latency. This raises new challenges to existing graph partitioning methods, due to the costly Wide Area Network (WAN) usage and the multi-levels of network heterogeneities in geo-distributed DCs. In this paper, we propose a geo-aware graph partitioning method named G-Cut, which aims at minimizing the inter-DC data transfer time of graph processing jobs in geo-distributed DCs while satisfying the WAN usage budget. G-Cut adopts two novel optimization phases which address the two challenges in WAN usage and network heterogeneities separately. G-Cut can be also applied to partition dynamic graphs thanks to its light-weight runtime overhead. We evaluate the effectiveness and efficiency of G-Cut using realworld graphs with both real geo-distributed DCs and simulations. Evaluation results show that G-Cut can reduce the inter-DC data transfer time by up to 58% and reduce the WAN usage by up to 70% compared to state-of-the-art graph partitioning methods with a low runtime overhead.

GBooster: Towards Acceleration of GPU-intensive Mobile Applications

Elliott Wen (Victoria University of Wellington), Bryan Ng (Victoria University of Wellington), Winston Seah (Victoria University of Wellington), Xue Liu (McGill University), Jiannong Cao (The Hong Kong Polytechnic University), Xuefeng Liu (Huangzhong University of Science and Technology)

The performance of GPUs on mobile devices is generally the bottleneck of multimedia mobile applications (e.g., 3D games and virtual reality). Previous attempts to tackle the issue mainly migrate GPU computation to servers residing in remote cloud centers. However, the costly network delay is especially undesirable for highlyinteractive multimedia applications since a fast response time is critical for user experience. In this paper, we propose GBooster, a system that accelerates multimedia mobile applications by transparently offloading GPU tasks onto neighboring multimedia devices such as Smart TVs and Gaming Consoles. Specifically, GBooster intercepts and redirects system graphics calls by utilizing the Dynamic Linker Hooking technique, which requires no modification of the applications and the mobile systems. In addition, a major concern for offloading is the high energy consumption incurred by network transmissions. To address this concern, GBooster is designed to intelligently switch between the low-power Bluetooth and the high-throughput WiFi based on the traffic demand. We implement GBooster on the Android system and evaluate its performance. The results demonstrate that it can boost applications’ frame rates by up to 85%. In terms of power consumption, GBooster can preserve up to 70% energy compared with local execution.

Scaling k-Nearest Neighbors Queries (The right way)

Atoshum Samuel Cahaai (University Of Glasgow), Nikos Ntarmos (University Of Glasgow), Christos Anagnostopoulos (University Of Glasgow), Peter Triantafillou (University Of Glasgow)

Recently parallel / distributed processing approaches have been proposed for processing k-Nearest Neighbors (kNN) queries over very large (multidimensional) datasets aiming to ensure scalability. However, this is typically achieved at the expense of efficiency. With this paper we offer a novel approach that alleviates the performance problems associated with state of the art methods. The essence of our approach, which differentiates it from related research, rests on (i) adopting a coordinator-based distributed processing algorithm, instead of those employed over data-parallel execution engines (such as Hadoop/MapReduce or Spark), and (ii) on a way to organize data, to structure computation, and to index the stored datasets that ensures that only a very small number of data items are retrieved from
the underlying data store, communicated over the network, and processed by the coordinator for every KNN query. Our approach also pays special attention to ensuring scalability in addition to low query processing times. Overall, KNN queries can be processed in just tens of milliseconds (as opposed to the (tens of) seconds required by state of the art). We have implemented our approach, using a NoSQL DB (HBase) as the data store, and we compare it against the state-of-the-art: the Hadoop-based Spatial Hadoop (Shadoop) and the Spark-based Simba methods. We employ different datasets of various sizes, showcasing the contributed performance advantages. Our approach outperforms the state of the art, by 2-3 orders of magnitude, and consistently for dataset sizes ranging from hundreds of millions to hundreds of billions of data points. We also show that the key constituent performance overheads incurred during query processing (such as the number of data items retrieved from the data store, the required network bandwidth, and the processing time at the coordinator) scale very well, ensuring the overall scalability of the approach.

**Parallelizing Big De Bruijn Graph Construction on Heterogeneous Processors**
Shuang Qiu (The Hong Kong University of Science and Technology), Qiong Luo (The Hong Kong University of Science and Technology)

De Bruijn graph construction is the first step in de novo assemblers to connect input reads into a complete sequence without a reference genome. This step is both time and memory space consuming. To address this problem, we develop ParaHash, a system that partitions the input data in a compact format, parallelizes the computation on both the CPUs and the GPUs in a single computer, and performs hash-based De Bruijn graph construction. This way, ParaHash utilizes all available processors to assemble big genomes that cannot fit into memory. Furthermore, we analyze the characteristics of genome data to set the hash table size, design concurrent hashing algorithms to handle the inherent multiplicity, and pipeline the data transfer and the computation for further efficiency. Our experiments on real-world genome datasets show that the workload was balanced across heterogeneous processors, and that ParaHash was able to construct billion-node graphs on a single machine with an overall performance up to 20 times faster than the state-of-the-art shared-memory assemblers.

**Private, yet Practical, Multiparty Deep Learning**
Xinyang Zhang (Lehigh University), Shouling Ji (Zhejiang University), Hui Wang (Stevens Institute of Technology), Ting Wang (Lehigh University)

In this paper, we consider the problem of multiparty deep learning (MDL), wherein autonomous data owners jointly train accurate deep neural network models without sharing their private data. We design, implement, and evaluate $\text{	extcopyright}propto$MDL, a new MDL paradigm built upon three primitives: asynchronous optimization, lightweight homomorphic encryption, and threshold secret sharing. Compared with prior work, $\text{	extcopyright}propto$MDL departs in significant ways: a) besides providing explicit privacy guarantee, it retains desirable model utility, which is paramount for accuracy-critical domains; b) it provides an intuitive handle for the operator to gracefully balance model utility and training efficiency; c) moreover, it supports delicate control over communication and computational costs by offering two variants, operating under loose and tight coordination respectively, thus customizable for given system settings (e.g., limited versus sufficient network bandwidth). Through extensive empirical evaluation using benchmark datasets and deep learning architectures, we demonstrate the efficacy of $\text{	extcopyright}propto$MDL.

**Application 7: Distributed Middleware Systems**

**Fast and Flexible Networking for Message-oriented Middleware**
Lars Kroll (KTH Royal Institute of Technology), Alexandru A. Ormenisan (KTH Royal Institute of Technology), Jim Dowling (KTH Royal Institute of Technology)

Distributed applications deployed in multi-datacenter environments need to deal with network connections of varying quality, including high bandwidth and low latency within a datacenter and, more recently, high bandwidth and high latency between datacentres. In principle, for a given network connection, each message should be sent over the best available network protocol, but existing middlewares do not provide this functionality. In this paper, we present KompicsMessaging, a messaging middleware that allows for fine-grained control of the network protocol used on a per-message basis. Rather than always requiring application developers to specify the appropriate protocol for each message, we also provide an online reinforcement learner that optimises the selection of the network protocol for the current network environment. In experiments, we show how connection properties, such as the varying round-trip time, influence the performance of the application and we show how throughput and latency can be improved by picking the right protocol at the right time.

**TailCut: Power Reduction under Quality and Latency Constraints in Distributed Search Systems**
Chih-Hsün Chou (University of California, Riverside), Laxmi Bhuyan (University of California, Riverside), Shaolei Ren (University of California, Riverside)

Web search constitutes an important class of data intensive online services in data centers. Optimizing search systems for energy efficiency, timely response and high search quality (i.e., how relevant the returned results are to a search query), however, is very challenging, as a search system involves a distributed architecture with hundreds of thousands of index serving nodes (ISNs) that return searching results to an aggregator through multiple independent retrieval stages in a partition-aggregate fashion. In this paper, we discover through experiments two important characteristics that can affect the system performance: (1) response time and energy consumption are greatly impacted by a small fraction of queries with long processing times; (2) the quality contribution of the ISN is independent of the query processing time. Based on our observation, we propose TailCut, which judiciously discards long query executions and enables ISN-aggregator coordination to minimize energy consumption subject to latency and quality constraints. Our experimental results show that TailCut can achieve up to 39% power saving, while satisfying the tail latency and quality constraint.

**StoArranger: Enabling Efficient Usage of Cloud Storage Services on Mobile Devices**
Yongshu Bai (SUNY Binghamton), Yifan Zhang (SUNY Binghamton)

Cloud storage usages are becoming increasingly popular on mobile devices. Through an extensive motivation study, we find that cloud storage accesses from mobile apps suffer from several notable problems that undermine usage experiences. The root cause is that the way of cloud storage providers deploying their services onto mobile devices relies on app developers for the correct and appropriate implementations and lacks the ability of monitoring and servicing client-side cloud storage accesses. We propose StoArranger, a practical system framework that solves the problems by coordinating, rearranging, and transforming cloud storage communications on mobile devices. We have prototyped the proposed system using two different implementation approaches. We discuss our experiences of the implementations in the paper. The real-app evaluation experiments show that StoArranger can significantly improve mobile cloud storage access efficiency with little overheads.

**Characterizing Performance and Energy-efficiency of The RAMCloud Storage System**
Most large popular web applications, like Facebook and Twitter, have been relying on large amounts of in-memory storage to cache data and offer a low response time. As the main memory capacity of clusters and clouds increases, it becomes possible to keep most of the data in the main memory. This motivates the introduction of in-memory storage systems. While prior work has focused on how to exploit the low-latency of in-memory access at scale, there is very little visibility into the energy-efficiency of in-memory storage systems. Even though it is known that main memory is a fundamental energy bottleneck in computing systems (i.e., DRAM consumes up to 40% of a server’s power). In this paper, by the means of experimental evaluation, we have studied the performance and energy-efficiency of RAMCloud—a well-known in-memory storage system. We reveal that although RAMCloud is scalable for read-only applications, it exhibits non-proportional power consumption. We also find that the current replication scheme implemented in RAMCloud limits the performance and results in high energy consumption. Surprisingly, we show that replication can also play a negative role in crash-recovery.

**Proactively Secure Cloud-Enabled Storage**
Karim Eldefrawy (Hughes Research Lab), Tyler Kaczmarek (University of California, Irvine), Sky Faber (University of California, Irvine)

Attacking cloud-enabled storage is becoming increasingly lucrative as more personal and enterprise data moves to the cloud. Traditional security mechanisms temporarily limit such attacks, but over a long period of time attackers will eventually find vulnerabilities; this can lead to compromising large amounts of valuable data and lead to large-scale privacy breaches. This paper addresses this problem by incorporating proactive security guarantees into cloud-enabled storage. Proactive security deals with an adversary’s ability to eventually compromise all involved servers in a distributed storage or computation system. While there are several proactively secure secret sharing protocols that can be used to improve confidentiality of data stored in the cloud, their high overhead has traditionally limited them to less than ten parties and to only 100s of bytes typical for cryptographic keys. Realizing proactively secure cloud storage for larger data (e.g., MBs) requires careful design and calibration of system parameters, and faces several challenges. In this paper we design, implement and assess performance of the first system for Proactively Secure Cloud-Enabled Storage (PISCES) of data larger than cryptographic keys. Based on our practical performance results we advocate that the high level of resilience and long-term security and confidentiality guarantees enabled by proactive security should be considered in future distributed and cloud-based storage and computing services.

**BEES: Bandwidth- and Energy- Efficient Image Sharing for Real-time Situation Awareness**
Pengfei Zuo (Huazhong University of Science and Technology), Yu Hua (Huazhong University of Science and Technology), Xue Liu (McGill University), Dan Feng (Huazhong University of Science and Technology), Wen Xia (Huazhong University of Science and Technology), Shundao Cao (Huazhong University of Science and Technology), Jie Wu (Huazhong University of Science and Technology), Yuanyuan Sun (Huazhong University of Science and Technology), Yuncheng Guo (Huazhong University of Science and Technology)

In order to save human lives and reduce injury and property loss, Situation Awareness (SA) information is essential and important for rescue workers to perform the effective and timely disaster relief. The information is generally derived from the shared images via widely used smartphones. However, conventional smartphone-based image sharing schemes fail to efficiently meet the needs of SA applications due to two main reasons, i.e., real-time transmission requirement and application-level image redundancy, which is exacerbated by limited bandwidth and energy availability. In order to provide efficient image sharing in disasters, we propose a bandwidth- and energy- efficient image sharing system, called BEES. The salient feature behind BEES is to propose the concept of Approximate Image Sharing (AIS), which explores and exploits approximate feature extraction, redundancy detection, and image uploading to trade the slightly low quality of computation results in content-based redundancy elimination for higher bandwidth and energy efficiency. Nevertheless, the boundaries of the tradeoffs between the quality of computation results and efficiency are generally subjective and qualitative. We hence propose the energy-aware adaptive schemes in AIS to leverage the physical energy availability to effectively and quantitatively determine the tradeoffs between the quality of computation results and efficiency. Moreover, unlike existing work only for cross-batch similar images, BEES further eliminates in-batch ones via a similarity-aware submodular maximization model. We have implemented the BEES prototype which is evaluated via three real-world image datasets. Extensive experimental results demonstrate the efficacy and efficiency of BEES.

**Application 8: Distributed Systems and Optimizations**

**Transparent Fault-Tolerance using Intra-Machine Full-Software-Stack Replication**
Giuliano Losa (Virginia Tech), Antonio Barbalace (Virginia Tech), Yuzhong Wen (Virginia Tech), Marina Sadini (Virginia Tech), Ho-Ren Chuang (Virginia Tech), Binoy Ravindran (Virginia Tech)

As the number of processors and the size of the memory of computing systems keep increasing, the likelihood of CPU core failures, memory errors, and bus failures increases and can threaten system availability. Software components can be hardened against such failures by running several replicas of a component on hardware replicas that fail independently and that are coordinated by a State-Machine Replication protocol. One common solution is to replicate the physical machine to provide redundancy, and to rewrite the software to address coordination. However, a CPU core failure, a memory error, or a bus error is unlikely to always crash an entire machine. Thus, full machine replication may sometimes be an overkill, increasing resource costs. In this paper, we introduce full software stack replication within a single commodity machine. Our approach runs replicas on fault-independent hardware partitions (e.g., NUMA nodes), wherein each partition is software-isolated from the others and has its own CPU cores, memory, and full software stack. A hardware failure in one partition can be recovered by another partition taking over its functionality. We have realized this vision by implementing FT-Linux, a Linux-based operating system that transparently replicates race-free, multithreaded POSIX applications on different hardware partitions of a single machine. Our evaluations of FT-Linux on several popular Linux applications show a worst case slowdown (due to replication) by ~20%.

**A preventive auto-parallelization approach for elastic stream processing**
Roland Kotto Kombi (University Claude Bernard), Nicolas Lumineau (Université de Lyon), Philippe Lamarre (INSA Lyon)

Nowadays, more and more sources (connected devices, social networks, etc.) emit real-time data with fluctuating rates over time. Existing distributed stream processing engines (SPE) have to resolve a difficult problem: deliver results satisfying end-users in terms of quality and latency without over-consuming resources. This paper focuses on parallelization of operators to adapt their throughput to their input rate. We suggest an approach which prevents operator congestion in order to limit degradation of results quality. This approach relies on an automatic and dynamic adaptation of resource consumption for each continuous query. This solution takes advantage of i) a metric estimating the activity level of operators in the near future ii) the AUTOSCALE approach which evaluates the need to modify parallelism degrees at local and global scope iii) an integration into the Apache Storm solution. We show performance tests comparing our approach to the native solution of this SPE.
Dependable Cloud Resources with Guardian
Bara Abusalah (Purdue University), Derek Schatzlein (Purdue University), Julian James Stephen (Purdue University), Masoud Saeida Ardekani (Purdue University), Patrick Eugster (Purdue University)

Despite advances in making datacenters dependable, failures still happen. This is particularly onerous for long-running "big data" applications, where partial failures can lead to significant losses and lengthy recomputations. Big data processing frameworks like Hadoop MapReduce include fault tolerance (FT) mechanisms, but these are commonly targeted at specific system/failure models, and are often redundant between frameworks. This paper proposes the paradigm of dependable resources: big data processing frameworks are typically built on top of resource management systems (RMSs), and proposing FT support at the level of such an RMS yields generic FT mechanisms, which can be provided with low overhead by leveraging constraints on resources. We demonstrate our concepts through Guardian, a robust RMS based on YARN. Guardian allows frameworks to run their applications with individually configurable FT granularity and degree, with only minor changes to their implementation. We demonstrate the benefits of our approach by evaluating Hadoop, Tez, Spark and Pig on Guardian in Amazon-EC2, improving completion time by around 68% in the presence of failures, while maintaining around 6% overhead.

A Communication-aware Container Re-distribution Approach for High Performance VNFs
Yuchao Zhang (Tsinghua University), Yusen Li (Nankai University), Ke Xu (Tsinghua University), Dan Wang (Hong Kong Polytechnic University), Minghui Li (Baidu), Xuan Cao (Baidu), Qingqing Liang (Baidu)

Containers have been used in many applications for isolation purposes due to the lightweight, scalable and highly portable properties. However, to apply containers in virtual network functions (VNFs) faces a big challenge because high-performance VNFs often generate frequent communication workloads among containers while the container communications are generally not efficient. Compared with hardware modification solutions, properly distributing containers among hosts is an efficient and low-cost way to reduce communication overhead. However, we observe that this approach yields a trade-off between the communication overhead and the overall throughput of the cluster. In this paper, we focus on the communication-aware container redistribution problem to optimize the communication overhead and the overall throughput jointly for VNF clusters. We propose a solution called FreeContainer which utilizes a novel two-stage algorithm to re-distribute containers among hosts. We implement FreeContainer in Baidu clusters with 6000 servers and 35 services deployed. Extensive experiments on real networks are conducted to evaluate the performance of the proposed approach. The results show that FreeContainer can increase the overall throughput up to 90% with significant reduction on communication overhead.

Minimizing Cost in IaaS Clouds via Scheduled Instance Reservation
Qiushi Wang (Nanyang Technological University), Ming Ming Tan (Nanyang Technological University), Xueyan Tang (Nanyang Technological University), Wentong Cai (Nanyang Technological University)

Regular diurnal patterns are often seen in the workloads of cloud-based online applications. This kind of non-stationary workloads changes the processing demands over time. To run application services with minimum costs, the number of cloud instances can be dynamically adjusted according to the workload variations. Recently, a new type of scheduled instances has emerged in the infrastructure-as-a-Service market to facilitate such configurations. Scheduled instances can be reserved based on a recurring schedule and they offer price discounts. Meanwhile, cloud vendors require minimum scheduled durations to avoid the overhead of frequently launching and terminating cloud instances. Coupled with traditional on-demand and reserved instances, it becomes more complicated for users to find the optimal combination of these three pricing options to minimize their monetary costs. For the new scheduled instances, not only the number of instances but also their start and stop times have to be decided. In this paper, we develop a fast and effective strategy to solve this problem. Based on the hourly workload distributions, we first compute the optimal number of instances to acquire for each pricing option. Then, we design a scheduling algorithm to arrange the scheduled instances in compliance with the restriction of their scheduled durations. Using the workloads of the LOL online game and the Wikipedia Mobile service as two case studies, the efficacy of our strategy is demonstrated.

Efficient Distributed Coordination at WAN-scale
Aliidani Ailijiang (SUNY Buffalo), Aleksey Charapko (SUNY Buffalo), Murat Demirbas (SUNY Buffalo), Bekir Oguz Turkkan (SUNY Buffalo), Tevfik Kosar (SUNY Buffalo)

Traditional coordination services for distributed applications do not scale well over wide-area networks (WAN): centralized coordination fails to scale with respect to the increasing distances in the WAN, and distributed coordination fails to scale with respect to the number of nodes involved. We argue that it is possible to achieve scalability over WAN using a hierarchical coordination architecture and a smart token migration mechanism, and lay down the foundation of a novel design for a flexible-consistent coordination framework, called WanKeeper. We implemented WanKeeper based on the ZooKeeper API and deployed it over WAN as a proof of concept. Our experimental results based on the Yahoo! Cloud Serving Benchmark (YCSB), Apache BookKeeper replicated log service, and the Shared Cloud-based File System (SCFS) show that WanKeeper provides multiple folds improvement in write/update performance in WAN compared to ZooKeeper, while keeping the same read performance.

Application 9: Distributed Systems and Applications
Specifying a Distributed Snapshot Algorithm as a Meta-program and Model Checking it at Meta-level
Ha Thi Thu Doan (Japan Advanced Institute of Science and Technology), Francois Bonnet (Osaka University), Kazuhiro Ogata (Japan Advanced Institute of Science and Technology)

The paper proposes a new approach to model checking Chandy-Lamport Distributed Snapshot Algorithm (CLDSA). The essential of the approach is that CLDSA is specified as a meta-program in Maude such that the meta-program takes a specification of an underlying distributed system (UDS) and generates the specification of the UDS on which CLDSA is superimposed (UDS-CLDSA). To model check that a UDS-CLDSA enjoys a desired property, it suffices that human users specify the UDS for the proposed approach, while human users need to specify the UDS-CLDSA for the existing approach for each UDS. Since the proposed approach conducts model checking at meta-level, it produces a counterexample if a UDS-CLDSA does not enjoy the property, while the existing approach does not. Our method specifying CLDSA as a meta-program can be applied to formal specification of the class of distributed algorithms that are superimposed on UDSs.

Self-Evolving Subscriptions for Content-Based Publish/Subscribe Systems
Traditional pub/sub systems cannot adequately handle workloads of applications with dynamic, short-lived subscriptions such as location-based social networks, predictive stock trading, and online games. Subscribers must continuously interact with the pub/sub system to remove and insert subscriptions, thereby inefficiently consuming network and computing resources, and sacrificing consistency. In the aforementioned applications, we recognize that the changes in the subscriptions can follow a predictable pattern over some variable (e.g., time). In this paper, we present a new type of subscription, called evolving subscription, which encapsulates these patterns and allow the pub/sub system to autonomously adapt to the dynamic interests of the subscribers without incurring an expensive re-subscription overhead. We propose a general model for expressing evolving subscriptions and a framework for supporting them in a pub/sub system. To this end, we propose three different designs to support evolving subscriptions, which are evaluated and compared to the traditional resubscription approach in the context of two use cases: online games and high-frequency trading. Our evaluation shows that our solutions can reduce subscription traffic by 96.8% and improve delivery accuracy when compared to the baseline resubscription mechanism.

**Scalable Routing for Topic-based Publish/Subscribe Systems under Fluctuations**
Volker Turau (Hamburg University of Technology), Gerry Siegemund (Hamburg University of Technology)

The loose coupling and the inherent scalability make publish/subscribe systems an ideal candidate for event-driven services for wireless networks using low power protocols such as IEEE 802.15.4. This work introduces a distributed algorithm to build and maintain a routing structure for such networks. The algorithm dynamically maintains a multicast tree for each node. While previous work focused on minimizing these trees, our approach aims to keep the effort to maintain them in case of fluctuations of subscribers low. The multicast trees are implicitly defined by a novel structure called augmented virtual ring. The main contribution is a distributed algorithm to build and maintain this augmented virtual ring. Maintenance operations after subscription and unsubscriptions require message exchange in a limited region only. We compare the average lengths of the constructed forwarding paths with an almost ideal approach. As a result of independent interest we present a distributed algorithm using messages of size O(log n) for constructing virtual rings of graphs that are on average shorter than rings based on depth-first search.

**OPPay: Design and Implementation of A Payment System for Opportunistic Data Services**
Fengrui Shi (Imperial College London), Zhijin Qin (Imperial College London), Julie McCann (Imperial College London)

The large number of personal wireless devices in the urban areas could be used to provide various opportunistic data services, such as WiFi sharing, content-based file sharing and opportunistic networking. In order to facilitate these services, it is essential to incentivize the device owners to become service providers. However, previous research failed to deliver any practical payment systems for opportunistic data services. Inspired by smart contracts functionalities of bitcoin, this paper proposes a payment system named OPPay for opportunistic data services, which implements a micropayment communication protocol for mobile devices to perform data transactions and make payments using bitcoin. The system is designed to make incremental payments and thus resilient to interrupted communications caused by human mobility in the mobile network. By implementing and evaluating the system for three different applications, we show that the system is able to work in heterogeneous hardware and software environments and can achieve fast transactions confirmation with small fee overhead and low faulty payment value.

**Optimal Resource Allocation for Multi-user Video Streaming over mmWave Networks**
Zhifeng He (Auburn University), Shiwen Mao (Auburn University)

We investigate the resource allocation problem, including time slot allocation, channel allocation, and power adaptation, in a millimeter Wave (mmWave) network with multiple transmission links, multiple channels, and a PicoNet Coordinator (PNC). Each link has a video session to transmit from the transmitter to the receiver. The objective is to minimize the number of time slots to finish the video sessions of all links by jointly optimizing channel allocation and time slot allocation for links, while considering the possible interference between different links on the same channel. The optimal solution for the formulated problem is computationally prohibitive to obtain due to the exponential complexity. We developed a column generation based method to reformulate the original problem into a main problem along with a series of sub-problems, with greatly reduced complexity. We prove that the optimal solution for the reformulated problem converges to the optimal solution of the original problem, and we derived a lower bound for the performance of the reformulated problem at each iteration, which will finally converge to the global optimal solution. The proposed scheme is validated with simulations with its superior performance over existing work is observed.

**A Multi-Agent Parallel Approach to Analyzing Large Climate Data Sets**
Jason Woodring (University of Washington Bothell), Matthew Sell (University of Washington Bothell), Munehiro Fukuda (University of Washington Bothell), Hazeline Asuncion (University of Washington Bothell), Eric Salathe (University of Washington Bothell)

Despite various cloud technologies that have parallelized and scaled up big data analysis, they target data mostly in texts with which are easy to partition and thus easy to map over a cluster system. Therefore, their parallelization do not necessarily cover scientific structured data such as NetCDF or need additional, user-provided tools to convert the original data into specific formats. To facilitate user-intuitive parallelization of such scientific data analysis, this paper presents an agent-based approach that instantiates distributed arrays over a cluster system, maintains structured scientific data in these arrays, deploys many mobile agents over the arrays to perform computational actions on data, and collects necessary results. To demonstrate the practicability of our agent-based approach, we focused on climate change research and implemented a web-interfaced climate analysis, using the MASS (multi-agent spatial simulation) library. In this paper, we show practical advantages of, performance improvements by, and challenges for our agent-based approach in structured data analysis.

**Application 10: Distributed Systems and Services**

**Energy Proportional Servers: Where Are We in 2016?**
Congfeng Jiang (Hangzhou Dianzi University), Yumei Wang (Hangzhou Dianzi University), Dongyang Ou (Hangzhou Dianzi University), Bing Luo (Wayne State University), Weisong Shi (Wayne State University)

The huge energy consumption in data centers produces not only high electricity bills but also tremendous carbon footprints. Although today’s servers and data centers of leading Internet companies are more energy efficient than ever before, the fluctuations in external workload and internal resource utilization calls for energy proportional computing. Insight into server energy proportionality can help improve workload placement while also reducing energy consumption. In this paper, we investigate all 477 valid published results of SPECTpower ssl benchmark from 2007 to 2016Q3 and reorganize them by hardware availability year for more accurate analysis on production servers. Through comprehensive analysis we find that: (1) The specious stagnation of energy proportionality in recent years is
mainly caused by the adoption of processors of specific microarchitecture and is not the indicative trend of energy proportionality improvement. (2) Microarchitecture evolution has more influence on energy efficiency improvement than energy proportionality. (3) Today's servers' peak energy efficiencies are shifting from 100% resource utilization to 80% or 70% utilization and server energy proportionality improves with such shifting. We then conduct extensive experiments on 4 rack servers to investigate the energy efficiency variations under different hardware configurations, including memory per core installation and processor frequency scaling. Our experiments show that hardware configuration has significant impact on server's energy efficiency. Our findings presented in this paper provide useful insights and guidance to system designers, as well as data center operators for energy proportionality aware workload placement and energy savings.

Are HTTP/2 Servers Ready Yet?
Muhui Jiang (The Hong Kong Polytechnic University), Xiapu Luo (The Hong Kong Polytechnic University), Tungngai Miu (Nexusguard Limited), Shengtuo Hu (The Hong Kong Polytechnic University), Weixiong Rao (Tongji University)

Superseding HTTP/1.1, the dominating web protocol, HTTP/2 promises to make web applications faster and safer by introducing many new features, such as multiplexing, header compression, request priority, server push, etc. Although a few recent studies examined the adoption of HTTP/2 and evaluated its impacts, little is known about whether the popular HTTP/2 servers have correctly realized the new features and how the deployed servers use these features. To fill in the gap, in this paper, we conduct the first systematic investigation by inspecting six popular implementations of HTTP/2 servers (i.e., Nginx, Apache, H2O, Lightspeed, nghttpd and Tengine) and measuring the top 1 million Alexa web sites. In particular, we propose new methods and develop a tool named H2Scope to assess the new features in those servers. The results of the large-scale measurement on HTTP/2 web sites reveal new observations and insights. This study sheds light on the current status and the future research of HTTP/2.

Data Integrity for Collaborative Applications over Hosted Services
Ertem Esiner (Nanyang Technological University), Anwitaman Datta (Nanyang Technological University)

In this work we focus on integrity and consistency of data accessed and manipulated by multiple collaborating users, and stored in an (untrusted) hosted service. This is a problem, aspects of which have been studied in isolation in hitherto distinct communities. Consistency is one of the cardinal problems of distributed computing. Integrity of hosted data has been studied over the last decade, and numerous techniques for proof of data possession and/or retrievability have been explored. The latter line of work however has often assumed static data, and techniques to handle dynamic or versioned data have only very recently been proposed. Yet, even the existing solutions that handle mutable content do so under the assumption that only a single data owner (using a single client) manipulate and verify said data. This is a serious limitation in terms of the variety of applications that can benefit from such mechanisms for proof of data possession. The novelty, and primary contribution of this work is in filling this gap. Specifically, we extend the existing ideas of proof of possession of dynamic data, in order to support multiple users who may collaborate in real time or asynchronously. In contrast (and in addition) to the challenge of an untrusted storage server that existing techniques for proof of data possession need to overcome, we had to, simultaneously account for data integrity violations that may be incurred due to all the usual challenges of maintaining consistency of collaborative data (even if the storage server was trusted).

Virtual Machine Power Accounting with Shapley Value
Weixiang Jiang (Huazhong University of Science & Technology), Fangming Liu (Huazhong University of Science and Technology), Guoming Tang (University of Victoria), Kui Wu (University of Victoria), Hai Jin (Huazhong University of Science & Technology)

The ever-increasing power consumption of datacenters has eaten up a large portion of their profit. One possible solution is to charge datacenter users for their actual power usage. However, it poses a great technical challenge as the power of VMs co-existing in a physical machine cannot be measured directly. It is thus critical to develop a fair method to disaggregate the power of a physical machine to individual VMs. We tackle the above challenge by modeling the power disaggregation problem as a cooperative game and propose non-deterministic Shapley value to discover the fair power share of VMs (in the sense of satisfying four desired axiomatic principles), while compensating the negative impact of VM power variation. We demonstrate that the results from existing power model-based solution can deviate from the “ground truth” by 25.22%-46.15%. And compared with the exact Shapley value, our non-deterministic Shapley value can achieve less than 5% error for 90% of the time.

A Versatile Platform for Mobile Data Gathering Experiments in Wireless Sensor Networks
Li Ji (Stony Brook University), Cong Wang (Stony Brook University), Yuanyuan Yang (Stony Brook University)

In recent years, mobile data gathering in wireless sensor networks has attracted much interest in the research community. However, despite extensive efforts, many of previous work in this area lies only in theory and evaluates network performance with computer simulations, which leaves a large gap from reality. In this paper, we present the design and implementation of a general purpose, flexible platform for mobile data gathering in wireless sensor networks to evaluate network performance and algorithms in a practical setting. Instead of relying on hand-crafted theoretical models, our platform integrates both mobile data collector and sensor nodes to provide realistic performance evaluations. In addition, the platform adopts a modular design in mobile data collector and sensor nodes, and equips the mobile data collector with advanced computing capability, which makes it versatile for evaluating the performance of a wide-range of applications. Finally, as a case study, we implement a wildlife monitoring system on our platform. Our experimental results demonstrate that real implementations can evaluate many practical performance factors which would have a great impact on the sensing results and are very difficult to fully capture by theoretical models and simulations. We expect that this platform can become a very powerful general tool for more accurate network simulations and facilitate performance optimization in wireless sensor networks.

On Directional Neighbor Discovery in mmWave Networks
Yu Wang (Auburn University), Shiwenn Mao (Auburn University), Theodore S. Rappaport (New York University)

The directional neighbor discovery problem, i.e., spatial rendezvous, is a fundamental problem in millimeter wave (mmWave) networks. The challenge is how to let the transmitter and receiver beams meet in space under deafness caused by directional transmission and reception. In this paper, we present a Hunting-based Directional Neighbor Discovery (HDND) scheme, where a node continuously rotates its directional beam to scan its neighborhood for neighbors. Through a rigorous analysis, we derive the conditions for ensured neighbor discovery, as well as a bound for the worst case discovery time. We validate the analysis with extensive simulations, and demonstrate the superior performance of the proposed scheme over two benchmark schemes.
**Vision 1: Internet of Things, Smart Cities and Cyber-Physical Systems**

**Observable-by-Design**
Masaru Kitsuregawa (National Institute of Informatics (NII)/Institute of Industrial Science, University of Tokyo)

We present the observable-by-design principle. We believe, that the new generation of services, products, and environment, management systems should be designed to adapt to changes. Therefore, they should be designed to be observable, and their design, should proactively and reactively adapt to the changes observed, both internally and externally. Two concrete examples illustrate, the application of observable-by-design principle: (1) ship, building and management, and (2) river dam water flow management. We believe that the observable-by-design principle can be, applied in a large scale. In the long term, a new generation of observable-by-design, infrastructures can be built that incorporates, the sensing and adapting capabilities in their construction.

**An Architectural Vision for a Data-Centric IoT: Rethinking Things, Trust and Clouds**
Eve M. Schooler (Intel), David Zage (Intel), Jeff Sedayao (Intel), Hassnaa Moustafa (Intel), Andrew Brown (Intel), Moreno Ambrosin (University of Padua)

The Internet of Things (IoT) is producing a tidal wave of data, much of it originating at the network edge and originating from applications with requirements unmet by the traditional back-end Cloud architecture. To address the disruption caused by the ocean of data, this paper offers a holistic data-centric architectural vision for the data-centric IoT. It advocates that we rethink our approach to the design and definition of key elements: that we shift our focus from Things to Smart Objects; grow Trust organically; and evolve back-end Clouds toward Edge and Fog clouds, which leverage data-centric networks and enable optimal handling of upstream data flows. Along the way, we wax poetic about several blue-sky topics, assess the status of these elements in the context of related work, and identify known gaps in meeting this vision.

**Edge Computing and IoT Based Research for Building Safe Smart Cities Resistant to Disasters**
Teruo Higashino (Osaka University), Hirozumi Yamaguchi (Osaka University), Akihito Hiromori (Osaka University), Akira Uchiyama (Osaka University), Keiichi Yasumoto (Nara Institute of Science and Technology)

Recently, several researches concerning with smart and connected communities have been studied. Soon the 4G / 5G technology becomes popular, and cellular base stations will be densely located in the urban space. They may offer intelligent services for autonomous driving, urban environment improvement, disaster mitigation, elderly/disabled people support and so on. Such infrastructure might function as edge servers for disaster support base. In this paper, we enumerate several research issues to be developed in the ICDCS community in the next decade in order for building safe smart cities resistant to disasters. In particular, we focus on (A) up-to-date urban crowd mobility prediction and (B) resilient disaster information gathering mechanisms based on the edge computing paradigm. We investigate recent related works and projects, and introduce our on-going research work and insight for disaster mitigation.

**The Internet of Things and Multiagent Systems: Decentralized Intelligence in Distributed Computing**
Munindar Singh (North Carolina State University), Amit Chopra (Lancaster University)

Traditionally, distributed computing concentrates on computation understood at the level of information exchange and sets aside human and organizational concerns as largely to be handled in an ad hoc manner. Increasingly, however, distributed applications involve multiple loci of autonomy. Research in multiagent systems (MAS) addresses autonomy by drawing on concepts and techniques from artificial intelligence. However, MAS research generally lacks an adequate understanding of modern distributed computing. In this Blue Sky paper, we envision decentralized multiagent systems as a way to place decentralized intelligence in distributed computing, specifically, by supporting computation at the level of social meanings. We motivate our proposals for research in the context of the Internet of Things (IoT), which has become a major thrust in distributed computing. From the IoTs representative applications, we abstract out the major challenges of relevance to decentralized intelligence. These include the heterogeneity of IoT components; asynchronous and delay-tolerant communication and decoupled enactment; and multiple stakeholders with subtle requirements for governance, incorporating resource usage, cooperation, and privacy. The IoT yields high-impact problems that require solutions that go beyond traditional ways of thinking. We conclude with highlights of some possible research directions in decentralized multiagent systems, including programming models; interaction-oriented software engineering; and what we term enlightenment governance.

**Internet of Things: From Small- to Large-Scale Orchestration**
Charles Consel (Inria / Bordeaux INP), Milan Kabac (Imperial College)

The domain of Internet of Things (IoT) is rapidly, expanding beyond research, and becoming a major industrial market with such stakeholders as major manufacturers of chips, and connected entities (i.e., things), and fast-growing operators, of wide-area networks. Importantly, emerging domain is, driven by applications that leverage an IoT infrastructure to, provide users with innovative, high-value services. IoT infrastructures, range from small scale (e.g., homes and personal, health) to large scale (e.g., cities and transportation systems). In this paper, we argue that there is a continuum between orchestrating, connected entities in the small and in the large. We propose a unified approach to application development, which, covers this spectrum. To do so, we examine the requirements for, orchestrating connected entities and address them with domain-specific, design concepts. We then show how to map these design, concepts into dedicated programming patterns and runtime, mechanisms. Our work revolves around domain-specific concepts and, notations, integrated into a tool-based design methodology and, dedicated to develop IoT applications. We have applied our, work across a spectrum of infrastructure sizes, ranging from, an automated pilot in avionics, to an assisted living platform, for the home of seniors, to a parking management system in, a smart city.

**EdgeOS_H: A Home Operating System for Internet of Everything**
Jie Cao (Wayne State University), Lanyu Xu (Wayne State University), Raef Abdallah (Wayne State University), Weisong Shi (Wayne State University)

The proliferation of Internet of Everything (IoE) and the success of rich Cloud services have pushed the horizon of a new computing paradigm, Edge Computing, which calls for processing the data at the edge of the network. Smart home as a typical IoE application is being widely adapted into peoples life. Edge Computing has the potential to empower the smart home, but it needs more contribution from the community before it truly benefits our lives. In this paper, we first present the
Institute, University of Chicago and Argonne National Laboratory, Ryan Chard (Victoria University of Wellington)

vision of EdgeOSH, a home operating system for Internet of Everything, followed by the challenges in EdgeOSH, namely programming interface, self-management, data management, security & privacy, and naming. Within each challenge we also discuss the potential directions that are worth further investigation.

Vision 2: Future Networking and Cyberinfrastructure

A Vision for Zero-Hop Networking (ZeN)
Mostafa Ammar (School of Computer Science, Georgia Tech), Ellen Zegura (School of Computer Science, Georgia Tech), Yimeng Zhao (School of Computer Science, Georgia Tech)

It has become increasingly important for content providers (CPs) to reach consumers with low latency. Peering links that connect CPs directly to access Internet service providers (access ISPs) have been used for this purpose thus provisioning one-hop AS paths from CPs to users. While providing improved latency, these peering links still do not give CPs control over the entire end-to-end path to their users. This has made it difficult for CPs to completely manage user experience. Motivated by this, we propose the deployment of Zero-Hop Networks (ZeN), where a CP's entire end-to-end path to users is under its control. We believe it is important to respond to the compelling demand for ZeN and enable its provision over the shared Internet infrastructure so that all may continue to reap its benefits. In this paper we lay out the vision for ZeN, describing its goals and challenges. We propose to deploy ZeN by allowing CPs to extend their network's control over the access ISP substrate in a way that allows the CP to control the entire end-to-end path. We develop two strawman architectures based on Software-Defined Networking ideas: one based on resource reservation and the other based on network virtualization. We also discuss some elements of a research agenda that is needed to bring ZeN deployments to realization.

Structured Overlay Networks for a New Generation of Internet Services
Amy Babay (Johns Hopkins University), Claudius Danilov (Boeing Research and Technology), John Lane (LTN Global Communications), Michal Miskin-Amir (LTN Global Communications, Spread Concepts LLC), Daniel Obenshain (Johns Hopkins University), John Schultz (LTN Global Communications, Spread Concepts LLC), Jonathan Stanton (LTN Global Communications, Spread Concepts LLC), Thomas Tantillo (Johns Hopkins University), Yair Amir (Johns Hopkins University), LTN Global Communications, Spread Concepts LLC)

The dramatic success and scaling of the Internet was made possible by the core principle of keeping it simple in the middle and smart at the edge (or the end-to-end principle). However, new applications bring new demands, and for many emerging applications, the Internet paradigm poses limitations. For applications in this new generation of Internet services, structured overlay networks offer a powerful framework for deploying specialized protocols that can provide new capabilities beyond what the Internet natively supports by leveraging global state and in-network processing. The structured overlay concept includes three principles: A resilient network architecture, a flexible overlay node software architecture that exploits global state and unlimited programmability, and flow-based processing. We demonstrate the effectiveness of structured overlay networks in supporting today's demanding applications and propose forward-looking ideas for leveraging the framework to develop protocols that push the boundaries of what is possible in terms of performance and resilience.

Ensuring Network Neutrality for Future Distributed Systems
Thiago Garrett (Federal University of Parana), Schahram Dustdar (TU Wien), Luis C. E. Bona (Federal University of Parana), Elias P. Duarte Jr. (Federal University of Parana)

Network Neutrality is essential for ensuring a level playing field for the development of new applications and services on the Internet. Laws and rules alone might not be enough to protect innovation, fair competition and consumers freedom of choice online. The research community has the responsibility to propose solutions that reveal discriminatory traffic management mechanisms on the Internet. We present the potential risks of a non-neutral Internet, identify several open challenges for designing solutions that detect traffic differentiation, and propose a model that addresses such challenges by taking advantage of distributed systems technologies.

Uncovering the Useful Structures of Complex Networks in Socially-Rich and Dynamic Environments
Jie Wu (Temple University)

Many group activities can be represented as a complex network where entities (vertices) are connected in pairs by lines (edges). Uncovering a useful global structure of complex networks is important for understanding system behaviors and in providing global guidance for application designs. We briefly review existing network models, discuss several tools used in the traditional graph theory, distributed computing, distributed systems, and social network communities, and point out their limitations. We discuss opportunities to uncover the structural properties of complex networks, especially in a mobile environment, and we summarize three promising approaches for uncovering useful structures: trimming, layering, and remapping. Finally, we present some challenges in algorithmic techniques, with a focus on distributed and localized solutions, to represent various structures.

Future Networking Challenges: The Case of Mobile Augmented Reality
Tristan Braud (The Hong Kong University of Science and Technology), Farshid Hassani Bjarbooneh (The Hong Kong University of Science and Technology), Dimitris Chatzopoulos (The Hong Kong University of Science and Technology), Pan Hui (The Hong Kong University of Science and Technology)

Mobile augmented reality (MAR) applications are gaining popularity due to the wide adoption of mobile and especially wearable devices. Such devices often present limited hardware capabilities while MAR applications often rely on computationally intensive computer vision algorithms with extreme latency requirements. To compensate for the lack of computing power, offloading data processing to a distant machine is often desired. However, this process introduces new constrains in the application, especially in terms of latency and bandwidth. If current network infrastructures are not ready for such traffic, we envision that future wireless networks such as 5G will rapidly be saturated by resource hungry MAR applications. Moreover, due to the high variance of wireless networks, MAR applications should not rely only on the evolution of infrastructures. In this article, we analyze MAR applications and justify their need for accessing external infrastructure. After a review of the existing network infrastructures and protocols, we define guidelines for future real-time and multimedia transport protocols, with a focus on MAR offloading.

Software Defined Cyberinfrastructure
Ian Foster (Argonne National Laboratory and The University of Chicago), Ben Blaiszik (The University of Chicago), Kyle Chard (Computation Institute, University of Chicago and Argonne National Lab), Ryan Chard (Victoria University of Wellington)
Within and across thousands of science labs, researchers and students struggle to manage data produced in experiments, simulations, and analyses. Largely manual research data lifecycle management processes mean that much time is wasted, research results are often irreproducible, and data sharing and reuse remain rare. In response, we propose a new approach to data lifecycle management in which researchers are empowered to define the actions to be performed at individual storage systems when data are created or modified: actions such as analysis, transformation, copying, and publication. We term this approach software-defined cyberinfrastructure because users can implement powerful data management policies by deploying rules to local storage systems, much as software-defined networking allows users to configure networks by deploying rules to switches. We argue that this approach can enable a new class of responsive distributed storage infrastructure that will accelerate research innovation by allowing any researcher to associate data workflows with data sources, whether local or remote, for such purposes as data ingest, characterization, indexing, and sharing. We report on early experiments with this approach in the context of experimental science, in which a simple if-trigger-then-action (IFTA) notation is used to define rules.

**Vision 3: Next Generation Cloud and Edge Services**

**Computing in the Continuum: Combining Pervasive Devices and Services to Support Data-driven Applications**

Manish Parashar (Rutgers University), Moustafa Abdelbaky (Rutgers University), Mengsong Zou (Rutgers University), Ali Reza Zamani (Rutgers University), Eduard Renart (Rutgers University), Javier Diaz-Montes (Rutgers University)

The exponential growth of digital data sources has, the potential to transform all aspects of society and our lives., However, to achieve this impact the data has to be processed, in a timely manner to extract critical insights that can drive, decision making. Further, traditional approaches that rely on, moving data to remote data centers for processing are no longer, feasible. Instead, new approaches that effectively leverage distributed, computational infrastructure and services are necessary., Specifically, these approaches must seamlessly combine resources, and services at the edge, in the core, and along the data, path as needed. This paper presents our vision for enabling, an approach for computing in the continuum, i.e., realizing a, fluid ecosystem where distributed resources and services are, programatically aggregated on-demand to support emerging, data-driven application workflows. This vision calls for novel, solutions for federating infrastructure, programming applications, and services, and composing dynamic workflows, which are, capable of reacting in real-time to unpredictable data sizes,, availabilities, locations, and rates.

**Decision-driven Execution: A Distributed Resource Management Paradigm for the Age of IoT**

Tarek Abdelzaher (UIUC), Tanvir Al Amin (UIUC), Amotz Bar-Noy (UIUC), William Dron (BBN), Ramesh Govindan (USC), Reginald Hobbs (ARL), Shaohan Hu (IBM), Jung-Eun Kim (UIUC), Shuochao Yao (UIUC), Yiran Zhao (UIUC)

This paper introduces a novel paradigm for resource management in distributed systems, called decision-driven execution. The paradigm is appropriate for mission-driven systems, where the goal is to enable faster, leaner, and more effective decision making. All resource consumption, in this paradigm, is tied to the needs of making decisions on alternative courses of action. A point of departure from traditional architectures lies in interfaces that allow applications to specify their underlying decision logic. This specification, in turn, allows the system to reason about most effective means to meet information needs of decisions, resulting in simultaneous optimization of decision accuracy, cost, and speed. The paper discusses the overall vision of decision-driven execution, outlining preliminary work and novel challenges.

**ACTiCLOUD: Enabling the Next Generation of Cloud Applications**

Georgios Goumas (National Technical University of Athens), Konstantinos Nikas (Computing Systems Laboratory, NTUA), Eunetu Bayuh Lakew (Dept. of Computing Science, Umea University), Christos Kotselidis (The University of Manchester), Vasileios Karakostas (Computing Systems Laboratory, NTUA), Atle Vesterkjaer (Numascale), Einar Rustad (Numascale), John Goodacre (Kaleao), Andrew Attwood (Kaleao), Michail Flouris (OnApp), John Thomson (OnApp), Nikos Foutris (The University of Manchester), Mikel Lujan (The University of Manchester), Ying Zhang (MonetDB Solutions), Panagiotis Koutsourakis (MonetDB Solutions), Martin Kersten (MonetDB Solutions), Jim Webber (Neo Technology), Davide Grohmann (Neo Technology), Erik Elmroth (Dept. of Computing Science, Umea University), Luis Tomas (Dept. of Computing Science, Umea University), Nectarios Koziris (National Technical University of Athens)

Despite their proliferation as a dominant computing paradigm, cloud computing systems lack effective mechanisms to manage their vast amounts of resources efficiently. Resources are stranded and fragmented, ultimately limiting cloud systems applicability to large classes of critical applications that pose non-moderate resource demands. Eliminating current technological barriers of actual fluidity and scalability of cloud resources is essential to strengthen cloud computing role as a critical cornerstone for the digital economy. ACTiCLOUD proposes a novel cloud architecture that breaks the existing scale-up and share-nothing barriers and enables the holistic management of physical resources both at the local cloud site and at distributed levels. Specifically, it makes advancements in the cloud resource management stacks by extending state-of-the-art hypervisor technology beyond the physical server boundary and localized cloud management system to provide an holistic resource management within a rack, within a site, and across distributed cloud sites. On top of this, ACTiCLOUD will adapt and optimize system libraries and runtimes (e.g., JVM) as well as ACTiCLOUD-native applications, which are extremely demanding, and critical classes of applications that currently face severe difficulties in matching their resource requirements to state-of-the-art cloud offerings.

**JointCloud: A Cross-Cloud Cooperation Architecture for Integrated Internet Service Customization**

Huaimin Wang (National University of Defense Technology), Peichang Shi (National University of Defense Technology), Yiming Zhang (National University of Defense Technology)

Cloud computing has completely changed the economics of IT industry. Recently, the new form of shared global economy requires cloud services to be collaboratively provisioned by different cloud providers in a Geo-distributed manner, which brings severe challenges in service performance and cost. To address this problem, in this paper we propose JointCloud, a cross-cloud cooperation architecture for integrated Internet service customization. JointCloud borrows the idea from airline alliances and aims at empowering the cooperation among multiple clouds to provide efficient cross-cloud services. JointCloud focuses not only on the vertical integration of cloud resources but also on the horizontal cooperation among different cloud vendors. This paper describes the concept and architecture of JointCloud, as well as the initial designs of JointCloud's key components, namely, communication, storage, and computation.

**Supporting Data Analytics Applications Which Utilize Cognitive Services**

Arun Iyengar (IBM Research)
A wide variety of services are available over the Web which can dramatically improve the functionality of applications. These services include information retrieval (including data lookups from a variety of sources and Web searches), natural language understanding, visual recognition, and data storage. A key problem is how to provide support for applications which use these services. This paper presents a rich software development kit (SDK) which accesses these services and provides a variety of features applications need to use these services, optimize performance, and compare them. A key aspect of our SDK is its support for natural language understanding services. We also present a personalized knowledge base built on top of our rich SDK that uses publically available data sources as well as private information. The knowledge base supports data analysis and reasoning over data.

**Trillion Operations Key-Value Storage Engine: Revisiting the Mission Critical Analytics Storage Software Stack**

Sangeeta Seshadri (IBM Almaden Research Center), Lawrence Chiu (IBM Almaden Research Center), Paul Muench (IBM Almaden Research Center)

Data is the new natural resource of this century. As data volumes grow and applications aimed at monetizing the data continue to evolve, data processing platforms are expected to meet new scale, performance, reliability and data retention requirements. At the same time, storage hardware continues to improve in performance and price-performance. In this paper, we present TOKVS - Trillion Operation Key-Value Store, a NoSQL storage engine that redefines the storage software stack to meet the requirements of next-generation applications on next-generation hardware.

**Vision 4: Security and Trust in Future Systems**

**How Computer Science Risks to Lose Its Innocence, and Should Attempt to Take Responsibility**

Karl Aberer (EPFL)

Computer science is playing a driving role in transforming today’s society through information technology. In this transformation we observe power shifts increasingly strengthening centralised organisations, which are negatively perceived by many people. We outline technical questions that computer science should pay attention to in order to enable individuals in preserving their interest and to take meaningful decisions based on reliable information.

**A Cognitive Policy Framework for Next-Generation Distributed Federated Systems - Concepts and Research Directions**

Elisa Bertino (Purdue University), Seraphin Calo (IBM), Maroun Touma (IBM), Dinesh Verma (IBM), Christopher Williams (UK DSTL), Brian Rivera (Army Research Labs)

Next-generation collaborative activities and missions will be carried out by autonomous groups of devices with a large variety of cognitive capabilities. These devices will have to operate in environments characterized by uncertainty, insecurity (both physical and cyber), and instability. In such environments, communications may be fragmented. Proper policy-based management of such autonomous device groups is thus critical. However current policy management systems have many limitations, including lack of flexibility. In this paper, we articulate novel architectural approaches addressing the requirements for the effective management of autonomous groups of devices and discuss the notion of generative policies a novel paradigm that enhances the flexibility of policy-based approaches to management. In this paper, we also survey types of policy that are essential for managing device groups. Even though many such policy types exist in conventional settings, their use in our context poses novel challenges that we articulate in the paper. We also introduce a research roadmap discussing several research directions towards the development of a cognitive and flexible policy-based approach to the management of autonomous groups of devices for collaborative missions. Finally, as our proposed policy paradigm is data-intensive, we discuss the problem of supplying the data required for policy decisions in environments characterized by mobility, uncertainty, and fragmented communications.

**Machine to Machine Trust in Smart Cities**

Margaret Loper (Georgia Tech Research Institute), Brian Swenson (Georgia Institute of Technology)

In the coming decades, we will live in a world surrounded by tens of billions of devices that will interoperate and collaborate in an effort to deliver personalized and autonomic services. This paradigm of smart objects and smart things interconnected and ubiquitously surrounding us is called the Internet of Things (IoT). Cities may be the first to benefit from the IoT, but reliance on these machines to make decisions has profound implications for trust, and makes mechanisms for expressing and reasoning about trust essential. This paper introduces the project funded by the Georgia Tech Research Institute to look at several dimensions of Machine to Machine Trust in the context of Smart Cities.

**Lateral Thinking for Trustworthy Apps**

Hermann Härtig (Technische Universität Dresden), Michael Roitzsch (Technische Universität Dresden), Carsten Weinhold (Technische Universität Dresden), Adam Lackorzynski (Technische Universität Dresden)

The growing computerization of critical infrastructure as well as the pervasiveness of computing in everyday life has led to increased interest in secure application development. Exemplified by ARM TrustZone and Intel SGX, we observe a flurry of new security technologies, but a lack of an architectural vision. We are convinced that point solutions are not sufficient to address the overall challenge of secure system design. In this paper, we sketch our take on a trusted component ecosystem of small individual building blocks with strong isolation. In our view, applications should no longer be designed as massive stacks of vertically layered frameworks, but instead as horizontal aggregates of mutually isolated components that collaborate across machine boundaries to provide a service. Lateral thinking is needed to create secure systems going forward.

**Rumor Initiator Detection in Infected Signed Networks**

Jiawei Zhang (University of Illinois at Chicago), Charu C. Aggarwal (IBM T. J. Watson Research Center), Philip S. Yu (University of Illinois at Chicago)

In many cases, the information spread in an online network may not always be truthful or correct; such information corresponds to rumors. In recent years, signed networks have become increasingly popular because of their ability to represent diverse relationships such as friends, enemies, trust, and distrust. Signed networks are ideal for information flow in a network with varying beliefs (trust or distrust) about facts. In this paper, we study the problem of influence analysis and diffusion models in signed networks and investigate the problem of rumor initiator detection, given the state of the network at a given moment in time. Conventional information diffusion models for unsigned networks cannot be applied to signed networks directly, and we show that the rumor initiator detection problem is NP-hard. We propose a new information diffusion model, referred to as asymMmetric Flipping Cascade (MFC), to model the propagation of information in signed networks. Based on MFC, a novel framework, Rumor Initiator Detector (RID), is introduced to determine the potential number and the identity of the rumor initiators from the state of the network at a given time. Extensive experiments conducted on real-world signed networks demonstrate that MFC works very well in modeling information diffusion in signed networks and RID can significantly outperform other comparison methods in identifying rumor initiators.
Addressing Smartphone-based Multi-factor Authentication via Hardware-rooted Technologies
Zhongjie Ba (The State University of New York at Buffalo), Kui Ren (The State University of New York at Buffalo)

Multi-factor authentication is a well-recognized access control method that enhances the security of users sensitive data and identities. A successful authentication attempt requires a user to correctly present two or more authentication factors such as knowledge factors, possession factors and inherence factors. For smartphone-based multi-factor authentication, a promising way to authenticate a user is to verify his possession of a legitimate smartphone, which calls for secure and usable device authentication schemes. In this article, we propose to authenticate a device through tracking the hardware fingerprint of its built-in sensor. We first review the existing hardware-rooted identification methods and discuss the merits of applying a hardware fingerprint as a smartphones unique identity. Then, we analyze the security issues underlying these methods and identify two security requirements for the identification methods to be used in an authentication scheme: Fingerprint Leakage Resilience and Fingerprint Forgery Resilience. Finally, we look into a specific hardware fingerprint originally used for digital cameras. We analyze the feasibility of applying this fingerprint to differentiate off-the-shelf smartphones and list several challenging practical issues underlying this method.

Vision 5: Future Distributed Systems
Enabling wide area data analytics with Collaborative Distributed Processing Pipes (CDPPs)
Anja Feldmann (TU Berlin), Manfred Hauswirth (TU Berlin), Volker Markl (TU Berlin)

The Millibottleneck Theory of Performance Bugs, and Its Experimental Verification
Calton Pu (Georgia Institute of Technology), Joshua Kimball (Georgia Institute of Technology), Chien-An Lai (Georgia Institute of Technology), Tao Zhu (Georgia Institute of Technology), Jack Li, Junhee Park, Qingyang Wang, Deepal Jayasinghe, Pengcheng Xiong, Simon Malkowski, Qinyi Wu, Gueyoung Jung, Younggyun Koh, Galen Swint

The performance of n-tier web-facing applications often suffer from response time long-tail problem. With relatively low resource utilization (less than 50%) and the vast majority of requests returning within a few milliseconds, a non-negligible number of normally short requests may take seconds to return. We propose the millibottleneck theory of performance bugs (that lead to long-tail problems). Several case studies have confirmed the millibottlenecks (that last a few tens to hundreds of milliseconds) as causal agents of long requests. A concrete example (garbage collection) illustrates the experimental verification of millibottlenecks. An open source fine-grain monitoring toolkit is being developed to facilitate the experimental research on millibottlenecks.

Execution: Enhancing Scientific Data Management for Exascale
Scott Klasky (Oak Ridge National Laboratory), Eric Suchyta (Oak Ridge National Lab), Mark Ainsworth (Brown University), Qing Liu (New Jersey Institute of Technology), Ben Whitney (Brown University), Matthew Wolf (Oak Ridge National Laboratory), Jong Choi (Oak Ridge National Laboratory), Jan Foster (Argonne National Laboratory), Mark Kim (Oak Ridge National Laboratory), Jeremy Logan (University Of Tennessee Knoxville), Kshitij Mehta (Oak Ridge National Laboratory), Todd Munson (Argonne National Laboratory), George Ostroumov (Oak Ridge National Laboratory), Manish Parashar (Rutgers University), Norbert Podhorszki (Oak Ridge National Laboratory), David Pugmire (Oak Ridge National Laboratory), Lipeng Wan (Oak Ridge National Laboratory)

As we continue toward exascale, scientific data volume is continuing to scale and becoming more burdensome to manage. In this paper, we lay out opportunities to enhance state of the art data management techniques. We emphasize well-principled data compression, and using it to achieve progressive refinement. This can both accelerate I/O and afford the user increased flexibility when she interacts with the data. The formulation naturally maps onto enabling one to partition the progressively improving quality representations of the same data quantity into different media-type destinations, to keep the highest priority information as close as possible to the computation, and take advantage of deepening memory/storage hierarchies in ways not previously possible. Careful monitoring is requisite to our vision, not only to verify that compression has not eliminated salient features in the data, but also to better understand the performance of high performance scientific applications. Increased mathematical rigor would ideal, to help bring compression on a better-understood theoretical footing, closer to the relevant scientific theory, more aware of constraints imposed by the science, and more tightly error controlled. Throughout, we highlight pathfinding research we have begun exploring related these topics, and comment toward future work that will be needed.

Hardware Acceleration Landscape for Distributed Real-time Analytics: Virtues and Limitations
Mohamadreza Najafi (Technische Universitat Munchen), Kaiwen Zhang (Technische Universitat Munchen), Hans-Arno Jacobsen (University of Toronto), Mohammad Sadoghi (Purdue University)

Arguably, we are now witnessing a new technological revolution with the potential that ranges from transforming our day-to-day life experiences (e.g., personalized medicine and education) to transforming every single industry (e.g., data-driven healthcare, commerce, agriculture, and mining). At the core of this revolution lies data. This transformation is facilitated by sensing, gathering, and connecting all physical entities to construct a rich and dynamic computational model of reality in real-time. Every procedure and every decision needed in the physical world will soon be optimized in real-time by ingesting and analyzing massive volume of present and past data at an unprecedented velocity. To cope with such extreme scale, we argue the need to revisit the hardware and software co-design in light of two key technological advancements. First is the virtualization of computation and storage over highly distributed data centers spanning across continents. Second is the emergence of a variety of specialized hardware accelerators that complement the traditional general-purpose processors. We argue there is an imminent need to exploit and unify these two trends in order to unleash and harness the power of data in real-time. In this paper, we focus on presenting a formulation and characterization of hardware acceleration landscape geared towards real-time analytics in the cloud environment. Our goal is to assist both researchers and practitioners navigating the newly revived field of software and hardware co-design for building next generation distributed systems. We further present a case study to explore software and hardware interplay for designing distributed real-time stream processing.

Coordinating Distributed Speaking Objects
Marco Lippi (DISMI – Università di Modena e Reggio Emilia), Marco Mamei (DISMI – Università di Modena e Reggio Emilia), Stefano Mariani (DISMI – Università di Modena e Reggio Emilia), Franco Zambonelli (DISMI – Università di Modena e Reggio Emilia)
In this paper we sketch a vision of future environments densely populated by smart sensors and actuators possibly embedded in everyday objects that, rather than simply producing streams of data, are capable of understanding and reporting, via factual assertions and arguments, about what is happening (for sensors) and about what they can make possibly happen (for actuators). These speaking objects form the nodes of a dense distributed computing infrastructure that can be exploited to monitor and control activities in our everyday environment. However, the nature of speaking objects will dramatically change the approaches to implementing and coordinating the activities of distributed processes. In fact, distributed coordination is likely to become associated with the capability of arguing about situations and about the current state of the affairs, with the aim of triggering and directing proper distributed conversations to collectively reach a future desirable state of the affairs. In this paper we discuss how such a novel vision can build upon some readily available technologies, and we highlight the research challenges that it poses. Two case studies are used throughout the paper as exemplary scenarios.

Model-Driven Domain-Specific Middleware
Fabio Costa (Federal University of Goias), Karl Morris (Temple University), Fabio Kon (University of Sáo Paulo), Peter Clarke (Florida International University)

Middleware was introduced to facilitate the development of sophisticated applications based on a uniform methodology and industry standards. However, early research and practice suggested that no one-size-fits-all approach was suitable for all application domains and scenarios. This gave rise to industry initiatives to standardize domain-specific middleware services and profiles, as well as research efforts on configurable, reflective, and adaptive middleware. The industry approach led to easy deployment, although with a level of flexibility limited by the extent of existing profiles. The approach of the research community, on the other hand, enabled high flexibility, allowing any middleware configuration to be defined. Nevertheless, creating sound configurations using this approach is a challenging task, limiting the target audience to expert engineers. As a consequence, both initiatives do not scale with the current prolification of specialized application domains. In this paper, we target this problem with an approach that leverages model-driven engineering for the construction of domain-specific middleware platforms. A set of high-level, yet expressive, building blocks is defined in the form of a metamodel, which is used to create models that specify the desired middleware configuration. We argue that this approach enables the rapid development of middleware platforms to match the proliferation of application domains, at the same time as it does not require per-application middleware construction or even highly skilled middleware engineers. We present the current state of our research and discuss research directions to fully realize the approach.

Vision 6: Innovation in Big Data Systems
On the Design of a Blockchain Platform for Clinical Trial and Precision Medicine
Zonyin Shae (ASIA University, Taiwan), Jeffrey Tsai (ASIA University, Taiwan)

This paper proposes a blockchain platform architecture for clinical trial and precision medicine and discusses various design aspects and provides some insights in the technology requirements and challenges. We identify 4 new system architecture components that are required to be built on top of traditional blockchain and discuss their technology challenges in our blockchain platform: (a) a new blockchain based general distributed and parallel computing paradigm component to devise and study parallel computing methodology for big data analytics, (b) blockchain application data management component for data integrity, big data integration, and integrating disparity of medical related data, (c) verifiable anonymous identity management component for identity privacy for both person and Internet of Things (IoT) devices and secure data access to make possible of the patient centric medicine, and (d) trust data sharing management component to enable a trust medical data ecosystem for collaborative research.

Towards Dataflow-based Graph Accelerator
Hai Jin (Huazhong University of Science and Technology), Pengcheng Yao (Huazhong University of Science and Technology), Xiaofei Liao (Huazhong University of Science and Technology), Long Zheng (Huazhong University of Science and Technology), Xianliang Li (Huazhong University of Science and Technology)

Existing graph processing frameworks greatly improve the performance of memory subsystem, but they are still subject to the underlying modern processor, resulting in the potential inefficiencies for graph processing in the sense of low instruction level parallelism and high branch misprediction. These inefficiencies, in accordance with our comprehensive micro-architectural study, mainly arise out of a wealth of data dependencies, serial semantic of instruction streams, and complex conditional instructions in graph processing. In this paper, we propose that a fundamental shift of approach is necessary to break through the inefficiencies of the underlying processor via the dataflow paradigm. It is verified that the idea of applying dataflow approach into graph processing is extremely appealing for the following two reasons. First, as the execution and retirement of instructions only depend on the availability of input data in dataflow model, a high degree of parallelism can be therefore provided to relax the heavy dependency and serial semantic. Second, dataflow is guaranteed to make it possible to reduce the costs of branch misprediction by simultaneously executing all branches of a conditional instruction. Consequently, we make the preliminary attempt to develop the dataflow insight into a specialized graph accelerator. We believe that our work would open a wide range of opportunities to improve performance of computation and memory access for large-scale graph processing.

Towards a RISC Framework for Efficient Contextualization in IoT
Dimitrios Georgakopoulos (Swinburne University), Ali Yavari (RMIT University), Prem Prakash Jayaraman (Swinburne University), Rajiv Ranjan (Newcastle University)

The Internet of Things (IoT) is a new internet evolution that involves connecting billions of internet-connected devices we refer to as IoT things. These devices can communicate directly and intelligently over the Internet, and generate a massive amount of data that needs to be by a variety of IoT applications. This paper focuses on the automatic contextualisation of IoT data, which also involves distilling information and knowledge from IoT aiming to simplify answering the following fundamental questions that often arise in IoT applications: Which data collected by IoT are relevant to myself and the IoT Things I care for? Related work around context management and contextualisation ranges from database techniques that involve query re-writing, to semantic web and rule-based context management approaches, to machine learning and data science-based solutions in mobile and ambient computing. All such existing approaches have two main aspects in common: They are highly incompatible and horribly inefficient from a scalability and performance perspective. In this paper, we discuss a new RISC Contextualisation Framework (RCF) we have developed, implemented key aspect off, and assesses its scalability. RCF provides fundamental contextualisation concepts that can be mapped to all existing contextualisation approaches for IoT data (and in this sense, it provides a common denominator that unifies the contextualisation space). RCF can be easily implemented as a cloud-based service, and provides better scalability and performance that any of the existing content management and contextualisation approach in the IoT space.
**The Future of the Semantic Web: Prototypes on a Global Distributed Filesystem**
Michael Cochez (Fraunhofer - FIT), Dominik Hüser (RWTH Aachen University), Stefan Decker (RWTH Aachen)

Recently, prototypes (in the meaning familiar from programming languages such as Javascript) were (re-)introduced for knowledge representation on the web. However, that work has a very theoretical focus and a more practical system is in demand. In this vision paper we describe how a distributed file system forms a natural habitat for the prototype knowledge representation. In particular, we describe how we envision deployment of Linked Data and Prototype Knowledge bases atop of the InterPlanetary File System (IPFS), which has several useful features matching the needs for the prototype system.

**On Broad Big Data**
Steffen Staab (Institut WeST, University Koblenz-Landau and WAIS, University of Southampton)

A broad data system explicitly represents a large number of concepts and properties together with its corresponding data proper. We observe the characteristics of several broad data systems and elicit three challenges we will need to research when scaling these broad data systems to become big data systems, too.
Short Paper 1: Distributed Operating Systems, Middleware, and Algorithms

**SRLB: The Power of Choices in Load Balancing with Segment Routing**
Yoann Desmouieux (École Polytechnique), Pierre Pfister (Cisco Systems), Jérôme Tollet (Cisco Systems), Mark Townsley (Cisco Systems), Thomas Clausen (École Polytechnique)

Network load-balancers generally either do not take application state into account, or do so at the cost of a centralized monitoring system. This paper introduces a load-balancer running exclusively within the IP forwarding plane, i.e. in an application protocol agnostic fashion – yet which still provides application-awareness and makes real-time, decentralized decisions. To that end, IPv6 Segment Routing is used to direct data packets from a new flow through a chain of candidate servers, until one decides to accept the connection, based on its local state. This way, applications themselves naturally decide on how to share incoming connections, while incurring minimal network overhead, and no out-of-band signaling. Tests on different workloads – including realistic workloads such as replaying actual Wikipedia access traffic towards a set of replica Wikipedia instances – show significant performance benefits, in terms of shorter response times, when compared to a traditional random load-balancer.

**Improving Efficiency of Link Clustering on Multi-Core Machines**
Guanhua Yan (Binghamton University)

Link clustering groups different edges in a graph according to their similarities. Link clustering can reveal the overlapping and hierarchical organizations in a wide spectrum of networks. This work studies how to improve efficiency of link clustering along three dimensions, algorithm, modeling, and parallelization, on multi-core machines. We evaluate the efficiency improved due to each of the three dimensions using word association graphs extracted from a twitter dataset.

**S3: Joint Scheduling and Source Selection for Background Traffic in Erasure-Coded Storage**
Shijing Li (George Washington University), Tian Lan (George Washington University), Moo-Ryong Ra (AT&T Labs Research), Rajesh Panta (AT&T Labs Research)

Erasure-coded storage systems have gained considerable adoption recently since they can provide the same level of reliability with significantly lower storage overhead compared to replicated systems. However, background traffic of such systems – e.g. repair, rebalance, backup and recovery traffic – often has large volume and consumes significant network resources. Independently scheduling such tasks and selecting their sources can easily create interference among data flows, causing severe deadline violation. We show that the well-known heuristic scheduling algorithms fail to consider important constraints, thus resulting in unsatisfactory performance. In this paper, we claim that an optimal scheduling algorithm that aims to maximize the number of background tasks completed before deadlines must simultaneously consider deadline-aware scheduling, network topology, chunk placement, and time-varying resource availability. To solve this problem, we propose a novel algorithm, called Linear Programming for Selected Tasks (LPST) to maximize the number of successful tasks and improve overall utilization of the datacenter network. It jointly schedules tasks and selects their sources based on a notion of Remaining Time Flexibility, which measures the slackness of the starting time of a task. We evaluated the efficacy of our algorithm using extensive simulations. Our results show that, under certain scenarios, LPST can perform 7×–70× better than the heuristics which blindly treat the infrastructure as a collection of homogeneous resources, and 46.6%–65.9% better than the algorithms that take into account the network topology.

**On the Feasibility of Inter-domain Routing via a Small Broker Set**
Dong Lin (Huawei Technologies Ltd Co.), David Hui (Huawei Technologies Ltd Co.), Weijie Wu (Huawei Technologies Ltd Co.), Tingwei Liu (The Chinese University of Hong Kong), Yating Yang (Beijing Institute of Technology), Yi Wang (Tsinghua University), John Chi-Shing Lui (Chinese University of Hong Kong), Gong Zhang (Huawei Technologies Ltd Co.), Yingtao Li (Huawei Technologies Ltd Co.)

The current inter-domain routing protocol, namely, the Border Gateway Protocol (BGP), cannot provide end-to-end (E2E) quality-of-service (QoS) guarantees. The main reason is that an autonomous system (AS) can only receive guarantees from its first hop ASes via service level agreements (SLAs). But beyond the first hop, QoS along the path from source to destination AS is not within the source AS’s control regime. In this paper, we investigate the feasibility of providing high QoS-guaranteed E2E transit services by utilizing a (small) set of ASes/IXPs to serve as “brokers” to provide supervision, control and resource negotiation. Finding an optimal set of ASes as brokers can be formulated as a Maximum Coverage with 8-dominating path Guarantee (MC8G) problem, which we prove to be NP-hard. To address this problem, we design a (1 + 1/4) -approximation algorithm and also an efficient heuristic algorithm when considering additional constraints (e.g., path length). Based on the current Internet topology, we discover a “3540-alliance” subset (accounting only 6.8%) of 52,079 ASes/IXPs, which can provide high QoS guarantees for 99.29% E2E connections.

**Subscription Covering for Relevance-based Filtering in Content-Based Publish/Subscribe Systems**
Kaixi Zhang (Technische Universität München), Vinod Muthusamy (IBM Research), Mohammad Sadoghi (Purdue University), Hans-Arno Jacobsen (University of Toronto)

Large-scale applications require a scalable data dissemination service with advanced filtering capabilities. We propose the use of a content-based publish/subscribe system with support for top-k filtering in the context of such applications. We focus on the problem of top-k subscription filtering, where a publication is delivered only to the k highest scoring subscribers. The naive approach to perform filtering early at the publisher edge works only if complete knowledge of the subscriptions is available, which is not compatible with the well-established covering optimization in scalable content-based publish/subscribe systems. We propose an efficient rank-cover technique to reconcile top-k subscription filtering with covering. We extend the covering model to support top-k and describe a novel algorithm for forwarding subscriptions to publishers while maintaining correctness. Finally, we compare our solutions to a baseline covering system. In a typical setting, our optimized solution is scalable and provides over 81% of the covering benefit.

**Workflow Optimization in PAW**
Maxim Filatov (UNIGE), Verena Kantere (University of Geneva)
Many industrial applications, from domains such as telecommunication, web and sales, require to perform complex analytics across several data processing systems. The performance of such analytics is usually expressed in workflows, and it is a task that is both labor-intensive and time-consuming. At the same time, with increasing amounts of data to be analysed, the optimization of analytics workflows becomes crucial for satisfying business objectives. This paper focuses on workflow optimization with respect to time efficiency, over multiple execution engines, such as a traditional DBMS, a MapReduce engine, and a scripting engine. This configuration is emerging as a common paradigm used to combine analysis of unstructured and structured data. We propose a novel optimization technique as part of our system called PAW (Platform for Analytics Workflows). This technique creates alternative workflow structures and their execution plans based on equivalent combinations and orders of operators. The technique employs an exhaustive and a heuristic algorithm to search efficiently the space of equivalent workflow structures and select the one with the optimal execution plan. We present a thorough experimental study and we showcase the efficiency of the proposed optimization technique in a fully fledged multi-engine system, applied on three real-world applications and their data, as well as on a synthetic benchmark.

A First Look at Information Entropy-Based Data Pricing
Xijun Li (Shanghai Jiao Tong University), Jianguo Yao (Shanghai Jiao Tong University), Xue Liu (McGill University), Haibing Guan (Shanghai Jiao Tong University)

Distribution of intangible information goods is experiencing tremendous growth in recent years, which has facilitated a blossoming of information goods economics. As big data develops, there are more and more information goods markets for data trading. In the current of data pricing policies in data trading, there are many metrics to measure the value of data goods, such as the data generation date, data volume, and data integrity, etc. However, it is very challenging to identify the amount of data information and its distribution, and the corresponding data pricing has rarely been discussed. In this paper, we propose a new data pricing metric, i.e., the data information entropy, which helps to make a reasonable price in the data trading. We first demonstrate a data information measurement method based on information entropy, and then propose a pricing function based on the result of data information measurement. To comprehensively understand the new data pricing metric and facilitate its application in data trading, we verify the rationality of the data information measurement method and give three concrete pricing functions. It is the first time to look at the information entropy-based data pricing, which can inspire the research concerning the pricing mechanism of data goods, further promoting the development of data products business.

Restrospective Lightweight Distributed Snapshots Using Loosely Synchronized Clocks
Aleksy Charapko (SUNY Buffalo), Ailidani Alijiang (SUNY Buffalo), Murat Demirbas (SUNY Buffalo), Sandeep Kulkarni (Michigan State University)

In order to take a consistent snapshot of a distributed system, it is necessary to collate and align local logs from each node to construct a pairwise concurrent cut. By leveraging NTP synchronized clocks, and augmenting them with logical clock causality information, Retroscope provides a lightweight solution for taking unplanned retrospective snapshots of past distributed system states. Instead of storing a multiversion copy of the entire system data, this is achieved efficiently by maintaining a configurable-size sliding window-log at each node to capture recent operations. In addition to retrospective snapshots, Retroscope also provides incremental and rolling snapshots that utilize an existing snapshot to reduce the cost of constructing a new snapshot in proximity. This capability is useful for performing stepwise debugging and root-cause analysis, and supporting data integrity monitoring and checkpoint-recovery. We implement Retroscope for the Voldemort distributed datastore and evaluate its performance under varying workloads.

Power-Aware Population Protocols
Chuan Xu (LRI(CNRS/UPSud)), Janna Burman (LRI(CNRS/UPSud)), Joffrey Beauquier (LRI(CNRS/UPSud))

In this paper, we propose a formal energy model which allows an analytical study of energy consumption, for the first time in the context of population protocols (PP). In PP, anonymous and bounded memory agents move unpredictably and communicate in pairs. In order to illustrate the power and the usefulness of the proposed energy model, we develop a new power-aware protocol (EB-TTFM) for the task of data collection. The analytical results show that, in terms of energy consumption, EB-TTFM outperforms a known data collection protocol under certain conditions. Finally, we present a lower bound concerning energy consumption of any possible data collection protocol in PP, which also justifies the efficiency of EB-TTFM.

MultiPub: Latency and Cost-Aware Global-Scale Cloud Publish/Subscribe
Julien Gascon-Samson (McGill University), Jörg Kienzle (McGill University), Bettina Kemme (McGill University)

Topic-based pub/sub is a widely used communication mechanism in distributed systems for targeted information dissemination between loosely coupled entities. To scale dynamically depending on the current communication demands, pub/sub services can be conveniently deployed in the cloud. To provide fast dissemination, the service can be distributed across multiple cloud regions. The architectural design and run-time deployment of such a middleware is tricky, though, as it can have a significant effect on communication latency and cloud-based cost. In this paper, we propose MultiPub, a flexible pub/sub middleware for latency-constrained, world-wide distributed applications that dynamically reconfigures the communication layer to ensure a predefined maximum latency for publication dissemination while minimizing cloud-based costs. This is achieved by routing publications either through a single or across multiple cloud regions. We demonstrate the effectiveness of MultiPub by presenting a set of experiments that report on the achieved communication latency and cost savings compared to traditional approaches, as well as a performance evaluation.

Reachability in Binary Multithreaded Programs Is Polynomial
Alexander Malikis (Technische Universität München), Steffen Borgwardt (UC Davis)

Automatic finding of bugs in multithreaded programs is an important but inherently difficult task, even in the finite-state interleaving-semantics case. The complexity of this task has only been partially explored so far. We measure quantities such as the diameter, which is the longest finite distance realizable in the transition graph of the program, the local diameter, which is the maximum distance from any program state to any thread-local state, and the computational complexity of bugfinding. For the subclass of so-called binary multithreaded programs, we prove new bounds: all these quantities are majorized by a polynomial and, in certain cases, by a linear, logarithmic, or even constant function. Our bounds present a preparation step towards the corresponding polynomial-bound claims for general programs. These claims contrast sharply with the common belief that the main obstacle to analyzing concurrent programs is the exponential state explosion in the number of threads.

An Event-Level Abstraction for Achieving Efficiency and Fairness in Network Update
Changes of network state are a common source of instability in networks. An update event typically involves multiple flows that compete for network resources at the cost of rescheduling and migrating some existing flows. Prior network updating schemes tackle such flows independently, rather than as the entity of an update event. They only optimize the flow-level metrics for the flows involved in an update event. In this paper, we present an event-level abstraction of network update which groups flows of an update event and schedules them together to minimize the event completion time (ECT). We then study the scheduling problem of multiple update events for achieving high scheduling efficiency and preserving fairness. The designed least migration traffic first (LMTF) method schedules all update events in the FIFO order, but avoids head-of-line blocking by randomly fine-tuning the queue order of some events. It can considerably reduce the update cost, the average, and tail ECTs of all update events. In addition, we design a general parallel-LMTF (P-LMTF) method to guarantee fairness and further improve scheduling efficiency among multiple update events. It improves the LMTF method by opportunistically updating multiple events simultaneously. The comprehensive evaluation results indicate that the average ECT of our approach is up to 10× faster than the flow-level scheduling method for network update events, and its tail ECT is up to 6× faster. Our P-LMTF method incurs 75% reduction in the average ECT compared with FIFO when the network utilization exceeds 70%, and it achieves a 42% reduction in tail ECT.

Short Paper 2: Cloud and Data Center Systems and Networks

DCM: Dynamic Concurrency Management for Scaling n-Tier Applications in Cloud
Hui Chen (Louisiana State University), Qingyang Wang (Louisiana State university), Balaji Palanisamy (University of Pittsburgh), Pengcheng Xiong (Hortonworks)

Scaling web applications such as e-commerce in cloud by adding or removing servers in the system is an important practice to handle workload variations, with the goal of achieving both high quality of service (QoS) and high resource efficiency. Through extensive scaling experiments of an n-tier application benchmark (RUBBoS), we have observed that scaling only hardware resources without appropriate adaptation of soft resource allocations (e.g., thread or connection pool size) of each server would cause significant performance degradation of the overall system by either under- or over-utilizing the bottleneck resource in the system. We develop a dynamic concurrency management (DCM) framework which integrates soft resource allocations into the system scaling management. DCM introduces a model which determines a near-optimal concurrency setting to each tier of the system based on a combination of operational queuing laws and online analysis of fine-grained measurement data. We implement DCM as a two-level actuator which scales both hardware and soft resources in an n-tier system on the fly without interrupting the runtime system performance. Our experimental results demonstrate that DCM can achieve significantly more stable performance and higher resource efficiency compared to the state-of-the-art hardware-only scaling solutions (e.g., Amazon EC2-AutoScale) under realistic bursty workload traces.

More Peak, Less Differentiation: Towards A Pricing-aware Online Control Framework for Inter-Datacenter Transfers
Wenxin Li (Dalian University of Technology), Xiaobo Zhou (Tiajian University), Keqi Li (Dalian University of Technology), Heng Qi (Dalian University of Technology), Deke Guo (National University of Defence Technology)

The emerging deployment of geographically distributed data centers (DCs) incurs a significant amount of data transfers over the Internet. Such transfers are typically charged by Internet Service Providers (ISPs) with the widely adopted q-th percentile charging model. In such charging model, the time slots with top 100%-q percentile of data transmission do not affect the total transmission cost, and can be viewed as free. This brings the opportunity to optimize the scheduling of inter-DC transfers to minimize the entire transmission cost. However, very little work has been done to exploit those free time slots for scheduling inter-DC transfers. The crux is that existing work either lacks a mechanism to accumulate traffic to free time slots, or inevitably relies on prior knowledge of traffic arrival patterns. In this paper, we attempt to exploit those free time slots by leveraging diverse time-sensitivities among inter-DC transfers, so as to reduce or even minimize the transmission cost. Specifically, we advocate that a simple principle should be followed: more traffic peaks should be scheduled in free time slots, while less traffic differentiation should be maintained among the remaining time slots. To this end, we take advantage of the Lyapunov optimization techniques to design a pricing-aware control framework. This framework efficiently makes online decisions for inter-DC transfers without requiring a prior knowledge of traffic arrivals. To verify our proposed framework, we conduct small-scale testbed implementation. The results show that our framework can realistically reduce the transmission cost by up to 19.38%.

Robust Multi-Tenant Server Consolidation in the Cloud for Data Analytics Workloads
Joseph Mate (University of Waterloo), Khuzaima Daudjee (University of Waterloo), Shahin Kamali (MIT CSAIL)

Server consolidation is the allocation or hosting of tenants on a minimum number of cloud server machines. Given a sequence of data analytics tenant loads defined by the amount of resources that the tenants require and a service-level agreement (SLA) between the customer and the cloud service provider, significant resource cost savings can be achieved by consolidating multiple tenants on server machines. Since server machines can fail causing their tenants to become unavailable, service providers can place replicas of each tenant on different servers and reserve capacity to ensure that tenant failover will not result in overload on any remaining server. We propose the CUBEFIT algorithm for multi-tenant server consolidation that saves resource costs by utilizing fewer servers than existing approaches for data analytics workloads. Unlike existing consolidation algorithms, CUBEFIT can tolerate multiple server failures while ensuring that no server becomes overloaded. We provide extensive theoretical analysis and experimental evaluation of CUBEFIT. We show that compared to existing algorithms, the average case and worst case behavior of CUBEFIT is superior and that it produces near-optimal tenant allocation when the number of tenants is large. Through evaluation and deployment on a cluster of up to 73 machines as well as through simulation studies, we experimentally demonstrate the efficacy of CUBEFIT.

Flow-Aware Adaptive Pacing to Mitigate TCP Incast in Data center Networks
Shaoujun Zou (Central South University), Jiawei Huang (Central South University), Yutao Zhou (Central South University), Jianxin Wang (Central South University), Tian He (University of Minnesota)

In data center networks, many network-intensive applications leverage large fan-in and many-to-one communication to achieve high performance. However, the special traffic patterns, such as micro-burst and high concurrency, easily cause TCP Incast problem and seriously degrade the application performance. To address the TCP Incast problem, we first reveal theoretically and empirically that alleviating packet burstiness is much more effective in reducing the Incast probability than controlling the congestion window. Inspired by the findings and insights from our experimental observations, we further propose a general supporting scheme Adaptive Pacing (AP), which dynamically adjusts burstiness according to the flow concurrency without any change on switch. Another feature of AP is its broad
applicability. We integrate AP transparently into different TCP protocols (i.e., DCTCP, L2DCT and D2TCP). Through a series of large-scale NS2 simulations, we show that AP significantly reduces the Incast probability across different TCP protocols and the network goodput can be increased consistently by on average 7x under severe congestion.

**Real-Time Power Cycling in Video on Demand Data Centres using Online Bayesian Prediction**
Vincent Marco Sanz (Lancaster University), Zheng Wang (Lancaster University), Barry Porter (Lancaster University)

Energy usage in data centres continues to be a major and growing concern as an increasing number of everyday services depend on these facilities. Research in this area has examined topics including power smoothing using batteries and deep learning to control cooling systems, in addition to optimisation techniques for the software running inside data centres. We present a novel real-time power-cycling architecture, supported by a media distribution approach and online prediction model, to automatically determine when servers are needed based on demand. We demonstrate with experimental evaluation that this approach can save up to 31% of server energy in a cluster. Our evaluation is conducted on typical rack mount servers in a data centre testbed and uses a recent real-world workload trace from the BBC iPlayer, an extremely popular video on demand service in the UK.

**A Distributed Access Control System for Cloud Federations**
Shorouq Alansari (University of Southampton), Federica Paci (University of Southampton), Vladimiro Sassone (University of Southampton)

Cloud federations are a new collaboration paradigm where organizations share data across their private cloud infrastructures. However, the adoption of cloud federations is hindered by federated organizations’ concerns on potential risks of data leakage and data misuse. For cloud federations to be viable, federated organizations’ privacy concerns should be alleviated by providing mechanisms that allow organizations to control which users from other federated organizations can access which data. We propose a novel identity and access management system for cloud federations. The system allows federated organizations to enforce attribute-based access control policies on their data in a privacy-preserving fashion. Users are granted access to federated data when their identity attributes match the policies, but without revealing their attributes to the federated organization owning data. The system also guarantees the integrity of the policy evaluation process by using blockchain technology and Intel SGX trusted hardware. It uses blockchain to ensure that users identity attributes and access control policies cannot be modified by a malicious user, while Intel SGX protects the integrity and confidentiality of the policy enforcement process. We present the access control protocol, the system architecture and discuss future extensions.

**Voyager: Complete Container State Migration**
Shripad Nadgowda (IBM TJ Watson Research Center), Sahil Suneja (IBM TJ Watson Research Center), Nilton Bila (IBM TJ Watson Research Center), Canturk Isci (IBM TJ Watson Research Center)

Due to the small memory footprint and fast startup times offered by container virtualization, made ever more popular by the Docker platform, containers are seeing rapid adoption as a foundational capability to build PaaS and SaaS clouds. For such container clouds, which are fundamentally different from VM clouds, various cloud management services need to be revisited. In this paper, we present our Voyager - just-in-time live container migration service, designed in accordance with the Open Container Initiative (OCI) principles. Voyager is a novel filesystem-agnostic and vendor-agnostic migration service that provides consistent full-system migration. Voyager combines CRUId-based memory migration together with the data federation capabilities of union mounts to minimize migration downtime. With a union view of data between the source and target hosts, Voyager containers can resume operation instantly on the target host, while performing disk state transfer lazily in the background.

**Keddah: Capturing Hadoop Network Behaviour**
Jie Deng (Queen Mary University London), Gareth Tyson (Queen Mary), Félix Cuadrado (Queen Mary University of London), Steve Uhlig (Queen Mary University of London)

As a distributed system, Hadoop heavily relies on the network to complete data processing jobs. While Hadoop traffic is perceived to be critical for job execution performance, the actual behaviour of Hadoop network traffic is still poorly understood. This lack of understanding greatly complicates research relying on Hadoop workloads. In this paper, we explore Hadoop traffic through experimentation. We analyse the generated traffic of multiple types of MapReduce jobs, with varying input sizes, and cluster configuration parameters. As a result, we present Keddah, a toolchain for capturing, modelling and reproducing Hadoop traffic, for use with network simulators. Keddah can be used to create empirical Hadoop traffic models, enabling reproducible Hadoop research in more realistic scenarios.

**A Scalable and Distributed Approach for NFV Service Chain Cost Minimization**
Zijun Zhang (University of Calgary), Zongpeng Li (University of Calgary), Chuan Wu (University of Hong Kong), Chuhanhe Huang (Wuhan University)

Network function virtualization (NFV) represents the latest technology advancement in network service provisioning. Traditional hardware middleboxes are replaced by software programs running on industry standard servers and virtual machines, for service agility, flexibility, and cost reduction. NFV users are provisioned with service chains composed of virtual network functions (VNFs). A fundamental problem in NFV service chain provisioning is to satisfy user demands with minimum system-wide cost. We jointly consider two types of cost in this work: nodal resource cost and link delay cost, and formulate the service chain provisioning problem using nonlinear optimization. Through the method of auxiliary variables, we transform the optimization problem into its separable form, and then apply the alternating direction method of multipliers (ADMM) to design scalable and fully distributed solutions. Through simulation studies, we verify the convergence and efficacy of our distributed algorithm design.

**Elastic Paxos: A Dynamic Atomic Multicast Protocol**
Samuel Benz (Università della Svizzera italiana), Fernando Pedone (Università della Svizzera italiana)

Replication is a common technique used to design reliable distributed systems by masking defective components. To cope with the requirements of modern Internet applications, replication protocols must allow for throughput scalability and dynamic reconfiguration, that is, on-demand replacement or provisioning of system resources. This paper describes Elastic Paxos, a new dynamic atomic multicast protocol that fulfills these requirements. Elastic Paxos allows to dynamically add and remove resources to an online partially replicated state machine. We implemented Elastic Paxos and evaluated its performance in OpenStack, a cloud environment. We demonstrate its practicality to dynamically scale up and down a partially replicated data store with it and to reconfigure a distributed system.

**Boosting The Benefits Of Hybrid SDN**
Wen Wang (McGill University), Wenbo He (McMaster University), Jinshu Su (National University of Defense Technology)
The upgrade of a legacy network to a full software-defined networking (SDN) deployment is usually an incremental process, during which SDN switches and legacy switches coexist in the hybrid network. However, with inappropriate deployment of SDN switches and design of hybrid control, the advantages of SDN control could not exert, and it even results in performance degradation or inconsistency (e.g., loops, black-holes). Therefore, the hybrid SDN requires considerable coordination of the centralized control and distributed routing. In this paper, we propose a solution to handle the heterogeneity caused by distinct forwarding characteristics of SDN and legacy switches, therefore boosting the benefits of hybrid SDN. We plan SDN placement to enhance the SDN controllability over the hybrid network, and conduct traffic engineering considering both the forwarding characteristics of SDN and legacy switches. The experiments with various topologies show that the SDN placement planning and hybrid forwarding yield better network performance especially in the early 70% SDN deployment.

Adopting SDN Switch Buffer: Benefits Analysis and Mechanism Design
Fuliang Li (Northeastern University), Jiannong Cao (The Hong Kong Polytechnic University), Xingwei Wang (Northeastern University), Yinchu Sun (Northeastern University), Tian Pan (Beijing University of Posts and Telecommunication), Xuefeng Liu (The Hong Kong Polytechnic University)

One critical issue in SDN is to reduce the communication overhead between the switches and the controller. Such overhead is mainly caused by handling miss-match packets, because for each miss-match packet, a switch will send a request to the controller asking for forwarding rule. Existing approaches to address this problem generally need to deploy intermediate proxy or authority switches to hold rule copies, so as to reduce the number of requests sent to the controller. In this paper, we argue that using the intrinsic buffer in a SDN switch can also greatly reduce the communication overhead without using additional devices. If a switch buffers each miss-match packet, only a few header fields instead of the entire packet are required to be sent to the controller. Experiment results show that this can reduce 78.7% control traffic and 37% controller overhead at the cost of increasing only 5.6% switch overhead on average. If the proposed flow-granularity buffer mechanism is adopted, only one request message needs to be sent to the controller for a new flow with many arrival packets. Thus the control traffic and controller overhead can be further reduced by 64% and 35.7% respectively on average without increasing the switch overhead.

Short Paper 3: Internet of Things, Smart Cities, and Cyber-Physical Systems
IOT SENTINEL: Automated Device-Type Identification for Security Enforcement in IoT
Markus Miettinen (Technische Universität Darmstadt), Samuel Marchal (Aalto University), Ibbad Hafeez (University of Helsinki), N. Asokan (Aalto University), Ahmad-Reza Sadeghi (Technische Universität Darmstadt), Sasu Tarkoma (University of Helsinki)

With the rapid growth of the Internet-of-Things (IoT), concerns about the security of IoT devices have become prominent. Several vendors are producing IP-connected devices for home and small office networks that often suffer from flawed security designs and implementations. They also tend to lack mechanisms for firmware updates or patches that can help eliminate security vulnerabilities. Securing networks where the presence of such vulnerable devices is given, requires a brownfield approach: applying necessary protection measures within the network so that potentially vulnerable devices can coexist without endangering the security of other devices in the same network. In this paper, we present IoT Sentinel, a system capable of automatically identifying the types of devices being connected to an IoT network and enabling enforcement of rules for constraining the communications of vulnerable devices so as to minimize damage resulting from their compromise. We show that IoT Sentinel is effective in identifying device types and has minimal performance overhead.

Efficient Z-order Encoding Based Multi-model Data Compression in WSNs
Xiaofei Cao (Missouri University of Science and Technology), Sanjay Madria (Missouri University of Science and Technology), Takahiro Hara (Osaka University)

Wireless sensor networks have significant limitations in available bandwidth and energy. The limited bandwidth in sensor networks can cause higher message delivery latency in applications such as monitoring poisonous gas leak. In such applications, there are multi-modal sensors whose values such as temperature, gas concentration, location and CO2 level need to be transmitted together for faster detection and timely assessment of gas leak. In this paper, we propose novel Z-order based data compression schemes (Z-compression) to reduce energy and save bandwidth without increasing the message delivery latency. Instead of using the popular Huffman tree style based encoding, Zcompression uses Z-order encoding to map the multidimensional sensing data into one-dimensional binary stream transmitted using a single packet. Our experimental evaluations using real-world data sets show that Z-compression has a much better compression ratio, energy saving, streaming rate than known schemes like LEC (and adaptive LEC), FELACS and TinyPack for multi-modal sensor data.

PTrack: Enhancing the Applicability of Pedestrian Tracking with Wearables
Yonghang Jiang (City University of Hong Kong), Zhenjiang Li (City University of Hong Kong), Jianping Wang (City University of Hong Kong)
The ability to accurately track pedestrians is valuable for variant application designs. Although pedestrian tracking has been investigated excessively and owned a well-suited sensing platform, the proposed solutions are far from being mature yet. Pedestrian tracking contains step counting and stride estimation two components. Step counting already has commercial products, but the performance is still unreliable and less trustworthy in practice. Stride estimation even stays in the research stage without ready solutions released on the market. Such a non-negligible gap between long-term research investigation and technique’s actual usage exists due to a series of crucial applicability issues unsolved, including design vulnerability to interfering activities, extracting purely body's movement from additive sensor signals, and parameter training without user's intervention. In this paper, we deeply analyze human's gait cycles and obtain inspiring observations to address these issues. We incorporate our techniques into existing pedestrian tracking designs and implement a prototype, PTrack, on LG smartwatch. We find PTrack effectively enhances the system applicability and achieves promising performance under very practical settings.

Source Location Privacy-Aware Data Aggregation Scheduling for Wireless Sensor Networks
Jack Kirton (University of Warwick), Matthew Bradbury (The University of Warwick), Arshad Jhumka (University of Warwick)
Source location privacy (SLP) is an important property for the class of asset monitoring problems in wireless sensor networks (WSNs). SLP aims to prevent an attacker from finding a valuable asset when a WSN node is broadcasting information due to the detection of the asset. Most SLP techniques focus at the routing level, with typically high message overhead. The objective of this paper is to investigate the novel problem of developing a TDMA MAC schedule that can provide SLP. We make a number of important contributions: (i) we develop a novel formalisation of a class of eavesdropping attackers and provide novel formalisations of SLP-aware data aggregation schedules (DAS), (ii) we present a decision procedure to verify whether a DAS schedule is SLP-aware, that returns a counterexample if the schedule is not, similar to model checking, and (iii) we develop a 3-stage distributed algorithm that transforms an initial DAS algorithm into a corresponding SLP-aware schedule against a specific class of eavesdroppers. Our simulation results show that the resulting SLP-aware DAS protocol reduces the capture ratio by 50% at the expense of negligible message overhead.
Velocity Optimization of Pure Electric Vehicles with Traffic Dynamics Consideration
Liuwang Kang (University of Virginia), Haiying Shen (University of Virginia), Ankur Sarkar (University of Virginia)

As Electric Vehicles (EVs) become increasingly popular, their battery-related problems (e.g., short driving range and heavy battery weight) must be resolved as soon as possible. Velocity optimization of EVs to minimize energy consumption in driving is an effective alternative to handle these problems. However, previous velocity optimization methods assume that vehicles will pass through traffic lights immediately at green traffic signals. Actually, a vehicle may still experience a delay to pass a green traffic light due to a vehicle waiting queue in front of the traffic light. In this paper, for the first time, we propose a velocity optimization system which enables EVs to immediately pass green traffic lights without delay. We collected real driving data on a 4.0 km long road section of US-25 highway to conduct extensive trace-driven simulation studies. The experimental results from Matlab and Simulation for Urban MOBility (SUMO) traffic simulator show that our velocity optimization system reduces energy consumption by up to 17.5% compared with real driving patterns without increasing trip time.

PIANO: Proximity-based User Authentication on Voice-Powered Internet-of-Things Devices
Neil Zhengqiang Gong (Iowa State University), Altay Ozen (Iowa State University), Yu Wu (UC Davis), Xiaoyu Cao (Iowa State University), Richard Shin (UC Berkeley), Dawn Song (UC Berkeley), Hongxia Jin (Samsung Research America), Xuan Bao (Google Inc.)

Voice is envisioned to be a popular way for humans to interact with Internet-of-Things (IoT) devices. We propose a proximity-based user authentication method (called PIANO) for access control on such voice-powered IoT devices. PIANO leverages the built-in speaker, microphone, and Bluetooth that voice-powered IoT devices often already have. Specifically, we assume that a user carries a personal voice-powered device (e.g., smartphone, smartwatch, or smartglass), which serves as the user’s identity. When another voice-powered IoT device of the user requires authentication, PIANO estimates the distance between the two devices by playing and detecting certain acoustic signals; PIANO grants access if the estimated distance is no larger than a user-selected threshold. We implemented a proof-of-concept prototype of PIANO. Through theoretical and empirical evaluations, we find that PIANO is secure, reliable, personalizable, and efficient.

Category Information Collection in RFID Systems
Jia Liu (Nanjing University), Shigang Chen (University of Florida), Bin Xiao (The Hong Kong Polytechnic University), Yanyan Wang (Nanjing University), Lijun Chen (Nanjing University)

In RFID-enabled applications, when a tag is put into use and associated with a specific object, the category-related information (e.g., the brands of clothes) about this object might be preloaded into the tag’s memory as required. Since such information reflects the category attributes, all tags in the same category carry the identical category information. To collect this information, we do not need to repeatedly interrogate each tag; one tag’s response in a category is sufficient. In this paper, we investigate the new problem of category information collection in a multi-category RFID system, which is referred to as information sampling. We propose an efficient two-phase sampling protocol (TPS). By quickly zooming into a category and isolating a tag from this category, TPS is able to sample a category by broadcasting only 7.5-bit polling vector (very efficient when compared to the 96-bit tag ID). We theoretically analyze the protocol performance and discuss the optimal parameter settings that minimize the overall execution time. Extensive simulations show that TPS outperforms the benchmark, greatly improving the sampling performance.

Scalable Role-based Data Disclosure Control for the Internet of Things
Ali Yavari (RMIT University), Arezou Soltani Panah (RMIT University), Dimitrios Georgakopoulos (Swinburne University of Technology), Prem Prakash Jayaraman (Swinburne University of Technology), Ron van Schyndel (RMIT University)

The Internet of Things (IoT) is the latest Internet evolution that interconnects billions of devices, such as cameras, sensors, RFID, smart phones, wearable devices, ODBII dongles, etc. Federations of such IoT devices (or ‘textit{things}) provides the information needed to solve many important problems that have been too difficult to harness before. Despite these great benefits, privacy in IoT remains a great concern, in particular when the number of things increases. This presages the need for the development of highly scalable and computationally efficient mechanisms to prevent unauthorised access and disclosure of sensitive information generated by things. In this paper, we address this need by proposing a lightweight, yet highly scalable, data obfuscation technique. For this purpose, a digital watermarking technique is used to control perturbation of sensitive data that enables legitimate users to de-obfuscate perturbed data. To enhance the scalability of our solution, we also introduce a contextualisation service that achieves real-time aggregation and filtering of IoT data for large number of designated users. We then, assess the effectiveness of the proposed technique by considering a health-care scenario that involves data streamed from various wearable and stationary sensors capturing health data, such as heart-rate and blood pressure. An analysis of the experimental results that illustrate the unconstrained scalability of our technique concludes the paper.

Multi-representation based Data Processing Architecture for IoT Applications
Vaibhav Arora (University of California, Santa Barbara), Faisal Nawab (University of California, Santa Barbara), Divyakant Agrawal (University of California, Santa Barbara), Amr El Abbadi (University of California, Santa Barbara)

Internet of Things (IoT) applications like smart cars, smart cities and wearables are becoming widespread and are the future of the Internet. One of the major challenges for IoT applications is efficiently processing, storing and analyzing the continuous stream of incoming data from a large number of connected sensors. We propose a multi-representation based data processing architecture for IoT applications. The data is stored in multiple representations, like rows, columns, graphs which provides support for diverse application demands. A unifying update mechanism based on deterministic scheduling is used to update the data representations, which completely removes the need for data transfer pipelines like ETL (Extract, Transform and Load). The combination of multiple representations, and the deterministic update mechanism, provides the ability to support real-time analytics and caters to IoT applications by minimizing the latency of operations like computing pre-defined aggregates.

Long Term Sensing via Battery Health Adaptation
Greg Jackson (Imperial College London), Zhijin Qin (Imperial College London), Julie A McCann (Imperial College London)

Energy Neutral Operation (ENO) has created the ability to continuously operate wireless sensor networks in areas such as environmental monitoring, hazard detection and industrial IoT applications. Current ENO approaches utilise techniques such as sample rate control, adaptive duty cycling and data reduction methods to balance energy generation, storage and consumption. However, the state of the art approaches makes a strong and unrealistic assumption that battery capacity is fixed throughout the deployment time of an application. This results in scenarios where ENO systems over allocate sensing tasks, therefore as battery capacity
Detecting Time Synchronization Attacks in Cyber-Physical Systems with Machine Learning Techniques
Jingxuan Wang (The University of Hong Kong), Wenting Tu (Shanghai University of Finance and Economics), Lucas C.K. Hui (The University of Hong Kong), Siu Ming Yiu (The University of Hong Kong), Eric Ke Wang (Harbin Institute of Technology Shenzhen Graduate School)

Recently, researchers found a new type of attacks, called time synchronization attack (TS attack), in cyber-physical systems. Instead of modifying the measurements from the system, this attack only changes the time stamps of the measurements. Studies show that these attacks are realistic and practical. However, existing detection techniques, e.g. bad data detection (BDD) and machine learning methods, may not be able to catch these attacks. In this paper, we develop a “first difference aware” machine learning (FDML) classifier to detect this attack. The key concept behind our classifier is to use the feature of “first difference”, borrowed from economics and statistics. Simulations on IEEE 14-bus system with real data from NYISO have shown that our FDML classifier can effectively detect both TS attacks and other cyber attacks.

Speed-based Location Tracking in Usage-based Automotive Insurance
Lu Zhou (Shanghai Jiao Tong University), Qingrong Chen (Shanghai Jiao Tong University), Zutian Luo (Shanghai Jiao Tong University), Haojin Zhu (Shanghai Jiao Tong University), Cailian Chen (Shanghai Jiao Tong University)

Usage-based Insurance (UBI) is regarded as a promising way to offer more accurate insurance premium by profiling driving behaviors. Compared with traditional insurance which considers drivers’ history of accidents, traffic violations and etc, UBI focuses on driving data and can give a more reasonable insurance premium based on the current driving behaviors. Insurers use sensors in smartphone or vehicle to collect driving data (e.g. mileage, speed, hark braking) and compute a risk score based on these data to recalculate insurance premium. Many insurance programs, which are advertised as being privacy-preserving, do not directly use the GPS-based tracking, but it is not enough to protect driver’s location privacy. In real world, many environment factors such as real-time traffic and traffic regulations can influence driving speed. These factors provide the side-channel information about the driving route, which can be exploited to infer the vehicle’s trace. Based on the observation, we propose a novel speed based trajectory inference algorithm which can track drivers only with the speed data and original location. We implement the attack on a public dataset in New Jersey. The evaluation results show that the attacker can recover the route with a high successful rate.

On efficient offloading control in cloud radio access network with mobile edge computing
Tong Li (Tsinghua University), Chathura Sarathchandra Magurawalage (University of Essex), Kezhi Wang (University of Essex), Ke Xu (Tsinghua University), Kun Yang (University of Essex), Haiyang Wang (University of Minnesota at Duluth)

Cloud radio access network (C-RAN) and mobile edge computing (MEC) have emerged as promising candidates for the next generation access network techniques. Unfortunately, although MEC tries to utilize the highly distributed computing resources in close proximity to user equipments equipments (UE), C-RAN suggests to centralize the baseband processing units (BBU) deployed in radio access networks. To better understand and address such a conflict, this paper closely investigates the MEC task offloading control in C-RAN environments. In particular, we focus on perspective of matching problem. Our model smartly captures the unique features in both MEC and C-RAN with respect to communication and computation efficiency constraints. We divide the cross-layer optimization into the following three stages: (1) matching between remote radio heads (RRH) and UEs, (2) matching between BBUs and UEs, and (3) matching between mobile clones (MC) and UEs. By applying the Gale-Shapley Matching Theory in the duplex matching framework, we propose a multi-stage heuristic to minimize the refusal rate for user’s task offloading requests. Trace-based simulation confirms that our solution can successfully achieve near-optimal performance in such a hybrid deployment.

Location Privacy in Mobile Edge Clouds
Ting He (Pennsylvania State University), Ertugrul Ciftcioglu (Army Research Laboratory), Shiqiang Wang (IBM), Kevin Chan (Army Research Laboratory)

In this paper, we consider user location privacy in mobile edge clouds (MECs). MECs are small clouds deployed at the network edge to offer cloud services close to mobile users, and many solutions have been proposed to maximize service locality by migrating services to follow their users. Co-location of a user and his service, however, implies that a cyber eavesdropper observing service migrations between MECs can localize the user up to one MEC coverage area, which can be fairly small (e.g., a femtocell). We consider using chaff services to defend against such an eavesdropper, with focus on strategies to control the chaffs. Assuming the eavesdropper performs maximum likelihood (ML) detection, we consider both heuristic strategies that mimic the user’s mobility and optimized strategies designed to minimize the detection or tracking accuracy. We show that a single chaff controlled by the optimal strategy can drive the eavesdropper’s tracking accuracy to zero when the user’s mobility is sufficiently random. The efficacy of our solutions is verified through extensive simulations.

Approximation Design for Cooperative Relay Deployment in Wireless Networks
Haotian Wang (Shanghai Jiao Tong University), Shilei Tian (Shanghai Jiao Tong University), Xiaofeng Gao (Shanghai Jiao Tong University), Lidong Wu (University of Texas at Tyler), Guihai Chen (Shanghai Jiao Tong University)

In this paper, we aim to maximize users’ satisfaction by deploying limited number of relays in a target region to form a wireless relay network, and define the Deployment of Cooperative Relay (DoCR) problem, which is proved to be NP-complete. We first propose an O(\(\log n\)) approximation algorithm that utilizes the algorithms for budget weighted Steiner tree problem with novel position weighting assignment. We further propose a heuristic method to solve the DoCR problem releasing potential location constraint. Our extensive experiments indicate that the algorithms we propose can significantly improve the total satisfaction of the network. Furthermore, we establish a testbed using USRP to showcase our designs in real scenarios. To the best of our knowledge, we are the first to propose approximation algorithm for relay placement problem to maximize user satisfaction, which has both theoretical and practical significance in the related area.

Dispersing Social Content in Mobile Crowd through Opportunistic Contacts
Lei Zhang (Simon Fraser University), Feng Wang (The University of Mississippi), Jiangchuan Liu (South China Agricultural University)

Short Paper 4: Mobile, Wireless, Edge, and Crowd Computing
Crowdsourced content sharing has become a fast-growing activity in today’s online social networks, where contents of interest are created by diverse source users and conveyed over the network as friends view and reshare. The rapid and boundless propagation in a mobile crowd however often creates severe bottlenecks on the server side and incurs significant energy and monetary costs on the mobile side, particularly with the still expensive 3G/4G cellular connections. This paper presents SoCrowd, a novel framework for large-scale content sharing in a mobile crowd by exploiting contacts, i.e., users happen to move close with such short range low power communications as WiFi and bluetooth being enabled. We formulate the scheduling problem for social content propagation in a mobile crowd with contacts, and present optimal dynamic programming solution, which further motivates a series of practical heuristics. The effectiveness of SoCrowd has been demonstrated by extensive simulations driven by realworld traces and datasets.

A Lightweight Recommendation Framework for Mobile User’s Link Selection in Dense Network
Ji Wang (National University of Defense Technology), Xiaomin Zhu (National University of Defense Technology), Weidong Bao (National University of Defense Technology), Guanlin Wu (National University of Defense Technology)

With the proliferation of mobile devices and the development of communication technology, mobile devices have permeated every aspect of our daily lives. However, in dense network where large crowd of mobile devices try to access to the network simultaneously, the severe interference between mobile devices may incur a remarkable deterioration of the wireless communication quality. How to improve individual’s experience in such scenario is a critical yet open problem. Inspired by the mobile device users’ usage pattern as well as the characteristic of most wireless communication systems, we propose a framework offering uplink/downlink selection recommendation to different mobile device users to enhance their utility in this paper. The design of the framework starts with formulating the problem as a link selection game. Analysis shows that the game can be categorized as a generalized ordinal potential game whose Nash Equilibrium is guaranteed. Then we devise a distributed link selection algorithm to generate a Nash Equilibrium of the game. To accommodate to the characteristic of dense network and the capacity limitation of mobile device, the design of the algorithm shows a light-weight property and does not require each mobile device user to know others’ current selection. The probability of incomplete information gathering is also considered. Extensive experiments are conducted to demonstrate the effectiveness and superiority of the proposed framework. Experimental results show that the global average utility increase rate reaches above 20%, and about 70% mobile device users can benefit from using our framework.

Making Smartphone Smart on Demand for Longer Battery Life
Marco Brocagnoli (The Ohio State University), Xiaorui Wang (The Ohio State University)

A major concern for today’s smartphones is their much faster battery drain than traditional feature phones, despite their greater battery capacities. The difference is mainly contributed by those more powerful but also much more powerconsuming smartphone components, such as the multi-core application processor. While the application processor must be active when any smart apps are being used, it is also unnecessarily wakes up, even during idle periods, to perform operations related to basic phone functions (i.e., incoming calls and text messages). In this paper, we investigate how to increase the battery life of smartphones by minimizing the use of the application processor during idle periods. We find that the application processor is often wakes up by a process running on it, called the Radio Interface Layer Daemon (RILD), which interfaces the user and apps to the GSM/LTE cellular network. In particular, we demonstrate that a great amount of energy could be saved if RILD is stopped, such that the application processor can sleep more often. Based on this key finding, we design a Smart On Demand (SOD) configuration that reduces smartphone idle energy consumption by running RILD operations on a secondary low-power microcontroller. As a result, RILD operations can be handled at much lower energy costs and the application processor is wakes up only when one needs to use any smart apps, in an on-demand manner. We have built a hardware prototype of SOD and evaluated it with real user traces. Our results show that SOD can increase its battery life by up to 2.5 more days.

FADEWICH: Fast Deauthentication over the Wireless Channel
Giulio Lovisotto (University of Oxford), Mauro Conti (University of Padua), Ivan Martinovic (University of Oxford), Gene Tsudik (University of California, Irvine)

Both authentication and deauthentication are instrumental for preventing unauthorized access to computers and other resources. While there are obvious motivating factors for using strong authentication mechanisms, convincing users to deauthenticate is not straightforward, since deauthentication is not considered mandatory. A user who leaves a logged-in workstation unattended (especially for a short time) is typically not inconvenienced in any way; in fact, the other way around – no annoying reauthentication is needed upon return. However, an unattended workstation is trivially susceptible to the well-known “lunchtime attack” by any nearby adversary who simply takes over the departed user’s login session. At the same time, since deauthentication does not intrinsically require user secrets, it can, in principle, be made unobtrusive. To this end, this paper designs the first automatic user deauthentication system – FADEWICH – that does not rely on biometric- or behavior-based techniques (e.g., keystroke dynamics) and does not require users to carry any devices. It uses physical properties of wireless signals and the effect of human bodies on their propagation. To assess FADEWICH’s feasibility and performance, extensive experiments were conducted with its prototype. Results show that it suffices to have nine inexpensive wireless sensors deployed in a shared office setting to correctly deauthenticate all users within six seconds (90% within four seconds) after they leave their workstation’s vicinity. We considered two realistic scenarios where the adversary attempts to subvert FADEWICH and showed that lunchtime attacks fail.

Cognitive Wireless Charger: Sensing-Based Real-Time Frequency Control For Near-Field Wireless Charging
Sang-Yoon Chang (University of Colorado Colorado Springs), Sristi Lakshmi Sravana Kumar (Advanced Digital Sciences Center), Yih-Chun Hu (University of Illinois at Urbana-Champaign)

A recent increase in mobile and IoT devices has led to the advancement of wireless charging. The state-of-the-art wireless charging systems operate at a particular frequency, controlled by the explicit networking from the power-receiving device (which relays the battery status information, useful for the frequency selection), but such control is not designed to cope with the variations in the power receiving device’s placements and alignments (which are more significant in near-field and pseudo-tightly coupled charging applications, as more charging pads are being deployed in the public domains and serving heterogeneous clients). In this work, we analyze the impact of the power transfer performance caused by the power receiver’s load, distance, and coil alignment/overlap and introduce cognitive wireless charger (CWC), which adaptively controls the operating frequency in real-time using implicit feedback from sensing for optimal operations. In addition to the theoretical and LTSpice-based simulation analysis, we build a prototype compatible to the Qi standard and analyze the performance of CWC with it. Through our analyses, we establish that frequency control achieves performance gains in inductive-coupling charging applications and is sensitive to the variations in the placement and alignment between the power-transmitting and the power-receiving coils. Our prototype, when CWC is turned off, has comparable performance to the commercial-grade Qi wireless chargers and, with CWC enabled, demonstrates significant improvement over modern wireless chargers.
Density and Mobility-driven Evaluation of Broadcast Algorithms for MANETs
Raziel Carvajal Gómez (University of Neuchatel), Intí González-Herrera (LaBRI/University of Bordeaux), Yérom-David Bromberg (University of Rennes 1), Laurent Réveillère (University of Bordeaux), Etienne Rivière (University of Neuchatel)

Broadcast is a fundamental operation in Mobile Ad-Hoc Networks (MANETs). A large variety of broadcast algorithms have been proposed. They differ in the way message forwarding between nodes is controlled, and in the level of information about the topology that this control requires. Deployment scenarios for MANETs vary widely, in particular in terms of nodes density and mobility. The choice of an algorithm depends on its expected coverage and energy cost, which are both impacted by the deployment context. In this work, we are interested in the comprehensive comparison of the costs and effectiveness of broadcast algorithms for MANETs depending on target environmental conditions. We describe the results of an experimental study of five algorithms, representative of the main design alternatives. Our study reveals that the best algorithm for a given situation, such as a high density and a stable network, is not necessarily the most appropriate for a different situation such as a sparse and mobile network. We identify the algorithms characteristics that are correlated with these differences and discuss the pros and cons of each design.

Energy-Aware CPU Frequency Scaling for Mobile Video Streaming
Wenjie Hu (The Pennsylvania State University), Guohong Cao (The Pennsylvania State University)

The energy consumed by video streaming includes the energy consumed for data transmission and CPU processing, which are both affected by the CPU frequency. High CPU frequency can reduce the data transmission time but it consumes more CPU energy. Low CPU frequency reduces the CPU energy but increases the data transmission time and then increases the energy consumption. In this paper, we aim to reduce the total energy of mobile video streaming by adaptively adjusting the CPU frequency. Based on real measurement results, we model the effects of CPU frequency on TCP throughput and system power. Based on these models, we propose an Energy-aware CPU Frequency Scaling (EFS) algorithm which selects the CPU frequency that can achieve a balance between saving the data transmission energy and CPU energy. Since the downloading schedule of existing video streaming apps is not optimized in terms of energy, we also propose a method to determine when and how much data to download. Through trace-driven simulations and real measurement, we demonstrate that the EFS algorithm can reduce 30% of energy for the Youtube app, and the combination of our download method and EFS algorithm can save 50% of energy than the default Youtube app.

Crazy Crowd Sourcing to Mitigate Resource Scarcity
Nova Ahmed (North South University), Md Mahfuzur Rahman Siddiquee (Independent Researcher), Refaya Karim (North South University), Mohsina Zaman (Independent Researcher), Sayed Mahmudul Alam (North South University), Syed Fahim Asraf (North South University)

Resource scarcity prohibits developing country population in many ways from ubiquitous services. One such service is providing information about the best route for an ambulance in a crisis situation due to lack of proper road network information and GPS data. We have worked on a routing method in Dhaka, Bangladesh and utilized the power of crowd sourcing in times of resource scarcity. We share our challenges and opportunities that opened up followed by the challenges in this paper.

Detecting Rogue AP with the Crowd Wisdom
Tongqing Zhou (National University of Defense Technology), Zhiping Cai (National University of Defense Technology), Bin Xiao (The Hong Kong Polytechnic University), Yueyue Chen (National University of Defense Technology), Ming Xu (National University of Defense Technology)

WiFi networks are vulnerable to rogue AP attacks in which an attacker sets up an imposter AP to lure mobile users to connect. The attacker can eavesdrop on the communication, severely threatening users’ privacy. Existing rogue AP detection solutions are confined to some specific attack scenarios (e.g., by relaying the traffic to a target AP) or require additional hardware. In this paper, we propose a crowdsensing based approach, named CRAD, to detect rogue APs in camouflage without specialized hardware requirement. CRAD exploits the spatial correlation of RSS to identify a potential imposter, which should be at a different location from the legitimate one. The RSS measurements collected from the crowd facilitate a robust profile and minimize the inaccuracy effect of a single RSS value. As a result, CRAD can filter out abnormal samples sensed in the realtime by dynamically matching the profile. We evaluate our approach with both a public dataset and a real prototype. The results show that CRAD can yield 90% detection accuracy and precision with proper crowd presence, even when the rogue AP is launched close to the legitimate one (e.g., within 1m).

Short Paper 5: Distributed Big Data Systems and Analytics
Towards Multilingual Automated Classification Systems
Aibek Musaev (University of Alabama), Calton Pu (Georgia Institute of Technology)

In this paper we propose and evaluate three approaches for automated classification of texts in over 60 languages without the need for a manually annotated dataset in those languages. All approaches are based on the randomized Explicit Semantic Analysis method using multilingual Wikipedia articles as their knowledge repository. We evaluate the proposed approaches by classifying a Twitter dataset in English and Portuguese into relevant and irrelevant items with respect to landslide as a natural disaster, where the highest achieved F1-score is 0.93. These approaches can be used in various applications where multilingual classification is needed, including multilingual disaster reporting using Social Media to improve coverage and increase confidence. As illustration, we present a demonstration that combines data from physical sensors and social networks to detect landslide events reported in English and Portuguese.

The Joint Effects of Tweet Content Similarity and Tweet Interactions for Topic Derivation
Robertus Nugroho (Macquarie University), Weiliang Zhao (Macquarie University), Jian Yang (Macquarie University), Cecile Paris (CSIRO – ICT Centre), Surya Nepal (CSIRO)

Interactions among tweets, i.e., mentions, retweets, replies, are important factors contributing to the quality of topic derivation on Twitter. If applied correctly, the incorporation of tweet interactions can significantly improve the quality of topic derivation in comparison with approaches that are mainly based on the content similarity analysis. However, how interactions can be measured and integrated with content similarity for topic derivation remains a challenge. In previous work, the strength of tweet-to-tweet relationship has been computed by simply adding measures for content similarity, mentions, and reply-retweets. This simple linear addition does not accurately reflect the various impacts these factors have on tweet relationships. In order to address this issue, we propose a joint probability model that can effectively integrate the effects of the content similarity, mentions, and reply-retweets to measure the tweet relationship for the purpose of topic
derivation. The proposed method is based on matrix factorization techniques, which enables a flexible implementation on a distributed system in an incremental manner. Experimental results show that the proposed model results in a significant improvement in the quality of topic derivation over existing methods.

**Timed-release of Self-emerging Data using Distributed Hash Tables**  
Chao Li (University of Pittsburgh), Balaji Palanisamy (University of Pittsburgh)

Releasing private data to the future is a challenging problem. Making private data accessible at a future point in time requires mechanisms to keep data secure and undiscovered so that protected data is not available prior to the legitimate release time and the data appears automatically at the expected release time. In this paper, we develop new mechanisms to support self-emerging data storage that securely hide keys of encrypted data in a Distributed Hash Table (DHT) network that makes the encryption keys automatically appear at the predetermined release time so that the protected encrypted private data can be decrypted at the release time. We show that a straightforward approach of privately storing keys in a DHT is prone to a number of attacks that could either make the hidden data appear before the prescribed release time (release-ahead attack) or destroy the hidden data altogether (drop attack). We develop a suite of self-emerging key routing mechanisms for securely storing and routing encryption keys in the DHT. We show that the proposed scheme is resilient to both release-ahead attack and drop attack as well as to attacks that arise due to traditional churn issues in DHT networks. Our experimental evaluation demonstrates the performance of the proposed schemes in terms of attack resilience and churn resilience.

**Caching for Pattern Matching Queries in Time Evolving Graphs: Challenges and Approaches**  
Muhammad Nisar (University of Georgia), Sahar Voghie (University of Georgia), Lakshmish Ramaswamy (University of Georgia)

Pattern matching is an important class of problems related to graphs. It is a fundamental problem for many applications and has been extensively studied in literature. With the advent of huge graphs, the challenges in this domain have increased manifold. Consequently a lot of recent research has led to new architectures and approaches for optimized solutions to the pattern matching problem. A vast majority of these graphs hardly remain static and constantly evolve over time (like social networks, web graphs, etc). Recently, caching has been studied in the context of static graphs to optimize the throughput of query processing systems. In this paper, we list the challenges in caching in the context of Time Evolving Graphs (TEGs). Amongst others, one major challenge is consistency which entails to making sure the cache is consistent with the streaming changes. We propose an approach to successfully implement caching that addresses those issues and based on the initial results, we see significant gains in the overall performance of system.

**GraphA: Adaptive Partitioning for Natural Graphs**  
Dongsheng Li (National University of Defense Technology), Chengfei Zhang (National University of Defense Technology), Jinyan Wang (National University of Defense Technology), Zhaoning Zhang (National University of Defense Technology), Yiming Zhang (National University of Defense Technology)

Large-scale graph computation is central to applications ranging from language processing to social networks. However, natural graphs tend to have skewed power-law distributions where a small subset of the vertices have a large number of neighbors. Existing graph-parallel systems suffer from load imbalance, high communication cost, or suboptimal and complex processing. In this paper we present GraphA, an Adaptive approach to efficient partitioning and computation of large-scale natural graphs. GraphA provides an adaptive and uniform graph partitioning algorithm, which partitions the datasets in a load-balanced manner by using an incremental number of hash functions. We have implemented GraphA both on Spark and on GraphLab. Extensive evaluation shows that GraphA remarkably outperforms state-of-the-art graph-parallel systems (GraphX and PowerLyra) in ingress time, execution time and storage overhead, for both real-world and synthetic graphs.

**Parallel Algorithm for Core Maintenance in Dynamic Graphs**  
Na Wang (Huazhong University of Science and Technology), Dongxiao Yu (Huazhong University of Science and Technology), Hai Jin (Huazhong University of Science and Technology), Chen Qian (Huazhong University of Science and Technology), Xia Xie (Huazhong University of Science and Technology), Qiang-Sheng Hua (Huazhong University of Science and Technology)

This paper initiates the studies of parallel algorithm for core maintenance in dynamic graphs. The core number is a fundamental index reflecting the cohesiveness of a graph, which is widely used in large-scale graph analytics. We investigate the parallelism in the core update process when multiple edges and vertices are inserted. Specifically, we discover a structure called superior edge set, the insertion of edges in which can be processed in parallel. Based on the structure of superior edge set, an efficient parallel algorithm is then devised. To the best of our knowledge, the proposed algorithm is the first parallel one for the fundamental core maintenance problem. Finally, extensive experiments are conducted on different types of real-world and synthetic datasets, and the results illustrate the efficiency, stability and scalability of the proposed algorithm. The algorithm shows a significant speedup in the processing time compared with previous results that sequentially handle edge and vertex insertions.

**DHCRF: A Distributed Conditional Random Field Algorithm on Heterogeneous CPU-GPU Cluster for Big Data**  
Ai Wei (Hunan University), Li Kenli (Hunan University), Chen Cen (Hunan University), Peng Jiwu (Hunan University), Li Keqin (Hunan University)

As one of the most recognized models in machine learning, the conditional random fields (CRF) has been widely used in many applications. As the parameter estimation of CRF is highly time-consuming, how to improve the performance of CRF has received significant attention, in particular in the big data environment. To deal with large-scale data, CPU-based or GPU-based parallelization solutions have been proposed to improve performance. However, the problem is an ongoing one. In this paper, we focus on the big data environment and propose a distributed CRF on a heterogeneous CPU-GPU cluster called DHCRF. Our approach differs from previous work. Specifically, it leverages a three-stage heterogeneous Map and Reduce operation to improve the performance, making full use of CPU-GPU collaborative computing capabilities in a big data environment. Furthermore, by combining elastic data partition and intermediate results multiplexing method, the distributed CRF is optimized. Elastic data partition is performed to keep the load balanced, and the intermediate results multiplexing method is adopted to reduce data communication. Experimental results show that the DHCRF outperforms the baseline CRF algorithm and the CPU-based parallel CRF algorithm with notable performance improvement while maintaining competitive correctness at the same time.

**Towards New Abstractions for Implementing Quorum-based Systems**  
Tormod Erevik Lea (University of Stavanger), Leander Jehl (University of Stavanger), Heim Meling (University of Stavanger)
This paper introduces Gorums, a novel RPC framework for building fault tolerant distributed systems. Gorums offers a flexible and simple quorum call abstraction, used to communicate with a set of processes, and to collect and process their responses. Gorums provides separate abstractions for (a) selecting processes for a quorum call and (b) processing replies. These abstractions simplify the main control flow of protocol implementations, especially for quorum-based systems, where only a subset of the replies to a quorum call need to be processed. To show that Gorums can be used in practical systems, we implemented EPaxos’ latency-efficient quorum system, and ran experiments using a key-value storage. Our results show that Gorums’ abstractions can provide additional performance benefits to EPaxos.

Selective Traffic Offloading On the Fly: a Machine Learning Approach
Zaiyang Tang (Huazhong University of Science and Technology), Peng Li (The University of Aizu), Song Guo (The Hong Kong Polytechnic University), Xiaofei Liao (Huazhong University of Science and Technology), Hai Jin (Huazhong University of Science and Technology), Daqing Zhang (Institut Mines-Telecom, Telecom SudParis)

It has been well recognized that network transmission constitutes a large portion of smartphone energy consumption, mainly because of the tail energy caused by cellular network interface. Traffic offloading has been proposed to reduce energy by letting a smartphone offload network traffic to its neighbors in vicinity via low-power direct connections (e.g., WiFi Direct or Bluetooth). Our experiments conducted in a realistic environment reveal that energy efficiency cannot be improved or even deteriorates without a carefully designed offloading strategy. In this paper, we propose a selective traffic offloading scheme implemented as a smartphone middleware in a software-defined fashion, which consists of a packet classifier and a traffic scheduler. Using a light-weight machine learning approach exploiting unique smartphone context information, the packet classifier identifies packets generated on the fly as offloadable or not with substantially improved efficiency and feasibility on resource limited smartphones compared to traditional approaches. Both testbed and simulation based experiments are conducted and the results show that our proposal always attains the superior performance on a number of comparison metrics.

A Fast Heuristic Attribute Reduction Algorithm using Spark
Minchengu Chen (Wuhan University of Technology), Jingling Yuan (Wuhan University of Technology), Lin Li (Wuhan University of Technology), Dongling Liu (Wuhan University of Technology), Tao Li (University of Florida)

Energy data, which consists of energy consumption statistics and other related data in green data centers, grows dramatically. The energy data has great value, but many attributes within it are redundant and unnecessary. Thus attribute reduction for the energy data has been conceived as a critical step. However, many existing attribute reduction algorithms are often computationally time-consuming. To address these issues, we extend the methodology of rough sets to construct data center energy consumption knowledge representation system. By taking good advantage of in-memory computing, an attribute reduction algorithm for energy data using Spark is proposed. In this algorithm, we use a heuristic formula for measuring the significance of attribute to reduce search space, and an efficient algorithm for simplifying energy consumption decision table, which further improves the computation efficiency. The experimental results show the speed of our algorithm gains up to 0.28X performance improvement over the traditional attribute reduction algorithm using Spark.

Profiling Users by Modeling Web Transactions
Radek Tomsu (Aalto University), Samuel Marchal (Aalto University), N. Asokan (Aalto University)

Users of electronic devices, e.g., laptop, smartphone, etc. have characteristic behaviors while surfing the Web. Profiling this behavior can help identify the person using a given device. In this paper, we introduce a technique to profile users based on their web transactions. We compute several features extracted from a sequence of web transactions and use them with one-class classification techniques to profile a user. We assess the efficacy and speed of our method at differentiating 25 synthetic users on a benchmark dataset (from a major security vendor) representing 6 months of web traffic monitoring from a small enterprise network.

JeCache: Just-Enough Data Caching with Just-in-Time Prefetching for Big Data Applications
Yifeng Luo (Fudan University), Jia Shi (Fudan University), Shuigeng Zhou (Fudan University)

Big data clusters introduce an intermediate cache layer between the computing frameworks and the underlying distributed file systems, to enable upper-level applications or end users to efficiently access big datasets in cache and effectively share them among different computing frameworks. As caches are shared by multiple applications or end users, directly applying existing on-demand caching strategies will result in intense conflicts, when big datasets are cached as a whole. Meanwhile, big data applications usually involve massive numbers of file scans, cached-in-data blocks may have little chance of being accessed before they are cached out to make way for other on-demand data blocks. Thus, it is unwise to cache data blocks long before they are actually accessed. In this paper, we propose a novel just-enough big data caching scheme for just-in-time block prefetching to improve the cache effectiveness of big data clusters. With just-in-time block prefetching, a block is cached in just before the task begins to process the block, rather than being cached in along with other blocks of the same dataset being processed. We monitor block accesses to measure the average processing time of data blocks, and then estimate the minimal number of blocks that should be kept in cache for a big dataset, so that the speed of data processing matches with that of data prefetching, and each upper-level task can obtain its input blocks from cache just in time. Our experimental results show that the proposed cache method can restrain over-requirement of cache resources in big data applications, and provides the same performance improvement as when all data blocks are cached.

Short Paper 6: Security, Privacy, Trust, and Fault Tolerance in Distributed Systems
Proximity Awareness Approach to Enhance Propagation Delay on the Bitcoin Peer-to-Peer Network
Muntadher Fadhil Sallal (University of Portsmouth), Gareth Owenson (University of Portsmouth), Mo Adda (University of Portsmouth)

In the Bitcoin system, a peer-to-peer electronic currency system, the delay overhead in transaction verification prevents the Bitcoin from gaining increasing popularity nowadays as it makes the system vulnerable to double spend attacks. This paper introduces a proximity-aware extension to the current Bitcoin protocol, named Bitcoin Clustering Based Ping Time protocol (BCBPT). The ultimate purpose of the proposed protocol, that is based on how the clusters are formulated and the nodes define their membership, is to improve the transaction propagation delay in the Bitcoin network. In BCBPT, the proximity of connectivity in the Bitcoin network is increased by grouping Bitcoin nodes based on ping latencies between nodes. We show, through simulations, that the proximity base ping latency defines better clustering structures that optimize the performance of the transaction propagation delay. The reduction of the communication link cost measured by the information propagation time between nodes is mainly considered as a key reason for this improvement. Bitcoin Clustering Based Ping Time protocol is more effective at reducing the transaction propagation delay compared to the existing clustering protocol (LBC) that we proposed in our previous work.
Catch Me If You Can: Detecting Compromised Users Through Partial Observation on Networks
Derek Wang (Deakin University), Sheng Wen (Deakin University), Jun Zhang (Deakin University), Surya Nepal (Data61), Yang Xiang (Deakin University), Wanlei Zhou (Deakin University)

People are suffering from a range of risks in the ubiquitous networks of current world, such as rumours spreading in social networks, computer viruses propagating throughout the Internet and unexpected failures happened in Smart grids. We usually monitor only a few users of detecting various risks due to the resource constraints and privacy protection. This leads to a critical problem to detect compromised users who are out of surveillance. In this paper, we propose a risk assessment method to address this problem. The aim is to assess the security status of unmonitored users according to the limited information collected from monitored users in networks. There are two innovative techniques developed: First, we identify the source of risk propagation by inversely disseminating risks from the influenced (by rumours) or infected (by viruses) monitored users. We show a new finding that the ones who synchronously receive the risk copies from all monitored users are most likely to be the sources. Second, we propose a microscopic mathematical model to present the risk propagation from the exposed sources. This model forms a discriminant to classify the compromised users from others. For evaluations, we collect three real networks on which we launch simulated risk propagation and then sample the status of monitored users. The experiment results show that our method is effective and the result of risk assessment well matches the real status of the unmonitored users.

Location Privacy Breach: Apps Are Watching You in Background
Dachuan Liu (College of William & Mary), Xing Gao (College of William & Mary), Haining Wang (University of Delaware)

Smartphone users can conveniently install a set of apps that provide Location Based Service (LBS) from markets. These LBS-based apps facilitate users in many application scenarios, but they raise concerns on the breach of privacy related to location access. Smartphone users can hardly perceive location access, especially when it happens in background. In comparison to location access in foreground, location access in background could result in more serious privacy breach because it can continuously know a user’s locations. In this paper, we study the problem of location access in background, and especially perform the first measurement of this background action on the Google app market. Our investigation demonstrates that many popular apps conduct location access in background within short intervals. This enables these apps to collect a user’s location trace, from which the important personal information, Points of Interest (PoIs), can be recognized. We further extract a user's movement pattern from the PoIs, and utilize it to measure the extent of privacy breach. The measurement results also show that using the combination of movement pattern related metrics and the other PoI related metrics can help detect the privacy breach in an earlier manner than using either one of them alone.

Android Malware Detection using Complex-Flows
Feng Shen (SUNY Buffalo), Justin Del Vecchio (SUNY Buffalo), Aziz Mohaisen (SUNY Buffalo), Steven Y. Ko (SUNY Buffalo), Lukasz Ziarek (SUNY Buffalo)

This paper proposes a new technique to detect mobile malware based on information flow analysis. Our approach examines the structure of information flows to identify patterns of behavior present in them and which flows are related, those that share partial computation paths. We call such flows Complex-Flows, as their structure, patterns, and relations accurately capture the complex behavior exhibited by both recent malware and benign applications. N-gram analysis is used to identify unique and common behavioral patterns present in Complex-Flows. The N-gram analysis is performed on sequences of API calls that occur along Complex-Flows’ control flow paths. We show the precision of our technique by applying it to different data sets totaling 7,798 apps. These data sets consist of both recent and older generation benign and malicious apps to demonstrate the effectiveness of our approach across different generations of apps.

Privacy Implications of DNSSEC Look-aside Validation
Aziz Mohaisen (SUNY Buffalo), Zhongshu Gu (IBM Research), Kui Ren (SUNY Buffalo)

To complement DNSSEC operations, DNSSEC Look-aside Validation (DLV) is designed for alternative off-path validation. While DNS privacy attracts a lot of attention, the privacy implications of DLV are not fully investigated and understood. In this paper, we take a first in-depth look into DLV, highlighting its lax specifications and privacy implications. By performing extensive experiments over datasets of domain names under comprehensive experimental settings, our findings firmly confirm the privacy leakages caused by DLV. We discover that a large number of domains that should not be sent to DLV servers are being leaked. We explore the root causes, including the lax specifications of DLV. We also propose two approaches to fix the privacy leakages. Our approaches require trivial modifications to the existing DNS standards and we demonstrate their cost in terms of latency and communication.

FlipNet: Modeling Covert and Persistent Attacks on Networked Resources
Sudip Saha (Virginia Polytechnic Institute and State University), Anil Vullikanti (Virginia Polytechnic Institute and State University), Mahantesh Halappanavar (Pacific Northwest National Lab)

Persistent and zero-day attacks have increased considerably in the recent past in terms of scale and impact. Security experts can no longer rely only on known defenses and thereby protect their resources permanently. It is increasingly common now to observe attackers being able to repeatedly break systems exploiting new vulnerabilities and defenders hardening systems with new measures. To model this phenomenon of the repeated takeover of the computing resources by system administrators and malicious attackers, a novel game framework, FlipIt, has been proposed by [Van Dijk et al. 2013] for a system consisting of a single resource. In this paper, we extend this and develop FlipNet, which is a repeated game framework for a networked system of multiple resources. This game involves two players—a defender and an attacker. Each player's objective is to maximize its gain (i.e., its control over the nodes in the network with stealthy moves), while minimizing the cost for making those moves. This leads to a novel and natural game formulation, with a very complex strategy space, that depends on the network structure. We show that finding the best response strategy for both the defender and attacker is NP-hard. In a key result in this study, we show that the attacker's gain for an instance of the game has a type of diminishing marginal return property, which leads to a near-optimal algorithm for maximizing the attacker's gain. We examine the impact of network structure on the strategy space using simulations.

Understanding the Market-level and Network-level Behaviors of the Android Malware Ecosystem
Chao Yang (Niara, Inc.), Jialong Zhang (IBM Research), Guofei Gu (Texas A&M University)

The prevalence of malware in Android marketplaces is a growing and significant problem. Most existing studies focus on detecting Android malware or designing new security extensions to defend against specific types of attacks. In this paper, we perform an empirical study on analyzing the market-level and network-level behaviors of the Android malware ecosystem. We focus on studying whether there are interesting characteristics of those market accounts that distribute malware...
and specific networks that are mainly utilized by Android malware authors. We further investigate community patterns among Android malware from the perspective of their market account infrastructure and remote server infrastructure. Spurred by these analysis, we design a novel community inference algorithm to find more malicious apps by exploiting their community relationships. By using a small seed set (50) of known malicious apps, we can effectively find another extra 20 times of malicious apps, while maintaining considerable accuracy higher than 94%.

**EnGarde: Mutually-Trusted Inspection of SGX Enclaves.**
Hai Nguyen (Rutgers University), Vinod Ganapathy (Rutgers University)

Intel’s SGX architecture allows cloud clients to create enclaves, whose contents are cryptographically protected by the hardware even from the cloud provider. While this feature protects the confidentiality and integrity of the client’s enclave content, it also means that enclave content is completely opaque to the cloud provider. Thus, the cloud provider is unable to enforce policy compliance on enclaves. In this paper, we introduce EnGarde, a system that allows cloud providers to ensure SLA compliance on enclave content. In EnGarde, cloud providers and clients mutually agree upon a set of policies that the client’s enclave content must satisfy. EnGarde executes when the client provisions the enclave, ensuring that only policy-compliant content is loaded into the enclave. EnGarde is able to achieve its goals without compromising the security guarantees offered by the SGX, and imposes no runtime overhead on the execution of enclave code. We have demonstrated the utility of EnGarde by using it to enforce a variety of security policies on enclave content.

**Truthful Online Auction for Cloud Instance Subletting**
Yifei Zhu (Simon Fraser University), Silvery Fu (Simon Fraser University), Jiangchuan Liu (Simon Fraser University), Yong Cui (Tsinghua University)

Despite that IaaS users are busy scaling up/out their cloud instances to meet the ever-increasing demands, the dynamics of their demands, as well as the coarse-grained billing options offered by leading cloud providers, have led to substantial instance underutilization in both temporal and spatial domains. This paper theoretically examines an instance subletting service, where underutilized instances are leased to others within user-specified periods. Serving as a secondary market that complements the existing instance market of IaaS providers, we specifically identify the theoretical challenges in instance subletting services, and design an online auction mechanism to make allocation and pricing decisions for the instances to be sublet. Our mechanism guarantees truthfulness and individual rationality with the best possible competitive ratio. Extensive trace-driven simulations show that our proposed mechanism achieves significant performance gains in both cost and social welfare.

Giuseppe Antonio Di Luna (La Sapienza), Paola Flocchini (University of Ottawa), Taisuke Izumi (Nagoya Institute of Technology), Tomoko Izumi (College of Information Science and Engineering), Nicola Santoro (Carleton University), Giovanni Viglietta (University of Ottawa)

In this paper we investigate the computational power of population protocols under some unreliable or weaker interaction models. More precisely, we focus on two features related to the power of interactions: omission failures and one-way communications. We start our investigation by providing a complete classification of all the possible models arising from the aforementioned weaknesses, and establishing the computational hierarchy of these models. We then address for each model the fundamental question of what additional power is necessary and sufficient to completely overcome the model’s weakness and make it able to simulate faultless two-way protocols. We answer this question by presenting simulators that work under certain assumptions and by proving that simulation is impossible without such assumptions.

**Distributed Fault Tolerant Linear System Solvers based on Erasure Coding**
Xuejiao Kang (Purdue University–West Lafayette), David F. Gleich (Purdue University–West Lafayette), Ahmed Sameh (Purdue University–West Lafayette), Ananth Grama (Purdue University–West Lafayette)

We present efficient coding schemes and distributed implementations of erasure coded linear system solvers. Erasure coded computations belong to the class of algorithmic fault tolerance schemes. They are based on augmenting an input dataset, executing the algorithm on the augmented dataset, and in the event of a fault, recovering the solution from the corresponding augmented solution. This process can be viewed as the computational analog of erasure coded storage schemes. The proposed technique has a number of important benefits: (i) as the hardware platform scales in size and number of faults, our scheme yields increasing improvement in resource utilization, compared to traditional schemes; (ii) the proposed scheme is easy to code – the core algorithms remain the same; and (iii) the general scheme is flexible – accommodating a range of computation and communication tradeoffs. We present new coding schemes for augmenting the input matrix that satisfy the recovery equations of erasure coding with high probability in the event of random failures. These coding schemes also minimize fill (non-zero elements introduced by the coding block), while being amenable to efficient partitioning across processing nodes. We demonstrate experimentally that our scheme adds minimal overhead for fault tolerance, yields excellent parallel efficiency and scalability, and is robust to different fault arrival models.

**Preserving Incumbent Users’ Privacy in Exclusion-Zone-Based Spectrum Access Systems**
Yanzhi Dou (Virginia Tech), He Li (Virginia Tech), Kexiong Zeng (Virginia Tech), Jinshan Liu (Virginia Tech), Yaling Yang (Virginia Tech), Bo Gao (Chinese Academy of Sciences), Kui Ren (SUNY Buffalo)

Dynamic spectrum access (DSA) technique has emerged as a fundamental approach to mitigate the spectrum scarcity problem. As a key form of DSA, the government is proposing to release more federal spectrum for sharing with commercial wireless users. However, the flourish of federal commercial sharing hinges upon how the federal privacy is managed. In current DSA proposals, the sensitive exclusion zone (E-Zone) information of federal incumbent users (IUs) needs to be shared with a spectrum access system (SAS) to realize spectrum allocation. However, SAS is not necessarily trust-worthy for holding the sensitive IU E-Zone data, especially considering that FCC allows some industry third parties (e.g., Google) to operate SAS for better efficiency and scalability. Therefore, the current proposals dissatisfy the IUs’ privacy requirement. To address the privacy issue, this paper presents an IU-privacy preserving SAS (IP-SAS) design, which realizes the spectrum allocation process through secure computation over ciphertext based on homomorphic encryption so that none of the IU EZone information is exposed to SAS. This paper also proposes mechanisms to prevent malicious parties from compromising IP-SAS. We prove the privacy-preserving properties of IP-SAS and demonstrate the scalability and practicality of IP-SAS using experiments based on real-world data. Evaluation results show that IP-SAS can respond an SU’s spectrum request in 1.25 seconds with communication overhead of 17.8 KB.
**Demonstration Track Paper Abstracts**

**Demo 1: Distributed Applications Cluster**

**LITMUS: Towards Multilingual Reporting of Landslides**
Ailek Musaev (University of Alabama), Qixuan Hou (Georgia Institute of Technology), Yang Yang (Georgia Institute of Technology), Calton Pu (Georgia Institute of Technology)

LITMUS is a real-time online and openly accessible service that collects high-quality information on landslide events from social media. This service uses disaster-related keywords, such as "landslide" and "mudslide," to analyze messages posted by English-speaking users. However, comprehensive coverage of disasters must include multilingual support as there are events that are reported in languages other than English. We discuss and evaluate possible implementations of such support using "native" and "translated" approaches. "Native" approach involves a complete reimplementation of the existing infrastructure in another language whereas in the "translated" approach the existing infrastructure can be used without modification. As an illustration, we present a demo that extends LITMUS to implement a "native" approach for multilingual reporting of landslide events.

**Pythia: A System for Online Topic Discovery of Social Media Posts**
Ioiliana Litou (Athens University of Economics and Business), Vana Kalogeraki (Athens University of Economics and Business)

Social media constitute nowadays one of the most common communication mediums. Millions of users exploit them daily to share information with their community in the network via messages, referred as \textit{posts}. The massive volume of information shared is extremely diverse and covers a vast spectrum of topics and interests. Automatically identifying the topics of the posts is of particular interest as this can assist in a variety of applications, such as event detection, trends discovery, expert finding etc. However, designing an automated system that requires no human agent participation to identify the topics covered in posts published in Online Social Networks (OSNs) presents manifold challenges. First, posts are unstructured and commonly short, limited to just a few characters. This prevents existing classification schemes to be directly applied in such cases, due to sparseness of the text. Second, new information emerges constantly, hence building a learning corpus from past posts may fail to capture the ever-evolving information emerging in OSNs. To overcome the aforementioned limitations we have designed Pythia, an automated system for short text classification that exploits the Wikipedia structure and articles to identify the topics of the posts. The topic discovery is performed in two phases. In the first step, the system exploits Wikipedia categories and articles of the corresponding categories to build the training corpus for the supervised learning. In the second step, the text of a given post is augmented using a text enrichment mechanism that extends the post with relevant Wikipedia articles. After the initial steps are performed, we deploy k-NN classifier to determine the topic(s) covered in the original post.

**Data-driven Serendipity Navigation in Urban Places**
Xiaoyu Ge (University of Pittsburgh), Ameya Daphalapurkar (University of Pittsburgh), Manali Shimpri (University of Pittsburgh), Kohli Darpan (University of Pittsburgh), Konstantinos Pelechrinis (University of Pittsburgh), Panos Chrysanthis (University of Pittsburgh), Demetrios Zeinalipour-Yazti (Max Planck Institute for Informatics and University of Cyprus)

With the proliferation of mobile computing and the ability to collect detailed data for the urban environment a number of systems that aim at providing Points of Interest (POIs) and tour recommendations have appeared. The overwhelming majority of these systems aims at providing an optimal recommendation, where optimality refers to objectives of minimizing the distance to be covered or maximizing the quality of the POIs recommended. A major problem is that by focusing on the optimization of these objectives, there remains little room to the user for serendipity. Urban and social scientists have identified serendipity, i.e., the ability to come across unexpected places, as a feature that makes a city livable. In this work, we introduce a prototype of an experimental platform for evaluating venue recommendation algorithms by providing informative tour recommendations based on the suggested venues. Our prototype system integrates the notion of serendipity in urban navigation at both the venue as well as the route recommendation level without compromising the quality and diversity of the recommended POIs. In addition, our system allows the user to upload their own algorithms and explore their performance as compared to many well-known algorithms.

**Toward An Integrated Approach to Localizing Failures in Community Water Networks (DEMO)**
Qing Han (University of California Irvine), Phu Nguyen (University of California Irvine), Ronald T. Eguchi (ImageCat, Inc.), Kuo-Lin Hsu (University of California Irvine), Nalini Venkatasubramanian (University of California Irvine)

We present a cyber-physical-human (CPHS) distributed computing framework, AquaSCALE, for gathering, analyzing and localizing anomalous operations of increasingly failure-prone community water services. Today, detection of water pipe leaks takes hours to days. AquaSCALE leverages dynamic data from multiple information sources including IoT (Internet of Things) sensory data, geophysical data, human input and simulation/modeling engines to create a sensor-simulation-data integration platform that can locate multiple simultaneous pipe failures at fine level of granularity with high level of accuracy and detection time reduced by orders of magnitude (from hours/days to minutes).

**Demo 2: Security and Privacy Cluster**

**PrivateGraph: A Cloud-Centric System for Privacy-Preserving Spectral Analysis of Large Encrypted Graphs**
Sagar Sharma (Wright State University), Keke Chen (Wright State University)

Graph datasets have invaluable use in business applications and scientific research. Because of the growing size and dynamically changing nature of graphs, graph data owners may want to use public cloud infrastructures to store, process, and perform graph analytics. However, when outsourcing data and computation, data owners are at risk to develop methods to preserve data privacy and data ownership from curious cloud providers. This demonstration exhibits a prototype system for privacy-preserving spectral analysis framework for large graphs in public clouds (PrivateGraph) that allows data owners to collect graph data from data contributors, and store and conduct secure graph spectral analysis in the cloud with preserved privacy and ownership. This demo system lets its audience interactively learn the major cloud-client interaction protocols: the privacy-preserving data submission, the secure Lanzcos and Nystr"{o}m approximate eigen-decomposition algorithms that work over encrypted data, and the outcome of an important application of spectral analysis - spectral clustering. In the process of demonstration the audience will understand the intrinsic relationship amongst costs, result quality, privacy, and scalability of the framework.
IoT Sentinel Demo: Automated Device-Type Identification for Security Enforcement in IoT
Markus Miettinen (Technische Universität Darmstadt), Samuel Marchal (Aalto University), Iibad Hafeez (University of Helsinki), Tommaso Frassetto (Technische Universität Darmstadt), N. Asokan (Aalto University), Ahmad-Reza Sadeghi (Technische Universität Darmstadt), Sasu Tarkoma (University of Helsinki)

The emergence of numerous new manufacturers producing devices for the Internet-of-Things (IoT) has given rise to new security concerns. Many IoT devices exhibit security flaws making them vulnerable for attacks and manufacturers have difficulties in providing appropriate security patches to their products in a timely and user-friendly manner. In this paper, we present our implementation of IoT SENTINEL, which is a system aimed at protecting the user’s network from vulnerable IoT devices. IoT SENTINEL automatically identifies vulnerable devices when they are first introduced to the network and enforces appropriate traffic filtering rules to protect other devices from the threats originating from the vulnerable devices.

Rogue Access Point Detector Using Characteristics of Channel Overlapping in 802.11n
Rhongho Jang (INHA University of Korea), Jeonil Kang (INHA University), Aziz Mohaisen (SUNY Buffalo), Daehun Nyang (Department of Computer and Information Engineering, INHA University, Incheon, Korea)

In this work, we introduce a powerful hardware-based rogue access point detector, which can relay traffic between a legitimate AP and a wireless station back and forth, and act as a man-in-the-middle attacker. Our PrAP is built of two dedicated wireless routers interconnected physically, and can relay traffic rapidly between a station and a legitimate AP. Through extensive experiments, we demonstrate that the state-of-the-art time-based rogue AP detectors cannot detect our PrAP, although effective against software-based rAP. To defend against PrAPs, we propose PrAP-Hunter based on intentional channel interference. PrAP-Hunter is highly accurate, even under heavy traffic scenarios. Using a high-performance (desktop) and low-performance (mobile) experimental setups of our PrAPHunter in various deployment scenarios, we demonstrate close to 100% of detection rate, compared to 60% detection rate by the state-of-the-art. We show that PrAP-Hunter is fast (takes 5-10 sec), does not require any prior knowledge, and can be deployed in the wild by real world experiments at 10 coffee shops. Keywords: Intrusion detection, Wireless LAN, Rogue AP, channel interference, IEEE 802.11n.

ReverseCloak: A Reversible Multi-level Location Privacy Protection System
Chao Li (University of Pittsburgh), Balaji Palanisamy (University of Pittsburgh), Aravind Kalaivanan (University of Pittsburgh), Sriram Raghunathan (University of Pittsburgh)

With the fast proliferation of mobile devices and wireless networks, along with advances in sensing and positioning technology, we are witnessing a huge proliferation of Location-based Services (LBSs). Location anonymization refers to the process of perturbing the exact location of LBS users as a cloaking region such that a user’s location becomes indistinguishable from the location of a set of other users. However, existing location anonymization techniques focus primarily on single level unidirectional anonymization, which fails to control the access to the cloak data to let data requesters with different privileges get information with varying degrees of anonymity. In this demonstration, we present a toolkit for ReverseCloak, a location perturbation system to protect location privacy over road networks in a multi-level reversible manner, consisting of an ‘Anonymizer’ GUI to adjust the anonymization settings and visualize the multi-level cloaking regions over road network for location data owners and a ‘De-anonymizer’ GUI to de-anonymize the cloaking region and display the reduced region over road network for location data requesters. With the toolkit, we demonstrate the practicality and effectiveness of the ReverseCloak approach.

Demo 3: Clouds and Virtualization Cluster

Hopworks: Improving User Experience and Development on Hadoop with Scalable, Strongly Consistent Metadata
Mahmoud Ismail (KTH - Royal Institute of Technology), Ermias Gebremeskel (RISE SICS), Theofilos Kakantousis (RISE SICS), Gautier Berthou (RISE SICS), Jim Dowling (KTH - Royal Institute of Technology)

Hadoop is a popular system for storing, managing, and processing large volumes of data, but it has bare-bones internal support for metadata, as metadata is a bottleneck and less meaningful in scalability. The result is a scalable platform with rudimentary access control that is neither user- nor developer-friendly. Also, metadata services that are built on Hadoop, such as SQL-on-Hadoop, access control, data provenance, and data governance are necessarily implemented as eventually consistent services, resulting in increased development effort and more brittle software. In this paper, we present a new project-based multi-tenancy model for Hadoop, built on a new distribution of Hadoop that provides a distributed database backend for the Hadoop Distributed Filesystem’s (HDFS) metadata layer. We extend Hadoop’s metadata model to introduce projects, datasets, and project-users as new core concepts that enable a user-friendly, UI-driven Hadoop experience. As our metadata service is backed by a transactional database, developers can easily extend metadata by adding new tables and ensure the strong consistency of extended metadata using both transactions and foreign keys.

Isolation in Docker through Layer Encryption
Ioannis Giannakopoulos (National Technical University of Athens), Konstantinos Papazafeiropoulos (National Technical University of Athens), Katerina Doka (National Technical University of Athens), Nectarios Koziris (National Technical University of Athens)

Containers are constantly gaining ground in the virtualization landscape as a lightweight and efficient alternative to hypervisor-based Virtual Machines, with Docker being the most successful representative. Docker relies on union-capable file systems, where any action performed to a base image is captured as a new file system layer. This strategy allows developers to easily pack applications into Docker image layers and distribute them via public registries. However, this image creation and distribution strategy does not protect sensitive data from malicious privileged users (e.g., registry administrator, cloud provider), since encryption is not natively supported. We propose and demonstrate a mechanism for secure Docker image manipulation throughout its life cycle: The creation, storage and usage of a Docker image is backed by a data-at-rest mechanism, which maintains sensitive data encrypted on disk and encrypts/decrypts them on-the-fly in order to preserve their confidentiality at all times, while the distribution and migration of images is enhanced with a mechanism that encrypts only specific layers of the file system that need to remain confidential and ensures that only legitimate key holders can decrypt them and reconstruct the original image. Through a rich interaction with our system the audience will experience first-hand how sensitive image data can be safely distributed and remain encrypted at the storage device throughout the container’s lifetime, bearing only a marginal performance overhead.

Dela - Sharing Large Datasets between Hadoop Clusters
Alexandru A. Ormenisan (KTH Royal Institute of Technology), Jim Dowling (KTH Royal Institute of Technology)
Big data has, in recent years, revolutionised an ever-growing number of fields, from machine learning to climate science to genomics. The current state-of-the-art for storing large datasets is either object stores or distributed filesystems, with Hadoop being the dominant open-source platform for managing ‘Big Data’. Existing large-scale storage platforms, however, lack support for the efficient sharing of large datasets over the Internet. Those systems that are widely used for the dissemination of large files, like BitTorrent, need to be adapted to handle challenges such as network links with both high latency and high bandwidth, and scalable storage backends that are optimised for streaming and not random access. In this paper, we introduce Dela, a peer-to-peer data-sharing service integrated into the Hops Hadoop platform that provides an end-to-end solution for dataset sharing. Dela is designed for large-scale storage backends and data transfers that are both non-intrusive to existing TCP network traffic and provide higher network throughput than TCP on high latency, high bandwidth network links, such as transatlantic network links. Dela provides a pluggable storage layer, implementing two alternative ways for clients to access shared data: stream processing of data as it arrives with Kafka, and traditional offline access to data using the Hadoop Distributed FileSystem. Dela is the first step for the Hadoop platform towards creating an open dataset ecosystem that supports user-friendly publishing, searching, and downloading of large datasets.

In Vivo Evaluation of the Secure Opportunistic Schemes Middleware using a Delay Tolerant Social Network
Corey E. Baker (University of California San Diego), Allen Starke (University of Florida), Tanisha G. Hill-Jarrett (University of Florida), Janise McNair (University of Florida)

Over the past decade, online social networks (OSNs) such as Twitter and Facebook have thrived and experienced rapid growth to over 1 billion users. A major evolution would be to leverage the characteristics of OSNs to evaluate the effectiveness of the many routing schemes developed by the research community in real-world scenarios. In this demonstration, we showcase the Secure Opportunistic Schemes (SOS) middleware which allows different routing schemes to be easily implemented relieving the burden of security and connection establishment. The feasibility of creating a delay tolerant social network is demonstrated by using SOS to enable AlleyOop Social, a secure delay tolerant networking research platform that serves as a real-life mobile social networking application for iOS devices. AlleyOop Social allows users to interact, publish messages, and discover others that share common interests in an intermittent network using Bluetooth, peer-to-peer WiFi, and infrastructure WiFi.

Demo 4: Distributed Systems and Networking Cluster

Scaling and Load Testing Location-based Publish and Subscribe
Bertil Chapuis (University of Lausanne), Benoît Garbinato (University of Lausanne)

The rise of the Internet of things (IoT) poses massive scalability issues for location-based services. More particularly, location-aware publish and subscribe services are struggling to scale out the computation of matches between publications and subscriptions that continuously update their location. In this demonstration paper, we propose a novel distributed and horizontally scalable architecture for location-aware publish and subscribe. Our middleware architecture relies on a multistep routing mechanism based on consistent hashing and range partitioning. To demonstrate its scalability, we present a traffic generator, which, in contrast to existing generators, can be used to perform real-time load tests. Finally, we show that our architecture can be deployed on a small 10-node cluster and can process up to 80,000 location updates per second producing 25,000 matches per seconds.

A Distributed Event-centric Collaborative Workflows Development System for IoT Application
Yongyang Cheng (BUCT), Shuai Zhao (BUCT), Bo Cheng (BUCT), Shoulu Hou (BUCT), Xulei Zhang (BUCT), Junliang Chen (BUCT)

The rapid development of Internet of Things (IoT) attracts growing attention from both industry and academia. IoT seamlessly connects the physical world and cyberspace via various sensors. It is more worth for us to pay attention to the mechanism of the events to work collaboratively rather than those standalone sensors. In this paper, we present a Distributed Event-centric Collaborative Workflows development system for IoT application, called DECW. It supports loosely coupled event-based interaction between processes, which enables real-time response to events from the physical world. Unlike traditional centralized control flow mode, the interaction between processes in DECW is constrained by the event interface. Users could dynamically adjust the interface between processes without modifying the internal logic of the process. In addition, DECW system provides a full lifecycle for the development and operation of the IoT application, including graphical creation of processes, dynamic definition of the process interaction interfaces, logical validation, distributed packaging and deployment, parallel execution, and real-time monitoring and managing the running status of the IoT application.

Incentive Mechanism for Data-Centric Message Delivery in Delay Tolerant Networks
Himanshu Jethawa (Missouri University of Science and Technology), Sanjay Madria (Missouri University of Science and Technology)

A key issue in delay tolerant networks (DTN) is to find the right node to store and relay messages. We consider messages annotated with the unique keywords describing the message subject, and nodes also adds keywords to describe their mission interests, priority and their transient social relationship (TSR). To offset resource costs, an incentive mechanism is developed over transient social relationships which enrich enroute message content and motivate better semantically related nodes to carry and forward messages. The incentive mechanism ensures avoidance of congestion due to uncooperative or selfish behavior of nodes.

Performance Of Cognitive Wireless Charger For Near-Field Wireless Charging
Sang-Yoon Chang (University of Colorado, Colorado Springs and Advanced Digital Sciences Center), Sristi Lakshmi Sravana Kumar (Advanced Digital Sciences Center), Yih-Chun Hu (University of Illinois at Urbana-Champaign)

Wireless charging provides a convenient way to charge various mobile and IoT devices. State-of-the-art wire-less charging systems operate at a particular frequency and are controlled by explicit networking with the power-receiving devices. However, control by explicit networking is not designed to cope with the variations in the power-receiving devices placements and alignments. This is especially more significant in near-field and pseudo-tightly coupled charging applications as more charging pads are being deployed in the public domains and serving heterogeneous clients. We establish that frequency control achieves better performance gains in inductive-coupling charging applications and is also sensitive to the variations in the placement and alignment between the power-transmitting and the power-receiving coils. In this demo, we show the impact in power transfer performance caused by the variations in the placement and alignment between the power-transmitting and the power-receiving coils and showcase the performance of our cognitive wireless charger (CWC), which adaptively controls the operating frequency in real-time using implicit feedback for optimal operations.
**Poster 1: Distributed Applications Cluster**

**Toward Vehicle Sensing: An integrated application with sparse video cameras and intelligent taxicabs**

Yang Wang (University of Science and Technology of China), Wujie Chen (University of Science and Technology of China), Wei Zheng (Sanofi-Aventis US LLC), He Huang (Soochow University), Wen Zhang (University of Science and Technology of China), Hengchang Liu (University of Science and Technology of China)

Due to the sparse distribution of road video surveillance cameras, precise trajectory tracking for vehicles remains a challenging task. To the best of our knowledge, none of the previous research considered using on-road taxicabs as mobile video surveillance cameras and road traffic flow patterns, therefore not suitable for recovering trajectories of vehicles. With this insight, we model the travel time-cost of a road segment during various time periods precisely with LNDs (Logarithmic Normal Distributions), then use LSNDs (Log Skew Normal Distributions) to approximate the time-cost of an urban trip during various time periods. We propose an approach to calculate possible location and time distribution of the vehicle, select the taxicab to verify the distribution by uploading and checking video clips of this taxicab, finally refine the restoring trajectory in a recursive manner. We evaluate our solution on real-world taxicab and road surveillance system datasets. Experimental results demonstrate that our approach outperforms alternative solutions in terms of accuracy ratio of vehicle tracking.

**Segmentation of Time Series based on Kinetic Characteristics for Storage Consumption Prediction**

Beibei Miao (Baidu, Inc), Yu Chen (Baidu, Inc), Xuebo Jin (School of Computer and Information Engineering, Beijing Technology and Business University), Bo Wang (Baidu, Inc), Xianping Qu (Baidu, Inc), Dong Wang (Baidu, Inc), Shimin Tao (Baidu, Inc), Zhi Zang (Baidu, Inc)

The Internet services generate huge amount of data, which require large space for storage. Determining device purchase plan turns out to be very important for the service providers. Under-purchasing might lead to data loss, while over-purchasing would result in waste. In this paper, we propose a linear regression based approach to predict the storage demand according to the time series of the storage consumption. We partitioned the storage consumption time series into several linear segments, and perform prediction on the last segment using linear regression. Since the position of turning points between adjacent segments and the total number of the segments are both unknown, how to achieve the online segmentation becomes a big challenge. Aiming to solve this problem, we carried out the KalmanAnova segmentation method. Experiment results show that our method has good accuracy in precision, recall and F-measure values. Moreover, the method is able to segment nonlinear time series as well, suggesting a potential wider application. The proposed method has been deployed in Baidu Inc. and saves about 45 thousand dollars in one of its device purchase program.

**A Multi-stage Hierarchical Window Model with Application to Real-Time Graph Analysis**

Sachini Jayasekara (University of Melbourne), Shanika Karunasekera (University of Melbourne), Aaron Harwood (University of Melbourne)

The dynamic nature of real-world networks, such as social networks and communication networks, has increased the focus towards real-time dynamic graph analysis. Observations made based on real-time analysis of dynamic graphs reflect the latest properties of the graph and have the most value in real-time analysis. Computing graph properties of large-scale, fast-evolving graphs in real-time is challenging due, not only to the high computational and memory cost, but also to the understanding of the result with respect to the data from which it was derived. This paper proposes a multi-stage hierarchical window model that can aid in rigorous understanding of complicated real-time results and we apply it to generate graphs based on real-time updates along with periodic computations on graph snapshots for processing dynamic graphs. Moreover, the paper discusses the utilization of parallel window computation. The paper evaluates the hierarchical model through analyzing graphs formed by cooccurring hashtags in a Twitter data-stream.

**Dynamic Pricing at Electric Vehicle Charging Stations for Queueing Delay Reduction**

Xiaoshan Sun (University of Science and Technology of China), Peng Xu (University of Science and Technology of China), Jinyang Li (University of Science and Technology of China), Wei Zheng (Sanofi-Aventis)

The research of electric vehicles (EVs) has gained more and more attention in recent years in both industry and academia, and new registrations of EVs increase rapidly, while the long delay at the convenient but crowded charging stations may discourage many drivers from switching to EVs. To address the problems, we propose a novel dynamic pricing policy that allows charging stations to adjust their service fees in real time based on the load at the stations. In our work, the selection of drivers is modeled by a new dissatisfaction function with multiple variables, which can be easily validated and improved by real applications, and our solution is evaluated from the real-world e-charge dataset. To the best of our knowledge, this is the first work that considers dynamic service fees among various charging stations for load balancing and reduction of queueing delay. This makes our work more realistic and beneficial.

**Pairwise Ranking Aggregation by Non-interactive Crowdsourcing with Budget Constraints**

Changjiang Cai (Stevens Institute of Technology), Haipei Sun (Stevens Institute of Technology), Boxiang Dong (Montclair State University), Bo Zhang (Stevens Institute of Technology), Ting Wang (Lehigh University), Wendy Hui Wang (Stevens Institute of Technology)

Crowdsourced ranking algorithms ask the crowd to compare the objects and infer the full ranking based on the crowdsourced pairwise comparison results. In this paper, we consider the setting in which the task requester is equipped with a limited budget that can afford only a small number of pairwise comparisons. To make the problem more complicated, the crowd may return noisy comparison answers. We propose an approach to obtain a good-quality full ranking from a small number of pairwise preferences in two steps, namely task assignment and result inference. In the task assignment step, we generate pairwise comparison tasks that produce a full ranking with high probability. In the result inference step, based on the transitive property of pairwise comparisons and truth discovery, we design an efficient heuristic algorithm to find the best full ranking from the potentially conflicting pairwise preferences. The experiment results demonstrate the effectiveness and efficiency of our approach.

**Buffer-Based Reinforcement Learning for Adaptive Streaming**

Yue Zhang (SUNY Binghamton), Yao Liu (SUNY Binghamton)
Adaptive streaming improves user-perceived quality by altering the streaming bitrate depending on network conditions, trading reduced video bitrates for reduced stall times. Existing adaptation approaches, e.g., rate-based, buffer-based, either rely heavily on accurate bandwidth prediction or can be overly-conservative about video bitrates. In this work, we propose a reinforcement learning approach to choose the segment quality during playback. This approach uses only the buffer state information and optimizes for a measure of user-perceived streaming quality. Simulation results show that our proposed approach achieves better QoE than rate-, buffer-based approaches, as well as other reinforcement learning approaches.

The case for using content-centric networking for distributing high-energy physics software
Mohammad Alhowaidi (University of Nebraska-Lincoln), Byrav Ramamurthy (University of Nebraska-Lincoln), Brian Bockelman (University of Nebraska-Lincoln), David Swanson (University of Nebraska-Lincoln)

Named Data Networking (NDN) is one of the promising future internet architectures, which focuses on the data rather than its location (IP/host-based system). NDN has several characteristics which facilitate addressing and routing the data: fail-over, in-network caching and load balancing. This makes it useful in areas such as managing scientific data. The CMS experiment on the Large Hadron Collider (LHC) has a data access problem amenable to content-centric networking. CERN Virtual Machine File System (CVMFS) is used by High Energy Physics (HEP) community for worldwide software distribution. CVMFS maintains its data by using content addressable storage, which makes it suitable for NDN. In this paper, we investigate the possibilities of using a content-centric networking architecture such as NDN on distributing CMS software.

LAVEA: Latency-aware Video Analytics on Edge Computing Platform
Shanhe Yi (College of William and Mary), Zijiang Hao (College of William and Mary), Qingyang Zhang (Wayne State University), Quan Zhang (Wayne State University), Weisong Shi (Wayne State University), Qun Li (College of William and Mary)

We present LAVEA, a system built for edge computing, which offloads computation tasks between clients and edge nodes, collaborates nearby edge nodes, to provide low-latency video analytics at places closer to the users. We have utilized an edge-first design to minimize the response time, and compared various task placement schemes tailored for inter-edge collaboration. Our results reveal that the client-edge configuration has task speedup against local or client-cloud configurations.

Complete Tolerance Relation based Filling Algorithm using Spark
Jingling Yuan (Wuhan University of Technology), Yao Xiang (Wuhan University of Technology), Xian Zhong (Wuhan University of Technology), Mincheng Chen (Wuhan University of Technology), Tao Li (University of Florida)

With the advent of cloud computing, renewable energy is integrated into data center power supply systems increasingly. The power statistics collection may not be available due to the instability of renewable energy, which results in incomplete data. The incomplete energy data will significantly disturb the management of data centers. We further propose a filling algorithm based on complete tolerance class. The algorithm expands the traditional tolerance relation, and fills the missing values of the energy data, which ensures the data integrity. By taking good advantage of in-Memory Computing, We further parallelize and optimize our algorithm using Spark. The experiment results demonstrate that our algorithm outperforms other general filling algorithms in terms of filling accuracy. The proposed algorithm also shows good performance as the missing rate rises up.

Poster 2: Security and Privacy Cluster
Towards Secure Public Directory for Privacy-Preserving Data Sharing
Amin Fallahi (Syracuse University), Xi Liu (Syracuse University), Yuzhe Tang (Syracuse University), Shuang Wang (UCSD), Rui Zhang (Chinese Academy of Sciences)

In emerging federated database systems, such as Health Information Exchange (or HIE), an important yet understudied problem is the privacy-preserving sharing of personal records among autonomous data owners. The goal poses technical design challenges, including the assured privacy preservation under background-knowledge attacks, and scalable and secure multi-party computations on private big-data in a large-scale system. To tackle the challenges, we propose a protocol, multi-party deterministic noising or MPDN, which deterministically injects noises to the published meta-data while staying aware of the background knowledge. It also optimizes the performance of multi-party computation (or MPC) by pre-computation on the public background knowledge. The pre-computation exhibits data-level parallelism and we leverage general-purpose computing on graphics processing units (GPGPU) in our implementation to exploit the parallelism and to further optimize performance. The proposed protocol is implemented on open-source MPC software (i.e., GMW) and its efficiency with a speedup of more than an order of magnitude is demonstrated in a geo-distributed setting. Through evaluation on real-world datasets, the assurance of privacy preservation is also verified.

Anonymous Routing to Maximize Delivery Rates in DTNs
Kazuya Sakai (Tokyo Metropolitan University), Min-Te Sun (National Central University), Wei-Shinn Ku (Auburn University), Jie Wu (Temple University)

Security and privacy issues are considered to be two of the most significant concerns to organizations and individuals using mobile applications. In this paper, we seek to address anonymous communications in delay tolerant networks (DTNs). While many different anonymous routing protocols have been proposed for ad hoc networks, to the best of our knowledge, only variants of onion-based routing have been tailored for DTNs. Since each type of anonymous routing protocol has its advantages and drawbacks, there is no single anonymous routing protocol for DTNs that can adapt to the different levels of security requirements. In this paper, we first design a set of anonymous routing protocols for DTNs, called anonymous Epidemic and zone-based anonymous routing, based on the original anonymous routing protocols for ad hoc networks. Then, we propose a framework of anonymous routing (FAR) for DTNs, which subsumes all the aforementioned protocols. By tuning its parameters, the proposed FAR is able to outperform onion-based, anonymous Epidemic, and zone-based routing. In addition, numerical analyses for the traceable rate and node anonymity models are well as real traces are conducted to demonstrate that given appropriate parameter settings, our FAR outperforms all the existing anonymous routing protocols for DTNs.

Evaluating Connection Resilience for the Overlay Network Kademia
Henner Heck (Universität Kassel), Olga Kieselmann (Universität Kassel), Arno Wacker (Universität Kassel)
Kademlia is a decentralized overlay network, up to now mainly used for highly scalable file sharing applications. Due to its distributed nature, it is free from single points of failure. Communication can happen over redundant network paths, which makes information distribution with Kademlia resilient against failing nodes and attacks. In this paper, we simulate Kademlia networks with varying parameters and analyze the number of node-disjoint paths. With our results, we show the influence of these parameters on the network connectivity and, therefore, the resilience against failing nodes and communication channels.

**Shortfall-based Optimal Security Provisioning for Internet of Things**
Antonino Rullo (University of Calabria), Edoardo Serra (Boise State University), Jorge Lobo (Universitat Pompea Fabra), Elisa Bertino(Purdue University)

We present a formal method for computing the best security provisioning for Internet of Things (IoT) scenarios characterized by a high degree of mobility. The security infrastructure is intended as a security resource allocation plan, computed as the solution of an optimization problem that minimizes the risk of having IoT devices not monitored by any resource. We employ the shortfall as a risk measure, a concept mostly used in the economics, and adapt it to our scenario. We show how to compute and evaluate an allocation plan, and how such security solutions address the continuous topology changes that affect an IoT environment.

**Group Differential Privacy-preserving Disclosure of Multi-level Association Graphs**
Balaji Palanisamy (University of Pittsburgh), Chao Li (University of Pittsburgh), Prashant Krishnamurthy (University of Pittsburgh)

Traditional privacy-preserving data disclosure solutions have focused on protecting the privacy of individual's information with the assumption that all aggregate (statistical) information about individuals is safe for disclosure. Such schemes fail to support group privacy where aggregate information about a group of individuals may also be sensitive and users of the published data may have different levels of access privileges entitled to them. We propose the notion of Group Differential Privacy that protects sensitive information of groups of individuals at various defined privacy levels, enabling data users to obtain the level of access entitled to them. We present a preliminary evaluation of the proposed notion of group privacy through experiments on real association graph data that demonstrate the guarantees on group privacy on the disclosed data.

**Tracking Information Flow in Cyber-Physical Systems**
Stefan Gries (University of Duisburg-Essen), Marc Hesienus (University of Duisburg-Essen), Volker Gruhn (University of Duisburg-Essen)

Cyber-Physical Systems are distributed, heterogeneous, decentralized and loosely coupled networks in which individual systems measure physical processes, exchange information, and influence processes. Sensors measure these physical processes, while aggregators process them and actuators perform resulting actions. Decisions are often based on sensor data collected by other systems. Furthermore, the aggregators also interchange information and use them to derive own decisions. Decisions must be comprehensible. However, this is only the case if all data dependencies are known. Due to the size of these networks, their loose coupling and their dynamic behavior, decisions made by a system are not always easy to understand. If an error occurs in the system, the error source must be identified. It must be known on which data a decision was based. However, since the decision can be based on information from other nodes, the search for the error source is not a trivial task. Keep in mind, that dependent nodes can have dependencies themselves as well. We present the Information Flow Monitor (IFM) that collects information about semantic data dependencies in dynamic networks. The collected dependency information is provided at a central network location. Subsequently, semantic dependencies between information can be visualized.

**Privacy-preserving Matchmaking in Geosocial Networks with Untrusted Servers**
Qiuxiang Dong (Arizona State University), Dijiang Huang (Arizona State University)

As a major branch of LBSs, geosocial networking services become popular. An important functionality of geosocial networking services is allowing people to find potential friends who have similar profiles within close proximity and initiate communication with each other. However, in order to realize this functionality, most existing services require mobile users to reveal their profiles and location information to an untrusted service provider, which may expose LBSs to vulnerabilities for abuse and endanger mobile users’ privacy. To address this problem, we propose to encrypt users’ profile with a new searchable encryption scheme. Combining this searchable encryption scheme with other cryptographic techniques we construct a privacy-preserving matchmaking system. Compared with a previous one that aims to solve the same problem, ours is more secure, supports more flexible functionalities and moves computationally heavy key updates to resourceful service providers.

**You've Been Tricked! A User Study of the Effectiveness of Typosquatting Techniques**
Jeffrey Spaulding (SUNY Buffalo), Shambhu Upadhyaya (SUNY Buffalo), Aziz Mohaisen (SUNY Buffalo)

The nefarious practice of Typosquatting involves deliberately registering Internet domain names containing typographical errors that primarily target popular domain names, in an effort to redirect users to unintended destinations or stealing traffic for monetary gain. Typosquatting has existed for well over two decades and continues to be a credible threat to this day. As recently shown in the online magazine Slate.com [16], cybercriminals have attempted to distribute malware through Netflix.com, a typosquatted variant of the popular streaming site Netflix.com that uses the country code top-level domain (ccTLD) for Oman (.om). While much of the prior work has examined various typosquatting techniques and how they change over time, none have considered how effective they are in deceiving users. In this paper, we attempt to fill in this gap by conducting a user study that exposes subjects to several uniform resource locators (URLs) in an attempt to determine the effectiveness of several typosquatting techniques that are prevalent in the wild. We also attempt to determine if the security education and awareness of cybercrimes such as typosquatting will affect the behavior of Internet users. Ultimately, we found that subjects tend to correctly identify typosquatting which adds characters to the domain names, while the most effective techniques to deceive users involves permutations and substitutions of characters. We also found that subjects generally performed better and faster at identifying typosquatted domain names after being thoroughly educated about them, and that certain attributes such as Age and Education affect their behavior when exposed to them.

**Real-time Detection of Illegal File Transfers in the Cloud**
Adam Bowers (Missouri University of Science and Technology), Dan Lin (Missouri University of Science and Technology), Anna Squicciarini (The Pennsylvania State University), Ali Hurson (Missouri University of Science and Technology)

There has been a prolific rise in the popularity of cloud storage in recent years. While cloud storage offers many advantages such as flexibility and convenience, users are now unable to tell or control the actual locations of their data. This limitation may affect users’ confidence and trust in the storage provider, or even be unsuitable for storing data with strict location requirements. To address this issue, we propose an illegal file transfer detection framework that constantly monitors...
the real-time file transfers in the cloud and is capable of detecting potential illegal transfers which moves sensitive data outside the ("legal") boundaries specified by the file owner. The main idea is to classifying multiple users' location preferences when making the data storage arrangement in the cloud nodes. We model the legal file transfers among nodes as a weighted graph and then maximize the probability of storing data items of similar privacy preferences in the same region. Then we leverage the socket monitoring functions provided by LAST-HDFS (a recent location-aware Hadoop file storage system) to monitor the real-time communication among cloud nodes. Based on our legal file transfer graph and the detected communication, we propose an approach to calculate the probability of the detected transfer to be illegal. We have implemented our proposed framework and our experimental results indicate that our approach is able to detect much more illegal file transfers than the state of the art.

Eyes of the Swarm: Streamers' Detection in BitTorrent
Daniel Silva (Fluminense Federal University), Antonio Rocha (Fluminense Federal University)

Many BitTorrent (BT) clients are using these BT networks as a video-on-demand service, taking advantage of the popularity and the large collection of media available. However, transforming the swarms into an on-demand media service can cause serious damage to the overall network performance. In this paper, we propose a methodology, using the concepts of Entropy, and present a Spy BitTorrent client that is able to identify peers streaming in a swarm. Large scale monitoring, for real swarms, were performed to detect the presence of streamers.

Poster 3: Clouds and Virtualization Cluster

Load prediction for energy-aware scheduling for Clouds computing platforms
Alexandre Dambreville (LRI), Joanna Tomasik (CentraleSupélec), Johanne Cohen (LRI-CNRS), Fabien Dufoulon (LRI)

We address online scheduling for servers of cloud service providers. Each server is composed of several variablespeed processors whose power function is convex. The servers may be busy, idle or switched off. The objective of our scheduling is to minimize the energy consumed by a Cloud computing platform. To achieve this goal, we try to anticipate computing demands by predicting a workload, then we modify the set of available servers to fit this prediction and finally we schedule our jobs on the available servers. To schedule jobs we have developed the POD (Predict Optimize Dispatch) algorithm. We evaluate its performance for real-life traces in the presence of different types of prediction. The analysis shows that our scheduling reduces energy consumption considerably.

Learn-as-you-go with Megh: Efficient Live Migration of Virtual Machines
Debabrota Basu (National University of Singapore), Xiayang Wang (Institute of Parallel and Distributed Systems, Shanghai Jiao Tong University), Yang Hong (Shanghai Jiao Tong University), Haibo Chen (Shanghai Jiao Tong University), Stephane Bressan (National University of Singapore)

We propose a reinforcement learning algorithm, Megh, for live migration of virtual machines that simultaneously reduces the cost of energy consumption and enhances the performance. Megh learns the uncertain dynamics of workloads as it goes. Megh uses a dimensionality reduction scheme to project the combinatorially explosive state-action space to a polynomial dimensional space. These schemes enable Megh to be scalable and to work in real-time. We experimentally validate that Megh is more cost-effective and time-efficient than the MadVM and MMT algorithms.

Machine-Learning Based Performance Estimation for Distributed Parallel Applications in Virtualized Heterogeneous Clusters
Seontae Kim (UNIST), Nguyen Pham (UNIST), Woongki Baek (UNIST), Young-Ri Choi (UNIST)

In a virtualized heterogeneous cluster, for a distributed parallel application which runs in multiple virtual machines (VMs) concurrently, there are a huge number of possible ways to place its VMs. This paper investigates a performance estimation technique for distributed parallel applications in virtualized heterogeneous clusters. We first analyze the effects of different VM configurations on the performance of various distributed parallel applications. We then present a machine-learning based performance model for a distributed parallel application. Using a heterogeneous cluster with two different types of nodes, we show that our machine-learning based models can estimate the runtimes of distributed parallel applications with modest error rates.

Incremental elasticity for NoSQL data stores
Antonis Papaioannou (ICS-FORTH and University of Crete), Kostas Magoutis (ICS-FORTH and University of Ioannina)

Elasticity actions in NoSQL data stores move large amounts of data over the network to take advantage of new resources. Here we propose incremental elasticity, a new mechanism for scheduling data transfers to a joining server, leading to smoother elasticity actions with a reduced performance impact.

A Framework for Efficient Energy Scheduling of Spark Workloads
Stathis Maroulis (Athens University of Economics and Business), Nikos Zacheilas (Athens University of Economics and Business), Vana Kalogeraki (Athens University of Economics and Business)

Nowadays distributed processing frameworks like Apache Spark have been successfully used for the execution of big data applications. Despite their wide adoption little work has been done in terms of controlling the applications’ energy consumption. Datacenters contribute over 2% of the total US electric usage therefore minimizing the energy utilization of Spark application can be extremely helpful. Solving this energy consumption problem requires the scheduling of Spark applications in an energy-efficient way. However, the problem is challenging as we also have to consider application performance requirements. In this work, we provide the overview of a novel framework that orchestrates the execution order of Spark applications, exploiting DVFS to tune the computing nodes CPU frequencies in order to minimize the energy consumption and satisfy application’s performance requirements. Our early experimental results illustrate the working and benefits of our framework.

Towards a Complete Virtual Data Center Embedding Algorithm using Hybrid Strategy
M P Gilesh (National Institute of Technology Calicut), S D Madhu Kumar (National Institute of Technology Calicut), Lillykutty Jacob (National Institute of Technology Calicut), Umesh Bellur (Indian Institute of Technology Bombay)

Virtual Data Centers (VDCs) are a set of virtual machine (VM) end points connected by a virtual network (VN) topology. While VMs are specified by their capacity along the axes of CPU, memory, and other machine level resources, the VN is characterized by the resources of virtual switches, and the bandwidth and latency of links. Today’s cloud data centers support dynamic requests for VDCs, by using software defined embedding strategies, that allow them to mesh multiple VDCs onto their physical data center (PDC) network and machines. Over a period of time, entries and exits of different VDCs create multiple fragments of PDC resources, which
are unusable unless consolidated, resulting in poor acceptance rate of VDCs. However, such a consolidation would necessitate costly live VM and virtual switch migrations. A good strategy should tradeoff the cost of migrations for the acceptance rate of VDC requests. In this paper, we present a solution to this VDC embedding problem that achieves a higher acceptance rate by minimizing fragmentation, compared to existing strategies, while minimizing the migrations of VMs in the existing VDCs. Experimental results show that we can achieve up to 5% higher acceptance to existing solutions while having 6% fewer rate of migrations.

Federating Consistency for Partition-Prone Networks
Benjamin Bengfort (University of Maryland), Pete Keleher (University of Maryland)

Groups of strongly consistent devices can efficiently order events under ideal (data center) conditions, but become less effective in dynamic and heterogeneous environments. Weakly consistent devices efficiently tolerate both faults and dynamic conditions but are slow to converge on a single ordering of system events. We propose “federated consistency”, which combines the strengths of both approaches into a single protocol. Federated groups use a strongly consistent inner core of devices to maintain a totally ordered, fault-tolerant sequence of events. A cloud of weakly-consistent devices disseminates orderings and enables progress despite varying connectivity and partitions. Though the constituent sub-protocols take different (nearly opposite) approaches to resolving conflicts; we show that expanding distributed version vectors with a fortior component allows them to inter-operate effectively. We use a discrete event simulation to show that a group of federated devices can obtain the key advantages of both approaches. Such systems have been investigated before [1], [2], but our approach targets more active “weak nodes” in a wide-area setting.

Mitigating nesting-agnostic hypervisor policies in derivative clouds
Chandra Prakash (IIT Bombay), Prashanth (IIT Bombay), Purushottam Kulkarni (IIT Bombay), Umesh Bellur (IIT Bombay)

The fixed granularity of virtual machines offered by IaaS providers has prompted the evolution of derivative clouds where resources are repackaged into smaller containers and leased out typically in PaaS mode. In such a setup, containers are provisioned within virtual machines. Such a nested setup results in two control centers for the resources used by those containers—the guest OS and the Hypervisor. The latter’s control actions are agnostic of the application executing within a VM. This lack of visibility may result in hypervisor control that has a non-uniform effect on the VM’s nested containers which is undesirable. In this work, we propose policy based control of the effect of the hypervisor’s control actions amongst the containers nested in the affected VM.

A Novel Architecture for Efficient Fog to Cloud Data Management in Smart Cities
Amir Sinaeepourfard (UPC), Jordi Garcia (UPC), Xavier Masip-Bruin (UPC), Eva Marin-Tordera (UPC)

Traditional smart city resources management rely on cloud based solutions to provide a centralized and rich set of open data. The advantages of cloud based frameworks are their ubiquity, (almost) unlimited resources capacity, cost efficiency, as well as elasticity. However, accessing data from the cloud implies large network traffic, high data latencies, and higher security risks. Alternatively, fog computing emerges as a promising technology to absorb these inconveniences. The use of devices at the edge provides closer computing facilities, reduces network traffic and latencies, and improves security. We have defined a new framework for data management in the context of smart city through a global fog to cloud management architecture; in this paper we present the data acquisition block. As a first experiment we estimate the network traffic during data collection, and compare it with a traditional real system. We also show the effectiveness of some basic data aggregation techniques in the model, such as redundant data elimination and data compression.

Networklet: Concept and Deployment
Sheng Zhang (Nanjing University), Yu Liang (Nanjing University of Posts and Telecommunications), Zhuzhong Qian (Nanjing University), Mingjun Xiao (University of Science and Technology of China), Jie Wu (Temple University), Fanyu Kong (Ant Financial), Sanglu Lu (Nanjing University)

In today’s datacenters, resource requests from tenants are increasingly transforming into hybrid requests that may simultaneously demand IaaS, PaaS, and SaaS resources. This paper tackles the challenge of modeling and deploying hybrid tenant requests in datacenters, for which we coin “networklet” to represent a set of VMs that collaboratively provide a PaaS or SaaS service. Through extracting networklets from tenant requests and thus sharing them between tenants, we can achieve a win-win situation for datacenter providers and tenants.

Optimistic Causal Consistency for Geo-Replicated Key-Value Stores
Kristina Spirovska (EPFL), Diego Didona (EPFL), Willy Zwaenepoel (EPFL)

In this paper we present a new approach to implementing causal consistency in geo-replicated data stores, which we call Optimistic Causal Consistency (OCC). The optimism in our approach lies in that updates from a remote data center are immediately made visible in the local data center, without checking if their causal dependencies have been received. Servers perform the dependency check needed to enforce causal consistency only upon serving a client operation, rather than on the receipt of a replicated data item as in existing systems. OCC explores a novel trade-off in the landscape of causal consistency protocols. The potentially blocking behavior of OCC makes it vulnerable to network partitions. Because network partitions are rare in practice, however, OCC chooses to trade availability to maximize data freshness and reduce the communication overhead. We further propose a recovery mechanism that allows an OCC system to fall back on a pessimistic protocol to continue operating even during network partitions. POCC is an implementation of OCC based on physical clocks. We show that OCC improves data freshness, while offering comparable or better performance than its pessimistic counterpart.

Automated Performance Evaluation for Multi-Tier Cloud Service Systems Subject to Mixed Workloads
Xudong Zhao (Shandong University), Lizhen Cui (Shandong University), Jiwei Huang (Beijing University of Posts and Telecommunications), Shijun Liu (Shandong University), Lei Liu (Shandong University), Calton Pu (Georgia Tech)

In multi-tier cloud service systems, performance evaluation relies on numerous experiments in order to collect key metrics such as resources usage. The approach may result in highly time-consuming in practice. In this paper, we propose an automated framework for performance tracking, data management and analysis to minimize human intervention in multitier cloud service systems. The framework support fine-grained analysis of the mixed workloads through the Discrete-time Markov-modulated Poisson process (DMMP). A general multitier application is theoretically formulated as a queueing network to evaluate the performance. The effectiveness of the model has been validated through extensive experiments conducted in the RUBiS benchmark system.

Decentralised Runtime Monitoring for Access Control Systems in Cloud Federations

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Cloud federation is an emergent cloud-computing paradigm where partner organisations share data and services hosted on their own cloud platforms. In this context, it is crucial to enforce access control policies that satisfy data protection and privacy requirements of partner organisations. However, due to the distributed nature of cloud federations, the access control system alone does not guarantee that its deployed components cannot be circumvented while processing access requests. In order to promote accountability and reliability of a distributed access control system, we present a decentralised runtime monitoring architecture based on blockchain technology.

**Poster 4: Distributed Systems and Networking Cluster**

**DuoFS: An Attempt at Energy-Saving and Retaining Reliability of Storage Systems**
Shu Yin (Hunan University)

As issues of the Energy Wall and the Reliability Wall become unavoidable, it is a demanding and challenging task to reduce energy consumption in large-scale storage systems in modern data centres while retaining acceptable systems reliability. Most energy conservation techniques inevitably have adverse impacts on the parallel disk systems. To address the reliability issues of energy-efficient parallel storage systems, we propose a reliable energy-efficient storage system called DuoFS, which aims at improving both energy efficiency and reliability of parallel storage systems by seamlessly integrating HDDs and SSDs. With the help of the middleware layer, DuoFS can distribute popular data to SSD-based nodes and put HDD-based nodes into the low-power mode under light workload conditions without modification of the parallel systems.

**A Proposal of an Efficient Traffic Matrix Estimation under Packet Drops**
Kohei Watabe (Nagaoka University of Technology), Toru Mano (NTT Network Innovation Laboratories), Kimihiro Mizutani (NTT Network Innovation Laboratories), Osamu Akashi (NTT Network Innovation Laboratories), Kenji Nakagawa (Nagaoka University of Technology), Takeru Inoue (NTT Network Innovation Laboratories)

Traffic matrix (TM) estimation has been extensively studied for decades. Although conventional estimation techniques assume that traffic volumes are unchanged between origins and destinations, packets are often discarded on a path due to traffic burstiness, silent failures, etc. This paper proposes a novel TM estimation method that works correctly even under packet drops. The method is established on a Boolean fault localization technique; the technique requires fewer counters though it only determines whether each link is healthy. This paper extends the Boolean technique so as to deal with traffic volumes with error bounds just by a small number of counters. Along with submodular optimization for the minimum counter placement, we evaluate our method with real network datasets.

**Straggler Mitigation for Distributed Behavioral Simulation**
Eman Bin Khunayn (University of Melbourne), Shanika Karunasekera (University of Melbourne), Hairuo Xie (University of Melbourne), Kotagiri Ramamohanarao (University of Melbourne)

Running large-scale behavioral simulations requires high computational power, which can be acquired by distributing computation workload to multiple computing nodes (i.e., workers) that run in parallel. The implementations of such systems commonly follow the Bulk Synchronous Parallel (BSP) model. However, implementations using BSP usually suffer from the straggler problem, where the delay of any worker slows down the entire simulation. The problem usually occurs due to communication delays or imbalanced workload among workers. To mitigate the straggler problem, we propose a novel parallel computational model, called Priority Synchronous Parallel (PSP) model. PSP exploits data dependencies of parallel processes to determine high priority data to be computed and synchronized while computing the remaining data. PSP is implemented and evaluated using traffic simulations for three large cities. The proposed technique shows significant performance improvements over the BSP model.

**Supporting Resource Control for Actor Systems in Akka**
Ahmed Abdel Moamen (University of Saskatchewan), Dezhong Wang (University of Saskatchewan), Nadeem Jamali (University of Saskatchewan)

Although there are models and prototype implementations for controlling resource use in Actor systems, they are difficult to implement for production implementations of Actors such as Akka. This is because the messaging and scheduling infrastructures of runtime systems vary widely and are increasingly complex. In this paper, we compare two different ways of approximating actor-level control support for Akka. The first implementation expects actor messages to include estimates of resources required for processing them. The second implementation simply tracks actors’ resource use to decide when they should be scheduled next. We present experimental results on the performance cost of these resource control mechanisms, as well as their impact on resource utilization.

**A Distributed Operating System Network Stack and Device Driver for Multicores**
B M Saif Ansary (ECE, Virginia Tech), Antonio Barbalace (ECE, Virginia Tech), Binoy Ravindran (ECE, Virginia Tech), Thomas Lazor (ECE, Virginia Tech), Ho-Ren Chuang (ECE, Virginia Tech)

With the advances in network speeds a single processor cannot cope anymore with the growing number of data streams from a single network card. Multicore processors come at a rescue but traditional SMP OSes, which integrate the software network stack, scale only to a certain extent, limiting an application’s ability to serve more connections while increasing the number of cores. On the other hand, kernel bypass solutions seem to scale better, but limit resource flexibility and control. We propose attacking these problems with a distributed OS design, using multiple network stacks (one per kernel) and relying on multi-queue hardware and hardware flow steering. This creates a single-socket abstraction among kernels while minimizing inter-core communication. We introduce our design, consisting of a distributed network stack, a distributed device driver, and a load-balancing algorithm. We compare our prototype, NetPopcorn, with Linux, Affinity Accept, FastSocket. NetPopcorn accepts between 5 to 8 times more connections and reduces the tail latency compared to these competitors. We also compare NetPopcorn with mTCP and observe that for high core counts, mTCP accepts only 18% more connections yet with higher tail latency than NetPopcorn.

**Cache Potentiality of MONs: A Prime**
Peyyan Yuan (Henan Normal University), Honghai Wu (Henan University of Science and Technology), Xiaoyan Zhao (Henan Normal University), Zhengnan Dong (Henan Normal University)
Node buffer size has a big influence on performance of Mobile Opportunistic Networks (MONs). This is mainly because each node should temporarily cache packets to deal with the intermittently connected links. In this paper, we study fundamental bounds on node buffer size below which the network system can not achieve the expected performance. Given the condition that each link has the same probability \( p \) to be active, and \( q \) to be inactive during each time slot, there exits a critical value \( p_c \) from a percolation perspective. If \( p > p_c \), the network is in the supercritical case, there is an achievable upper bound on the buffer size of nodes, independent of the inactive probability \( q \). When \( p < p_c \), the network is in the subcritical case, and there exists a closed-form solution for buffer occupation, which is independent of the size of the network.

**Oak: User-Targeted Web Performance**

Marcel Flores(Northwestern University), Alexander Wenzel(Northwestern University), Aleksandar Kuzmanovic (Northwestern University)

Web performance has long proved to be one of the most sought after and difficult to achieve components for the web. Since the inception of the modern web infrastructure, the situation has been growing in complexity, adding remote hosts and objects, providing everything from computation infrastructure, content distribution capability, and targeted advertising. While many of these components provide improvements for some users, the complexity of the Internet often leaves other users suffering from poor performance. We propose Oak, a system which addresses client performance on the individual level, hence addressing challenges which may be unique to the user. Oak measures a user’s performance for objects loading on a page, and determines which components are underperforming. Oak further provides an automated mechanism by which sites are able to replace resources with those provided by a better performing alternative service for a particular user. In this work, we demonstrate the prevalence of underperforming services on the web, finding that over 60% of the Alexa Top 500 have at least one under-performing server. We further evaluate Oak on experimental and popular existing webpages, and demonstrate its effectiveness in making decisions in existing environments and with a distributed user base.

**Ctrl-A: A Self-* Distributed and In-band SDN Control Plane**

Marco Canini (Université catholique de Louvain), Iosif Salem (Chalmers University of Technology), Liron Schiff (Tel Aviv University), Elad Michael Schiller (Chalmers University of Technology), Stefan Schmid (Aalborg University & TU Berlin)

Adopting distributed control planes is critical towards ensuring high availability and fault-tolerance of dependable Software-Defined Networks (SDNs). However, designing and bootstrapping a distributed SDN control plane is a challenging task, especially if to be done in-band, without a dedicated control network, and without relying on legacy networking protocols. One of the most appealing and powerful notions of fault-tolerance is self-organization and this paper discusses the possibility of self-organizing algorithms for in-band control planes.
Tutorial Abstracts

Tutorial 1: Serverless Programming (Function as a Service)

Paul Castro (IBM T.J. Watson Research Center), Vatche Ishakian (Bentley University), Vinod Muthusamy (IBM T.J. Watson Research Center), Aleksander Slominski (IBM T.J. Watson Research Center)

Serverless Computing (Function as a Service) is emerging as a new and compelling paradigm for the deployment of cloud applications, largely due to the recent shift of enterprise application architectures to containers and microservices.

From the perspective of an Infrastructure-as-a-Service (IaaS) customer, this paradigm presents both an opportunity and a risk. On the one hand, it provides developers with a simplified programming model for creating cloud applications that abstracts away most, if not all, operational concerns; it lowers the cost of deploying cloud code by charging for execution time rather than resource allocation; and it is a platform for rapidly deploying small pieces of cloud native code that responds to events, for instance, to coordinate microservice compositions that would otherwise run on the client or on dedicated middleware. On the other hand, deploying such applications in a serverless platform is challenging and requires relinquishing to the platform design decisions that concern, among other things, quality-of-service (QoS) monitoring, scaling, and fault-tolerance schemes.

From the perspective of a cloud provider, serverless computing provides an additional opportunity to control the entire development stack, reduce operational costs by e cient optimization and management of cloud resources, and enabling a serverless ecosystem that encourages the deployment of additional cloud services.

Serverless platforms promise new capabilities that make writing scalable microservices easier and cost effective, positioning themselves as the next step in the evolution of cloud computing architectures. Most of the prominent cloud computing providers including Amazon, IBM, Microsoft, and Google have recently released serverless computing capabilities. There are also several open-source efforts including the OpenLambda project.

In this tutorial, we will present serverless computing, survey existing serverless platforms from industry, academia, and open source projects, identify key characteristics and use cases, and describe technical challenges and open problems. Our tutorial will involve a hands-on experience of using the serverless technologies available from different cloud providers (e.g. IBM, Amazon, Google and Microsoft). We expect our users to have basic knowledge of programming and basic knowledge of cloud computing.

Paul Castro, Ph.D. is a Research Staff Member at the IBM Watson Research Center. He has been active in research on mobile and pervasive computing, cloud infrastructure, wireless location systems, location databases, stream processing, and enterprise web applications and has been awarded several patents in these areas. He has worked on cloud services for supporting mobile applications running on various smart phone platforms. Work from his research in the area of multi-device application support was recently released as part of the IBM Bluemix Mobile Backend as a Service. He has earned two IBM Technical Achievement Awards for the IBM SmartCloud Web Meetings for mobile clients and the Intelligent Notification System. Most recently, he worked on IBM OpenWhisk for Bluemix, with a focus on mobile solutions.

Vatche Ishakian is an Assistant Professor in the Computer Information Systems department at Bentley University, before starting his academic career, Vatche was a Research Staff Member at IBM Research working on several projects including IBM OpenWhisk serverless computing platform. Vatche’s PhD in Computer Science from Boston University. His research interests include distributed business process management, Services composition, and priced based models for cloud services.

Vinod Muthusamy is a Research Staff Member in the Component Systems Group at the IBM T.J. Watson Research Center. He completed his PhD in Computer Engineering at the University of Toronto. Vinod’s research interests include publish/subscribe event processing, and distributed business process management. Most recently, he worked on IBM OpenWhisk Serverless Computing platform.

Aleksander Slominski is a Research Staff Member in the Services and API Ecosystems Group at the IBM T.J. Watson Research Center. He is interested in development of applications for for future API Economy that take advantage of upcoming cloud programming approaches, such as serverless computing, for compositions and orchestration of components into business workflows. Most recently, he worked on IBM IBM OpenWhisk Serverless Computing platform.

Tutorial 2: Sensor Cloud: A Cloud of Sensor Networks

Sanjay Madria (Missouri University of Science and Technology)

Traditional model of computing with wireless sensors imposes restrictions on how efficiently wireless sensors can be used due to resource constraints. Newer models for interacting with wireless sensors such as Internet of Things and Sensor Cloud aim to overcome these restrictions. In this tutorial, I will discuss sensor cloud architectures, which enable different wireless sensor networks, spread in a huge geographical area to connect together and be used by multiple users at the same time on demand basis. I will further discuss how virtual sensors assist in creating a multiuser environment on top of resource constrained physical wireless sensors and can help in supporting multiple applications on-demand basis. I will then present some security issues and provide overview of the solutions to the problems from the literature. In particular, I will discuss energy efficient privacy and data integrity preserving data aggregation algorithm, risk assessment in sensor cloud as well as attribute-based access control for sensor cloud applications. The topics covered will be: 1. Cloud of Sensors – Sensor Cloud Architectures 2. Virtualization in Sensor Cloud 3. Scheduling and QoS in Sensor Cloud 4. Data compression and Secure Aggregation in Sensor Cloud 5. Security, Privacy and Risk Issues in Sensor Cloud

Sanjay K Madria received his Ph.D. in Computer Science from Indian Institute of Technology, Delhi, India in 1995. He is a full professor in the Department of Computer Science at the Missouri University of Science and Technology (formerly, University of Missouri-Rolla, USA). He has published over 235 Journal and conference papers in the areas of mobile and sensor computing, cloud and cybersecurity. He won five IEEE best papers awards in conferences such as IEEE MDM 2011, IEEE MDM 2012 and IEEE SRDS 2015. He is a co-author of a book published by Springer in Nov 2003. He has presented tutorials in the areas of secure sensor cloud, cloud computing, mobile computing, etc. NSF, NIST, ARL, ARO, AFRL, DOE, Boeing, Hangsoft and Boeing have funded his research projects, among others. He was awarded JSPS (Japanese Society for Promotion of Science) visiting scientist fellowship in 2006 and ASEE (American Society of Engineering Education) fellowship from 2008 to 2017. In 2012, he was awarded NRC Fellowship by National Academies. He received faculty excellence and research awards in the years 2007, 2009, 2011, 2013 and 2015 from his university for excellence in research. He is ACM Distinguished Scientist, and ACM Distinguished Speaker and IEEE Senior Member as well as IEEE Golden Core Awardee.
Understanding and Improving Temporal Fairness on an Electronic Trading Venue
Hayden Melton (Deakin University)

Fairness, in general, is a topic that has received much attention in research on distributed systems. In their application as electronic trading venues, however, temporal fairness remains a topic that is poorly understood. This is concerning because operators of these venues generally have obligations to ensure their fairness. Consequently, this paper (1) describes what temporal fairness is and is not, (2) identifies things that can make it elusive, and (3) describes a mechanism for improving it that was recently retrofitted to a major FX trading venue: Thomson Reuters Matching.

CertificateLess Cryptography-based Rule Management Protocol for Advanced Mission Delivery Networks
Jongho Won (Purdue University), Ankush Singla (Purdue University), Elisa Bertino (Purdue University)

Assured Mission Delivery Network (AMDN) is a collaborative network to support data-intensive scientific collaborations in a multi-cloud environment. Each scientific collaboration group, called a mission, specifies a set of rules to handle computing and network resources. Security is an integral part of the AMDN design since the rules must be set by authorized users and the data generated by each mission may be privacy-sensitive. In this paper, we propose a CertificateLess cryptography-based Rule-management Protocol (CL-RP) for AMDN, which supports authenticated rule registrations and updates with non-repudiation. We evaluate CL-RP through test-bed experiments and compare it with other standard protocols.

Faulty Sensor Data Detection in Wireless Sensor Networks Using Logistical Regression
Tianyu Zhang (University of Hyogo), Qian Zhao (University of Hyogo), Yukikazu Nakamoto (University of Hyogo)

Wireless sensor networks (WSNs) are commonly used to monitor changes in an environment and prevent disasters such as structural instability, forest fires, and tsunamis. WSNs should rapidly respond to changes and must process and analyze sensor data in a distributed way to minimize battery consumption. On the other hand, machine learning (ML) algorithms are a powerful tool for data analyzing. However, ML algorithms are so complex that cannot be executed on resource-constrained sensor nodes. Another challenge of using ML algorithms in WSNs is that ML algorithms are difficult to be distributed on every sensor node. Because ML algorithms are based on statistics’ methods that need collecting amount of data to approach accuracy. In this paper, we propose a method that divides a logistical regression ML method into two steps, then distributes the two steps onto sink node and sensor nodes to detect faulty sensor data.

An Adaptability-Enhanced Routing Method for Multiple Gateway-based Wireless Sensor Networks Using Secure Dispersed Data Transfer
Ryuma Tani (Hiroshima City University), Kento Aoi (Hiroshima City University), Eitaro Kohno (Hiroshima City University), Yoshiaki Kakuda (Hiroshima City University)

In conventional wireless sensor networks (hereinafter referred to as WSNs), the single sink node model has been employed to collect and store the measured data to provide to the external users of WSNs. However, the single sink model of WSNs can be the single point of failure for some usage. To counter this problem, we can employ multiple gateway-based WSNs. In addition, WSNs are susceptible to various kinds of attacks such as eavesdropping. To counter eavesdropping, we already have proposed the secret sharing scheme-based secure dispersed data transfer method (hereinafter referred to as the secure dispersed data transfer method). While we had confirmed that the secure dispersed data transfer method is effective to counter eavesdropping through the use of radio area disjoint multiple paths, we also found that the secure dispersed data transfer method cannot be effective in severe environments such as in a network with a low density of nodes.

A Progressive Download Method Based on Timer-Driven Requesting Schemes Using Multiple TCP Flows on Multiple Paths
Hiroaki Horiba (Hiroshima City University), Tokumasa Hiraoka (Hiroshima City University), Junichi Funasaki (Hiroshima City University)

Due to the widespread use of broadband communication media, the conventional TCP cannot fully utilize such broad bandwidth, so many improvements on TCP itself and a lot of accelerating methods which use multiple TCP flows have been proposed. In addition, video hosting services on the Internet as a new medium have become popular, and progressive downloading methods, which download segmented video data while replaying them, are adopted on various sites. The playback quality of progressive download methods has been improved by the existing method which establishes multiple TCP flows on each of multiple paths. However, the existing method assumes that bandwidth, delay, and packet loss rate of each path are known. Therefore, in this paper, a method using the timer-driven requesting scheme which is to be effective even when bandwidth, delay, and packet loss rate are not given. Moreover, it features duplicate requesting scheme to cope with quality deterioration in video playback due to out-of-order block arrivals when applying progressive download using multiple paths. This paper evaluates the proposed method comparing with the existing method by simulation. As a result, it is found that the proposed method yields high performance enough to keep the video quality higher than the existing method even though the network condition is not clarified in advance. The proposal can be regarded as an assurance network technology so it can adapt to the current network status and keep the playback rate high.
BGP 2017 Workshop Abstracts

WolfPath: Accelerating iterative traversing-based graph processing algorithms on GPU
Huazhong Zhu (University of Warwick), Ligang He (University of Warwick)

There is a significant interest nowadays in developing the frameworks of parallelizing the processing for the large graphs such as social networks, Web graphs, etc. Most parallel graph processing frameworks employ iterative processing model. However, by benchmarking the state-of-art GPU-based graph processing frameworks, we observed that the performance of iterative traversing-based graph algorithms (such as Bread First Search, Single Source Shortest Path and so on) on GPU is limited by the frequent data exchange between host and GPU. In order to tackle the problem, we develop a GPU-based graph framework called WolfPath to accelerate the processing of iterative traversing-based graph processing algorithms. In WolfPath, the iterative process is guided by the graph diameter to eliminate the frequent data exchange between host and GPU. To accomplish this goal, WolfPath proposes a data structure called Layered Edge list to represent the graph, from which the graph diameter is known before the start of graph processing. In order to enhance the applicability of our WolfPath framework, a graph preprocessing algorithm is also developed in this work to convert any graph into the format of the Layered Edge list. We conducted extensive experiments to verify the effectiveness of WolfPath. The experimental results show that WolfPath achieves significant speedup over the state-of-art GPU-based in-memory and out-of-memory graph processing frameworks.

A Novel Auction-based Query Pricing Schema
Xingwang Wang (Jilin University), Xiaohui Wei (Jilin University), Shang Gao (Jilin University), Yuanyuan Liu (Jilin University), Zongpeng Li (University of Calgary)

As a common processing method, query is widely used in many areas, such as graph processing, machine learning, statistics, etc. However, queries are usually priced according to vendor-specified fixed views (API) or number of transactions, which ignores the heterogeneity of queries (computing resource consumption for query and information that the answer brings) and violates the monotone principle.

In this work we study the relational query pricing problem by taking both information (i.e., data) value and query resource consumptions into account. We design efficient auctions for query pricing. Different from the existing query pricing schemas, query auction determines data prices that reflect the demand-supply of shared computing resources and information value (i.e., price discovery). We target query auction that runs in polynomial time and achieves near-optimal social welfare with a good approximation ratio, while elicits truthful bids from consumers. Towards these goals, we adapt the posted pricing framework in game-theoretic perspective by casting the query auction design into an Integer Linear Programming problem, and design a primal-dual algorithm to approximate the NP-hard optimization problem. Theoretical analysis and empirical studies driven by real-world data market benchmark verify the efficiency of our query auction schema.

BlockGraphChi: Enabling Block Update in Out-of-core Graph Processing
Zhiyuan Shao (Huazhong University of Science and Technology), Zhenjie Mei (Huazhong University of Science and Technology), Xiaofeng Ding (Huazhong University of Science and Technology), Hai Jin (Huazhong University of Science and Technology)

In the past several years, lots of out-of-core graph processing systems are built to process big graph datasets in computer systems with limited main memory. Due to the iterative nature of graph algorithms, most of these systems employ synchronous execution model to organize the computation, i.e., divide the computing into multiple rounds, each of which corresponds to one iteration of the graph algorithm. In order to fully utilize the disk bandwidth, these systems sequentially scan the whole graph dataset at each iteration. However, as the graph dataset under processing may be huge, more iterations generally means larger I/O overheads. Although asynchronous implementation of the synchronous execution model allows message passing within an iteration, the effectiveness is still limited. Since in such model, at most one message is allowed to be passed from one vertex to another.

In this paper, we investigate the idea of block updating in the synchronous execution model framework in the out-of-core graph processing systems. With this new model, the system conducts graph algorithm on the loaded subgraph (i.e., block) to its local convergence, and then switches to other subgraphs to continue this process, until the global convergence is reached. We implement this new model in GraphChi (the result system is called BlockGraphChi), and propose a graph partition method, named as DMLP, to cooperate with this new model. By this study, we found that compared with the original execution model of GraphChi: 1) the new model can generally reduce the amount of iterations (and thus the I/O overheads) for graph algorithms, while the extent of reduction depends on the method of graph partitioning and the properties of the algorithms; 2) the new model can dramatically reduce the overall execution time of graph traversal algorithms (by up to 31x), and better partitioning method leads to better performance; 3) the new model has much smaller effectiveness on improving the overall performance of fix-point algorithms, such as PageRank, due to the increased computational overhead.

Incremental Parallel Computing using Transactional Model in Large-scale Dynamic Graph Structures
Anand Tripathi (University of Minnesota, Minneapolis), Rahul R. Sharma (University of Minnesota), Manu Khandelwal (University of Minnesota), Tanmay Mehta (University of Minnesota), Varun Pandey (University of Minnesota)

Many graph analytics problems benefit from the use of parallel computing techniques to reduce the execution time, which can still be quite high for large graph problems. The goal of our work is to eliminate the need of re-executing an analytics program when the graph structure is modified with a small set of updates after the initial execution of the program. Towards this goal, we present here the results of our investigation of incremental computation techniques in dynamic graph
structures using a transactional model of parallel programming. In this model, computation tasks in an analytics application are executed in parallel as serializable transactions. This paper describes how incremental computation techniques are supported by this model for dynamic graph structures. We use the problems of finding connected-components in a graph and the graph coloring problem to illustrate our approach for incremental computations. Using experimental evaluations, we show the benefits of this approach.

**Against Signed-Graph Deanonymization Attacks: Privacy Protection for Social Networks**

Jianliang Gao (Central South University), Yu Liu (Central South University), Ping Zhong (Central South University), Jianxin Wang (Central South University)

Social networks are usually presented as graphs. But the topological characteristics of graphs could be used by attackers to deanonymize target entities in social networks. Existing works mostly have an assumption that attacker knows only the target entities’ neighborhood graph. This assumption might result in privacy leakage because of the ignorance of link property between entities. In real applications, attackers might re-identify entities in social networks based on not only the links between entities, but also the property of links. In this paper, we take the property of links into consideration for the first time when achieving $k$-anonymity for social networks, which means the attackers cannot re-identify a target with confidence higher than $1/k$. The links are cataloged as positive and negative, which is called signed graph. In this background, we propose a $k$-anonymization scheme to protect the privacy of key entities in social networks. The proposed scheme minimizes the amount of modification on original graphs, which preserves the utility of the original data. Extensive experiments on real data sets and synthetic graph illustrate the effectiveness of the proposed scheme. The utility of anonymized networks are remained by demonstrating with the results of vertex degree, betweenness, closeness and their Kolmogorov-Smirnov (K-S) test.
CCN-CPS 2017 Workshop Abstracts

Policies Guiding Cohesive Interactions among Internet of Things with Communication Cloud and Social Networks
Henry Hexmoor (Southern Illinois University)

Cohesive interaction among Internet of thing nodes will benefit from formation of ad hoc communication network clouds for rapid exchange of information that is pertinent for their successful interaction. Long enduring interactions among such nodes will benefit from ad hoc socially linked networks for collaboration on shared objectives. We present guidelines for forming and using these constructs and policies that constrain them to requirements of specific applications.

Enhanced Security of Building Automation Systems Through Microkernel-Based Controller Platforms
Xiaolong Wang (University of South Florida), Richard Habeeb (University of South Florida), Xinming Ou (University of South Florida), Siddharth Amaravadi (Kansas State University), John Hatcliff (Kansas State University), Masaaki Mizuno (Kansas State University), Mitchell L Neilsen (Kansas State University), Raj Rajagopalan (Honeywell), Srivatsan Varadarajan (Honeywell Aerospace Advanced Technology Labs)

A Building Automation System (BAS) is a complex distributed Cyber-Physical System that controls building functionalities such as heating, ventilation, and air-conditioning (HVAC), lighting, access, emergency control, and so on. There is a growing opportunity and motivation for BAS to be integrated into enterprise IT networks together with various new "smart" technologies to improve occupant comfort and reduce energy consumption. These new technologies coexist with legacy applications, creating a mixed-criticality environment. In this environment, as systems are integrated into IT networks, new attack vectors are introduced. Thus, networked non-critical applications running on the OS platform may be compromised, leaving the control systems vulnerable. The industry needs a reliable computing foundation that can protect and isolate these endangered critical systems from untrusted applications.

This paper presents a novel kernel-based approach to secure critical applications. Our method uses a security-enhanced, microkernel architecture to ensure the security and safety properties of BAS in a potentially hostile cyber environment. We compare three system design and implementations for a simple BAS scenario: 1) using the microkernel MINIX 3 enhanced with mandatory access control for inter-process communication (IPC), 2) using seL4, a formally verified, capability-based microkernel, and 3) using Linux, a monolithic kernel OS. We show through experiment that when the non-critical applications are compromised in both MINIX 3 and seL4, the critical processes that impact the physical world are not affected. Whereas in Linux, the compromised applications can easily disrupt the physical processes, jeopardizing the safety properties in the physical world. This shows that microkernels are a superior platform for BAS or other similar control environments from a security point of view, and demonstrates through example how to leverage the architecture to build a robust and resilient system for BAS.

High level Design of a Home Autonomous System Based on Cyber Physical System Modeling
Basman Alhafidh (Florida Institute of Technology), William H. Allen (Florida Institute of Technology)

The process used to build an autonomous smart home system using cyber-physical systems (CPS) principles has received much attention by researchers and developers. However, there are many challenges during the design and implementation of such a system, such as Portability, Timing, Prediction, and Integrity. This paper presents a novel modeling methodology for a smart home system in the scope of cyber-physical interface that attempts to overcome these issues. We discuss a high-level design approach that simulates the first three levels of a SC architecture in CPS layers in a smart home environment. A detailed description of the model design, architecture, and a software implementation via Netlogo simulation program will be presented. Our design provides an example for developers on how to implement an ecosystem in a home environment as part of a smart cities' infrastructure based on CPS design principles.

A Cyber Physical Buses-and-Drones Mobile Edge Infrastructure for Large Scale Disaster Emergency Communications
Mamta Narang (Auckland University of Technology), William Liu (Auckland University of Technology), Jairo A Gutierrez (Auckland University of Technology), Luca Chiaraviglio (University of Rome Tor Vergata)

Immediately after a disaster, the normal telecommunication infrastructure, including wired and wireless networks, is often seriously compromised and cannot guarantee regular coverage and reliable communications services. These temporarily-missing communications capabilities are crucial to rescuers and affected citizens as the responders need to effectively coordinate and communicate to minimize the loss of lives and property. A cyber-physical system (CPS) is composed of integrated communication, computation and physical objects, and cyber-physical vehicle systems (CPVSs) are an emerging field due to the rapid advancements on real-time computing, mobile communications and autonomous control in intelligent transport systems. In this paper, we propose a cyber-physical buses-and-drones mobile edge infrastructure (AidLife) for disaster emergency communications, which aims at a rapidly deployable resilient system capable of supporting flexible communications to serve large-scale disaster situations by utilizing the existing public transport system. In particular we envision a proposal where public buses can be recruited to temporarily host portable base station (BS) and computation units as well as power resources so as to form a buses-based mobile edge infrastructure, and also accommodate drones to extend their coverage to hard-to-reach areas. Our preliminary results show that the AidLife system can guarantee a good coverage to users, even when a large number of normal BSs that are damaged.

A Performance Comparison of Containers and Virtual Machines in Workload Migration Context
Kumar Gaurav (VMware Software India Pvt Ltd), Pavan Karkun (VMware Software India Pvt Ltd), Y. C. Tay (National University of Singapore)

This paper gives a mathematical framework for decision making around placing and migrating workloads in a data-center where applications are packaged as OS containers running on virtual machines. The decision point on VM migration vs container kill/restart, VM fork vs container spawn are studied here. We propose a mathematical model for the migration of workloads aforementioned cases and also for shared memory decay in case of forking a virtual machine. Experimental results are analyzed to determine the validity of the model.

Towards Service-Oriented Middleware for Cyber Physical Systems
Nader Mohamed (Middleware Technologies Lab.), Sanja Lazarova-Molnar (University of Southern Denmark)

Cyber-Physical Systems (CPS) provide many smart features for enhancing physical systems and environments. They are designed with a set of distributed hardware, software, and network components that are embedded in physical systems and environments or attached to humans. Many CPS at different scales are being developed for a variety of applications that provide valuable interactions between the cyber world and the physical systems and environments. However, these developments face many challenges due to the complexity of these applications. An appropriate middleware is needed to provide infrastructural support and assist
the development and operations of diverse CPS applications. This paper studies utilizing the service-oriented middleware approach for CPS and discusses the advantages and requirements for such utilization. In addition, it proposes a service-oriented middleware for CPS, called CPSWare. This middleware views all CPS components as a set of services and provides an infrastructure to develop and operate CPS applications. This approach provides systemic solutions for solving many computing and networking issues in CPS. It also enables the integration of CPS with other systems such as Cloud Computing and Fog Computing. In addition, as CPS can be developed for various applications at different scales, this paper provides a classification for CPS applications and discusses how CPSWare can effectively deal with these categories.

**Networking and Communication in Cyber Physical Systems**

Imad Jawhar (UAE University), Jameela Al-Jaroodi (Robert Morris University)

Cyber-physical systems (CPSs) are emerging as a new technology, which is used to provide seamless interaction between the physical and cyber worlds. This novel paradigm is a natural evolution and extension of wireless sensor networks (WSNs) and control models to allow for effective monitoring and control of physical systems from the computing environment. In order to support this interface and allow such smooth interactions, efficient networking and communication between the physical and cyber worlds take a very important and critical role. In this paper, we identify the various applications and categories of CPS systems, and characterize the associated data traffic that is generated. We also discuss the different protocols and requirements that are needed at the various networking layers for these applications. Subsequently, we identify important parameters such as bandwidth, delay, reliability, security, and mobility, which are essential in order to allow for effective and robust operation of the various CPS systems.

**Optimal Deployment of Charging Stations for Electric Vehicles: A Formal Approach**

Amarjit Datta (Tennessee Technological University), Brian Ledbetter (Tennessee Technological University), Mohammad Ashiqur Rahman (Tennessee Technological University)

Electric vehicles (EVs) are a fascinating innovation of the modern automobile industry. Due to their attractive features and a growing worldwide environmental awareness, the number of EV purchases is growing at an increasing rate day by day. As the price of EVs is expected to drop in the near future, a large number of new EVs will hit the road consequently. However, our current infrastructure is not capable of supporting this growing number of EVs. We need more charging stations, placed optimally across an area, each equipped with multiple charging outlets to charge the incoming EVs in a reasonable amount of time. In this paper, we present a formal framework to optimally deploy charging stations for EVs in a given area. The framework designs this verification as an optimization problem where the goal is to optimally place the charging stations with a sufficient number of charging outlets to serve all EVs in a given area while satisfying the limited budget and other system constraints. We evaluate the proposed framework for its analysis capability as well as its scalability by executing experiments on different synthetic test cases.

**Formal Verification of Control Strategies for a Cyber Physical System**

Amjad Gawanmeh (Khalifa University of Science and Technology), Ali Alwadi (Auckland University of Technology), Sazia Parvin (University of New South Wales)

Cyber Physical Systems (CPS) use emerging computing, communication, and control methods to monitor and control geographically dispersed critical system components to allow a high level of confidence about their operation. Simulation methods are frequently used in testing such critical system components, however, it might not be adequate to show the absence of errors given the complexity of the system components under test. Failure in detecting errors in safety critical systems can lead to a catastrophic situation. In this paper we propose an approach, based on simulation and formal analysis, for the reliability analysis of CPS. We illustrate this approach on an industrial case study that demonstrates several challenging features in the design and implementation of CPS. Experimental results obtained show that the proposed approach is efficiently used in order to test and verify the four tanks process system, where simulation results show the validity of approximation and abstraction of the system, and formal analysis is used to validate that several design requirements were satisfied in the control strategies proposed.

**Lightweight Detection and Isolation of Black Hole Attacks in Connected Vehicles**

Samir Alboq (Oakland University), Erik Fredericks (Oakland University)

Connected Vehicles (CVs) can be exposed to black hole attacks that deceive legitimate nodes by falsifying an attractive route to a destination node. This occurs when an attacker sends a packet to the source node confirming the existence of a fresh route. In this paper, we propose a Black Hole Detection Protocol (BlackDP) that works on a highway divided into clusters and monitored by Road Side Units (RSUs) to detect both single and cooperative black hole attacks. Every RSU is tasked with performing both detection and isolation of black hole attacks for their respective highway section after authentication violations and suspicious route establishment activities that have been reported by a legitimate node. The design goal of BlackDP is to decouple the detection process from mobile nodes and construct a trusted semi-centric detection process that can collect needed information for lightweight detection and reliable isolation of malicious nodes. We validate BlackDP in a simulated highway environment to demonstrate its effectiveness.

**A new threat assessment method for integrating an IoT infrastructure in an information system**

Bruno Dorosmaine (Orange Labs), Jean-Philippe Gaulier (Orange Labs), Jean-Philippe Wary (Orange Labs), Nizar Kheir (Thales), Pascal Urien (Telecom ParisTech)

In this paper, we propose a new approach to manage the threats brought by an IoT infrastructure to an information system (IS). We first give a state of art for information security properties in IoT and IS based on standards such as ISO 16982 and ISO 27005 and a previously published taxonomy. Then we detail an innovative method, based on the evaluation of threats brought by an IoT infrastructure onto an IS. It is represented as a qualitative matrix between IoT infrastructure threats and the Security properties of the IS. The method is then applied to the use case of connected light bulbs. Thanks to this approach, it is possible to logically organize threat management while integrating an IoT infrastructure into an IS.

**A Security Framework for SDN-enabled Smart Power Grids**

Uttam Ghosh (Tennessee State University), Pushpita Chatterjee (SRM RESEARCH INSTITUTE), Sachin Shetty (Old Dominion University)

Emerging software defined networking (SDN) paradigm provides flexibility in controlling, managing, and dynamically reconfiguring smart grid networks. It can be seen in the literature that considerably less attention has been given to provide security in SDN-enabled smart grid networks. Most of the efforts focus on protecting
smart grid networks against various forms of outsider attacks only by providing consistent access control, applying efficient and effective security policies, and managing and controlling the network through the use of a centralized SDN controller. Furthermore, centralized SDN controllers are plagued by reliability and security issues. This paper presents a framework with multiple SDN controllers and security controllers that provides a secure and robust smart grid architecture. The proposed framework deploys a local IDS in a substation to collect the measurement data periodically and to monitor the control commands that are executed on SCADA slaves. A global IDS in control center collects the measurement data from the substations and estimates the state of the smart grid system by utilizing the theory of differential evolution. The global IDS further verifies the consequences of control-commands issued by SDN controller and SCADA master. An alarm is generated upon detection of an attacker or unsteady state of the smart grid system. The framework also deploys light-weight identity based cryptography to protect the smart grid network from outside attacks. Performance comparison and initial simulation result have been presented to show that the proposed framework is effective as compared to existing security frameworks for SDN-enabled smart grids.

Real-time Monitoring Steam Generators using a Hybrid Imaging System
Mahmoud Meribout (Petroleum Institute), Imran Saied (Petroleum Institute), Esra Al Hosani (Adco Group)
This paper presents a hybrid device for real-time measurement and imaging of solid and liquid contaminants that may occur in steam generators. The device uses a dedicated Near Infra-Red device to determine the type of contaminants (i.e. water droplets and iron oxide particles) and a THz imaging system which measures the amount of contaminants as well as its flow rate. The NIR device can also determine the concentration of contaminants at sub-ng accuracy when its value is relatively low using spectrometry technique combined with principal component analysis (PCA). Three principal components (PC1, PC2, and PC3) were enough for this purpose. The PCA classification was performed using the least square support vector machine (LS-SVM) method. In case of relatively high concentration, the THz imaging system which uses block-based motion estimation algorithm can determine the velocity of individual contaminant particles to compute the global motion vector, the intensity and direction of which represents the overall flow rate and flow regime of the contaminants. The usage of image processing techniques together with NIR spectrometry constitutes a new promising step in flow metering. This is demonstrated by the extensive experiments which have been conducted for different scenario where the NIR subsystem system could determine the concentration of water droplets and solid contaminants with a maximum uncertainty of +/- 1.45% and +/- 1.16% respectively. With the NIR subsystem, pixel-level accuracy of motion vector was achieved, while the concentration of solid contaminants showed consisted proportionality with the average pixel intensity.

Securing big Data Efficiently through Microaggregation Technique and Huffman Compression
Shakila Mahjabin Tonni (Bangladesh Army International University of Science and Technology), Mohammad Zahidur Rahman (Jahangirnagar University), Sazia Parvin (University of New South Wales), Amjad Gawannmeh (Khalifa University of Science and Technology)
Cyber-Physical Systems (CPS) requires big data communications as well as integration from several distributed sources. This data can usually be interconnected with physical applications, such as power grids or SCADA systems. In addition, it can be publicly accessible for using by third party users or data scientists. Therefore, it becomes imperative to ensure that this big data is well secured. Microaggregation is an widely used technique to protect a dataset through anonymity in order to prevent exposure of a person's identity. This data disclosure may also result from an unpredicted data linkage with another dataset. As, most of these survey datasets store records using numerical values, many of the microaggregation techniques are developed and tested on numerical data. These algorithms are not suitable for those data where both numerical and categorical data are stored. In this paper we're proposing a microaggregation technique in order to provide data anonymity regarding of its type. The records are clustered into several groups using an evolutionary attribute grouping algorithm and each group records are then microaggregated applying Huffman data compression algorithm.

Model Based Energy Consumption Analysis of Wireless Cyber Physical Systems
Jing Liu (Peking University), Ping Wang (Peking University), Jinlong Lin (Peking University), Chao-Hsien Chu (Pennsylvania State University)
Wireless mesh networks begin to be used as an infrastructure of cyber-physical systems. A critical issue in developing wireless cyber physical systems (WCPSs) is the limited amount of energy available in the nodes. Energy consumption analysis can help designer to conduct a power-aware design process. In this paper, we propose a model based energy consumption analysis framework at architecture level for WCPSs. We extract event chains from the architecture model, with the energy consumption model for processing each type of event, we can estimate the energy consumption for each control loop and each node, as well as the overall energy consumption. All these energy consumption indexes can help us to design a performance and energy consumption balanced WCPS.
Router-based Brokering for Surrogate Discovery in Edge Computing
Julien Gedeon (Technische Universität Darmstadt), Christian Meurisch (Technische Universität Darmstadt), Disha Bhat (Technische Universität Darmstadt), Michael Stein (Technische Universität Darmstadt), Lin Wang (Technische Universität Darmstadt), Max Mühlhäuser (Technische Universität Darmstadt)

In-network processing pushes computational capabilities closer to the edge of the network, enabling new kinds of location-aware, real-time applications, while preserving bandwidth in the core network. This is done by offloading computations to more powerful or energy-efficient surrogates that are opportunistically available at the network edge. In mobile and heterogeneous usage contexts, the question arises how a client can discover the most appropriate surrogate in the network for offloading a task. In this paper, we propose a brokering mechanism that matches a client with the best available surrogate, based on specified requirements and capabilities. The broker is implemented on standard home routers, and thus, leverages the ubiquity of such devices in urban environments. To motivate the feasibility of this approach, we conduct a coverage analysis based on collected access point locations in a major city. Furthermore, the brokering functionality introduces only a minimal resource overhead on the routers and can significantly reduce the latency compared to distant, cloud-based solutions.

Modeling the Spread of Influence for Independent Cascade Diffusion Process in Social Networks
Zesheng Chen (Indiana University - Purdue University Fort Wayne), Kurtis Taylor (Indiana University - Purdue University Fort Wayne)

Modeling the spread of influence in online social networks is important for predicting the influence of individuals and better understanding many scenarios in social networks, such as the influence maximization problem. The previous work on modeling the spread of influence makes the assumption that the statuses of nodes in a network are independent of each other, which is apparently not correct for social networks. The goal of this work is to derive an accurate mathematical model to characterize the spread of influence for the independent cascade diffusion process in online social networks. Specifically, we apply the susceptible-infected-recovered epidemic model from epidemiology to characterize the independent cascade diffusion process and derive a general mathematical framework. To approximate the complex spatial dependence among nodes in a network, we propose a Markov model to predict the spread of influence. Through the extensive simulation study over several generated topologies and a real coauthorship network, we show that our designed Markov model has much better performance than the existing independent model in predicting the influence of individuals in online social networks.

Thank You For Being A Friend: An Attacker View on Online-Social-Network-based Sybil Defenses
David Koll (University of Goettingen), Martin Schwarzmaier (University of Goettingen), Jun Li (University of Oregon), Xiang-Yang Li (University of Science and Technology of China), Xiaoming Fu (University of Goettingen)

Online Social Networks (OSNs) have become a rewarding target for attackers. One particularly popular attack is the Sybil attack, in which the adversary creates many fake accounts called Sybils in order to, for instance, distribute spam or manipulate voting results. A first generation of defense systems tried to detect these Sybils by analyzing changes in the structure of the OSN graph—unfortunately with limited success. Based on these efforts, a second generation of solutions enriches the graph-structural approaches with higher-level user features in order to detect Sybil nodes more efficiently. In this work, we provide an in-depth analysis of these defenses. We describe their common design and working principles, analyze their vulnerabilities, and design simple yet effective attack strategies that an adversary could launch to circumvent these systems. In our evaluation we reveal that an miscreant can exploit the credulity of OSN users and follow a targeted attack strategy to successfully avoid detection by all existing approaches.

Efficient Dynamic Service Function Chain Combination of Network Function Virtualization
Wenke Yan (Beijing University of Posts and Telecommunications), Konglin Zhu (Beijing University of Posts and Telecommunications), Lin Zhang (Beijing University of Posts and Telecommunications), Sixi Su (Beijing University of Posts and Telecommunications)

Network Function Virtualization (NFV) and Software Defined Network (SDN) are recently introduced to provide the virtualization technology for tackling the deployment of network service functions in corporate networks, broadband access networks, and more recently in data centers. How to enhance the flexibility, efficiency and effective of service function deployment is full of challenge. Although Service Function Chain (SFC) is carried out to support the flexibility of network services, it still needs one step forward to fulfill the efficient and effective combination of network services. In this paper, we propose an orthogonal crossover differential evolution (OXDE) to optimize SFC combination with respect to processing delay, energy consumption, and packet loss rate. The evaluation results show that the proposed OXDE algorithm outperforms the other algorithms and it can achieve the efficiency and effectiveness of SFC combination.

When Augmented Reality meets Big Data
Carlos Bermejo (The Hong Kong University of Science and Technology), Zhanpeng Huang (The Hong Kong University of Science and Technology), Tristan Braud (The Hong Kong University of Science and Technology), Pan Hui (The Hong Kong University of Science and Technology)

We live in an era where we are overloaded with data, and this can be the key for gaining rich insights about our world. Augmented reality (AR) enables us the possibility to visualise and analyse the growing torrent of data in a interactive, usable canvas. We can display complex data structures in simpler and more understandable ways that was not possible before. Big Data is a new paradigm results from the myriad data sources such as transactions, Internet, social networks, health care devices and sensor networks. AR and big data have a logical maturity that inevitably will converge. The trend of harnessing AR and big data to breed new interesting applications is starting to have a tangible presence. In this paper, we explore the potential to capture value from the marriage between AR and big data technologies, following with several challenges that must be addressed to fully realize this potential.

Sampling Based Efficient Algorithm to Estimate the Spectral Radius of Large Graphs
Samar Abbas (Lahore University of Management Sciences), Juvaria Tariq (Lahore University of Management Sciences), Arif Zaman (Lahore University of Management Sciences), Imdadullah Khan (Lahore University of Management Sciences)

Evaluating an extremely useful graph property, the spectral radius (largest absolute eigenvalue of the graph adjacency matrix), for large graphs requires excessive computing resources. This problem becomes especially challenging, for instance with distributed or remote storage, when accessing the whole graph itself is expensive in terms of memory or bandwidth. One approach to tackle this challenge is to estimate the spectral radius of the graph while reading only a small portion
of the graph. In this paper we present a sampling approach to estimate the spectral radius of large graphs. We define a score for vertices that i) is more of a combinatorial nature and is easier to compute and ii) has solid theoretical justifications hence, it closely approximate a vertex's contribution to the largest eigenvalue of the graph. Using this score, we model the sampling problem as a budgeted optimization problem and design a greedy algorithm to select a subgraph whose spectral radius approaches that of the whole graph. We provide analytical bound on computational complexity of our algorithm. We demonstrate effectiveness of our algorithm on various synthetic and real-world graphs and show that our algorithm also empirically outperforms known techniques. Furthermore, we compare the quality of our results to estimates obtained from well known upper and lower bounds known in the spectral graph theory literature.

**Extemporaneous Micro-Mobile Service Execution Without Code Sharing**
Zheng Song (Virginia Tech), Minh Le (Utah State University), Young-Woo Kwon (Utah State University), Eli Tilevich (Virginia Tech)

In mobile edge computing, a mobile or IoT device requests a nearby device to execute some functionality and return back the results. However, the executable code must either be pre-installed on the nearby device or be transferred from the requester device, reducing the utility or safety of device-to-device computing, respectively. To address this problem, we present a micro-service middleware that executes services on nearby mobile devices, with a trusted middleman distributing executable code. Our solution comprises (1) a trusted store of vetted mobile services, self-contained executable modules, downloaded to devices and invoked at runtime; and (2) a middleware system that matches service requirements to available devices to orchestrate the device-to-device communication. Our experiments show that our solution (1) enables executing mobile services on nearby devices, without requiring a device to receive executable code from an untrusted party; (2) supports mobile edge computing in practical settings, increasing performance and decreasing energy consumption; (3) reduces the mobile development workload by reusing services.

**Preventing Colluding Identity Clone Attacks in Online Social Networks**
Georges A. Kamhoua (Florida International University), Niki Pissinou (Florida International University), S.S. Iyengar (Florida International University), Jonathan Beltran (Florida International University), Charles Kamhoua (Air Force Research Laboratory), Brandon L Hernandez (UTRGV), Laurent Njilla (Air Force Research Laboratory)

Nowadays, Online Social Networks (OSNs) become one of the most common way amongst people to facilitate communication, this has made it a target for attackers to steal information from influential users. This has brought new forms of customized attacks for OSNs. Attackers take advantage of the user trustworthiness when using OSN. This exploitation leads to attacks with a combination of both classical and modern threats. Specifically, colluding attackers have been taken advantage of many OSNs by creating fake profiles of friends of the target in the same OSN or others. Colluders impersonate their victims and ask friend requests to the target in the aim to infiltrate her private circle to steal information. This type of attacks are difficult to detect in OSNs because multiple malicious users may have a similar purpose to gain information from their targeted user. In this paper, to overcome this type of attack, we first address the problem of matching user profiles across multiple OSNs; second, by using both textual and features extracted from user profile and based on supervised learning techniques, we build a classifier. Simulation and experimental results are provided to validate the accuracy of our findings.
Towards Privacy-Aware Smart Buildings: Capturing, Communicating, and Enforcing Privacy Policies and Preferences
Primal Pappachan (University of California Irvine), Martin Degelingy (Carnegie Mellon University), Roberto Yus (University of California Irvine), Anupam Dasy (Carnegie Mellon University), Sruti Bhagavatula (Carnegie Mellon University), William Melichery (Carnegie Mellon University), Pardis Emami Naeini (Carnegie Mellon University), Shikun Zhang (Carnegie Mellon University), Lujo Bauery (Carnegie Mellon University), Alfred Kobusa (University of California Irvine), Sharad Mehrotra (University of California Irvine), Norman Sadeh (Carnegie Mellon University), Nalini Venkatasubramanian (University of California Irvine)

The Internet of Things (IoT) is changing the way we interact with our surrounding environment in domains as diverse as health, transportation, office buildings or our homes. In smart building environments, information captured about a building's infrastructure and its inhabitants will help develop services that can help us become more productive, increase our comfort, enhance our social interactions, increase safety, save energy and more. But by relying on the collection and sharing of information about a building's inhabitants and their activities, these services also open the door to privacy risks. In this paper, we introduce a framework where IoT assistants capture and manage the privacy preferences of their users and communicate them to privacy-aware smart buildings, which enforce them when collecting user data or sharing it with building services. We outline elements of an infrastructure necessary to support such interactions and also discuss important privacy policy attributes that need to be captured. This includes looking at attributes necessary to describe – (1) the data collection and sharing practices associated with deployed sensors and services in smart buildings as well as (2) the privacy preferences we need to capture to help users manage their privacy in such environments.

Deploying Data-Driven Security Solutions on Resource-Constrained Wearable IoT System
Hang Cai (Worcester Polytechnic Institute), Tianlong Yun (Worcester Polytechnic Institute), Josiah Hester (Dartmouth College), Krishna K. Venkatasubramanian (Clemson University)

Wearable Internet-of-Things (WIoT) environments have demonstrated great potential in a broad range of applications in healthcare and well-being. Security is essential for WIoT environments. Lack of security in WIoTs not only harms user privacy, but may also harm the user’s safety. Though devices in the WIoT can be attacked in many ways, in this paper we focus on adversaries who mount what we call sensor-hijacking attacks, which prevent the constituent medical devices from accurately collecting and reporting the user’s health state (e.g., reporting old or wrong physiological measurements). In this paper we outline some of our experiences in implementing a data-driven security solution for detecting sensor-hijacking attack on a secure wearable internet-of-things (WIoT) base station called the Amulet. Given the limited capabilities (computation, memory, battery power) of the Amulet platform, implementing such a security solution is quite challenging and presents several tradeoffs with respect to resources requirements. We conclude the paper with a list of insights into what capabilities constrained WIoT platforms should provide developers so as to make the inclusion of data-driven security primitives on such systems easy.

A Motif based IoT Framework for Data Efficiency
Akash Sahoo (Texas A&M University), Rabi Mahapatra (Texas A&M University)

Internet of Things (IoT) has allowed embedded devices to connect to the vast Internet network worldwide. With billions of IoT devices waiting to be connected, it is necessary to build efficient infrastructure to handle large amount of data for efficient storage and network traffic. The amount of data created at the IoT edges is regarded as one the biggest challenges of IoT. This paper proposes a motif-based encoding scheme for IoT framework that helps to reduce data generated by sensors at edge nodes. This simple encoding feature resides in both the server and the end devices like in server-client model. Our experiments demonstrated the scheme’s benefits by using slow and fast baud rate sensors such as temperature and accelerometer respectively as the case studies. The results obtained show the proposed motif based framework reduces the data redundancy up to two orders of magnitude while retaining more than 80% accuracy towards motif recognition.

CoTWare: A Cloud of Things Middleware
Jameela Al-Jaroodi (Robert Morris University), Nader Mohamed ( Middleware Technologies Lab.), Imad Jawhar (Midcomp Research Center)

There are many applications that require integrating a large number of physical objects and devices in a large-scale Internet of Things (IoT) networks. Some examples of these applications are smart grids, smart water networks, and intelligent transportation systems. These applications need real-time controls, powerful and scalable data storage and processing capabilities, and advanced data analytics mechanisms. One of the promising technologies to support such applications is the Cloud of Things (CoT). CoT can provide a platform for linking an IoT with Cloud Computing (CC). Another technology that can be utilized for enhancing IoT applications is Fog Computing, which extends the traditional Cloud Computing paradigm to the edge of the network to enable better support for operating enhanced services. However, proper integration and efficient utilization of CoT and Fog Computing for large-scale IoT applications is not an easy task. This paper proposes a service-oriented middleware, called CoTWare, to facilitate effective integration and utilization of CoT and Fog Computing for large-scale IoT applications.

Securing the Internet of Things: A Meta-Study of Challenges, Approaches, and Open Problems
Mahmud Hossain (University of Alabama at Birmingham), Ragib Hasan (University of Alabama at Birmingham), Anthony Skjellum (Auburn University)

The Internet of Things (IoT) is becoming a key infrastructure for the development of smart ecosystems. However, the increased deployment of IoT devices with poor security has already rendered them increasingly vulnerable to cyber attacks. In some cases, they can be used as a tool for committing serious crimes. Although some researchers have already explored such issues in the IoT domain and provided solutions for them, there remains the need for a thorough analysis of the challenges, solutions, and open problems in this domain. In this paper, we consider this research gap and provide a systematic analysis of security issues of IoT-based systems. Then, we discuss certain existing research projects to resolve the security issues. Finally, we highlight a set of open problems and provide a detailed description for each. We posit that our systematic approach for understanding the nature and challenges in IoT security will motivate researchers to addressing and solving these problems. Index Terms—Internet of Things; Security Issue; Attack Sur- face; Attack Taxonomy; IoT Forensics.

Internet of Things Framework for Smart Learning Analytics
Ali Yavari (Swinburne University of Technology), Reza Soltanpoor (RMIT University)
Learning Analytics (LA) has become a prominent paradigm in the context of education lately which adopts the recent advancements of technology such as cloud computing, big data processing, and Internet of Things. LA also requires an intensive amount of processing resource to generate relevant analytical results. However, the traditional approaches have been inefficient to tackle LA challenges such as real-time, high performance, and scalable processing of heterogeneous datasets and streaming data. An Internet of Things (IoT) scalable, distributed and high performance framework has the potential to address mentioned LA challenges by efficient contextualization of data. In this paper, Smart Learning Analytics conceptual model is proposed to improve the effectiveness of LA by utilizing an IoT-based platform in terms of performance, scalability, and efficiency.
Heterogeneous Malware Spread Process in Star Network
Libo Jiao (Tsinghua University, Hao Yin (Tsinghua University), Dongchao Guo (Tsinghua University), Yongqiang Lyu (Tsinghua University)

The heterogeneous SIS model for virus spread in any finite size graph characterizes the influence of factors of SIS model and could be analyzed by the extended N-Intertwined model introduced in [1]. We specifically focus on the heterogeneous virus spread in the star network in this paper. The epidemic threshold and the average meta-stable state fraction of infected nodes are derived for virus spread in the star network. Our results illustrate the effect of the factors of SIS model on the steady state infection.

Cost Reduction in Hybrid Clouds for Enterprise Computing
Biyu Zhou (Institute of Computing Technology, Chinese Academy of Sciences), Fa Zhang (Institute of Computing Technology, Chinese Academy of Sciences), Jie Wu (Temple University), Zhiyong Liu (Institute of Computing Technology, Chinese Academy of Sciences)

Hybrid cloud-based deployment is a trend in cloud computing which enables enterprise to benefit from cloud infrastructures while honoring privacy restrictions on some services. Enterprise application migration is an effective way to improve the efficiency of using the cloud infrastructures. However, it is a challenging problem to decide which parts of the applications to migrate and where to migrate. In this paper, we focus on the problem of planning the migration of enterprise applications in hybrid cloud infrastructures. Unlike previous studies, we consider a general hybrid cloud architecture that involves multiple public clouds rather than only one. Our aim is to maximize the enterprise cost reduction under the constraint of user experience in terms of response time. We first formulate the application migration problem as an optimization problem. Aware of its NP-hardness, we design an efficient migration framework to approximate the optimum for a large problem size. First, we leverage the application characteristic to reduce the scale of the problem by dividing it into multiple smaller subproblems. Then, an efficient algorithm based on dynamic programming is proposed to solve the small scale subproblems. Finally, we construct a feasible solution to the original problem. Simulation results demonstrate that our framework can bring significant benefits to enterprises.

DC-RSF: A Dynamic and Customized Reputation System Framework for Joint Cloud Computing
Fanghua Ye (Sun Yat-sen University), Zibin Zheng (Sun Yat-sen University), Chuan Chen (Sun Yat-sen University), Yuren Zhou (Sun Yat-sen University)

Joint cloud computing (JointCloud), as a brand-new paradigm of cloud computing, aims at building a cloud ecosystem, in which end users are agnostic to cloud service vendors as applications and services are built upon virtual clouds. In case of low quality cloud resources provided deliberately and in order to facilitate the persistent and sound development of JointCloud ecosystem, we propose a dynamic and customized reputation system framework (DC-RSF) to evaluate the credibility of cloud service vendors. At the core of DC-RSF is the customized and dynamic credibility model (CDCM), which calculates credit value for each cloud service vendor based on service requirements of end users and credential attributes of cloud service vendors. We further incorporate a Blockchain-based module into DC-RSF to prevent the credit value from being artificially tampered.

Web Service Appliance Based on Unikernel
Kai Yu (National Lab for Parallel and Distributed Processing), Chengfei Zhang (National Lab for Parallel and Distributed Processing), Yunxiang Zhao (National Lab for Parallel and Distributed Processing)

Mini-OS is a tiny OS (operating system) kernel distributed with Xen Project Hypervisor. It is mainly used as an OS for stub domain aimed at Dom0 disaggregation and also a stepping stone for Unikernel development. We implemented a simple http server on Mini-OS, and built Mini-OS into a web service appliance. We evaluated its performance compared with the same implemented server on Ubuntu PV (para-virtualization) DomU, and achieved about 39% performance improvement. The results shows that Mini-OS can be a web service appliance and has a good performance.

Analysis and Evaluation of the GAS Model for Distributed Graph Computation
Wang Jinyan (National Lab for Parallel and Distributed Processing), Zhang Chengfei (National Lab for Parallel and Distributed Processing)

Compared with distributed graph computation, traditionally single node computation is unfitted in processing large scale graph data. The GAS (Gather, Apply and Scatter) Model is a universal vertex-cut graph computation programming model based on edge-centric programs to support graph algorithms, which process distributed graph computation after graph partition. In this paper, we introduce that three minor-steps of GAS. We then analyze more complete process of GAS considering intra-node computation and inter-node communication of distributed graph computation. Based on our analysis, we evaluate the performance in different nodes of graph analysis algorithm applying GAS model. The evaluation shows that the bottleneck is computation performance or communication bandwidth depending on number of nodes, which is an inspiration of optimizing the GAS model.

Traffic Signs Detection Based on Faster R-CNN
Zhongrong Zuo (National Lab for Parallel and Distributed Processing), Kai Yu (National Lab for Parallel and Distributed Processing), Qiao Zhou (National Lab for Parallel and Distributed Processing), Xu Wang (National Lab for Parallel and Distributed Processing), Ting Li (National Lab for Parallel and Distributed Processing)

In this paper, we use a advanced method called Faster R-CNN to detect traffic signs. This new method represents the highest level in object recognition, which don’t need to extract image feature manually anymore and can segment image to get candidate region proposals automatically. Our experiment is based on a traffic sign detection competition in 2016 by CCF and UISEE company. The mAP value of the result is 0.3449 that means Faster R-CNN can indeed be applied in this field. Even though the experiment did not achieve the best results, we explore a new method in the area of the traffic signs detection. We believe that we can get a better achievement in the future.

JCLedger: A Blockchain Based Distributed Ledger for JointCloud Computing
Xiang Fu (National University of Defense Technology), Huaimin Wang (National University of Defense Technology), Peichang Shi (National University of Defense Technology), Yingwei Fu (National University of Defense Technology), Yijie Wang (National University of Defense Technology)

With the development of Economic Globalization, traditional single-cloud providers cannot meet the needs of the explosive, global, diverse cloud services. JointCloud aims at empowering the cooperation among multiple Cloud Service Providers (CSP) to provide cross-cloud services. Our work in this paper is mainly focused on the accounting technology for JointCloud computing and we propose the JCLedger - a blockchain based distributed ledger. A new participant CCP (Cryptocurrency Provider) is introduced into the JointCloud collaboration environment to provide the cryptocurrency transferred. We have a detailed description of JCLedger model. We further analyze the four most important mechanisms for JCLedger and provide basic perspectives for in-depth analysis. Finally, we discuss the innovations of JCLedger and our future work in this field.

Corporation Architecture for Multiple Cloud Service Providers in JointCloud Computing
Peichang Shi (National University of Defense Technology), Huaimin Wang (National University of Defense Technology), Xikun Yue (National University of Defense Technology), Shilian Yang (National University of Defense Technology), Shangzhi Yang (National University of Defense Technology), Yuxing Peng (National University of Defense Technology)

Nowadays, cloud computing is hard to effectively sustain the implementation of the commercial model of Internet Service globalization. There is a growing trend to build an environment of cloud service, with the capacity to serve anytime and anywhere, by mutual cooperation between cloud service providers around the world. However, this tendency will raise a key issue which is how to provide a benign environment, that allows self-collaboration and fair competition, for different cloud service providers with diverse stakeholder. Guided by the concept and structure of Service-Oriented Architecture (SOA) service, this paper proposes a structure named JointCloud Corporation Environment (JCCE), which offers a mutual benefit and win-win JointCloud environment for global cloud service providers. JCCE contains three core services, which are Distributed Cloud Transaction, Distributed Cloud Community and Distributed Cloud Supervision. Also, facing with different cloud service participants, JCCE offers three main service modes for their consumption, supply and coordination. This study plays a significant role in supporting the sharing and self-collaboration of multiple cloud entities, and promoting the development of cloud service market healthy and orderly.

Sharing Privacy Data in Semi-Trustworthy Storage through Hierarchical Access Control
Yuzhao Wu (Tsinghua University), Yongqiang Lyu (Tsinghua University), Qian Fang (Tsinghua University), Geng Zheng (Tsinghua University), Hao Yin (Tsinghua University), Yuanchun Shi (Tsinghua University)

Data outsourcing in cloud is emerging as a successful paradigm that benefits organizations and enterprises with high-performance, low-cost, scalable data storage and sharing services. However, this paradigm also brings forth new challenges for data confidentiality because the outsourced are not under the physic control of the data owners. The existing schemes to achieve the security and usability goal usually apply encryption to the data before outsourcing them to the storage service providers (SSP), and disclose the decryption keys only to authorized user. They cannot ensure the security of data while operating data in cloud where the third-party service providers are usually semi-trustworthy, and need lots of time to deal with the data. We construct a privacy data management system appending hierarchical access control called HAC-DMS, which can not only assure security but also save plenty of time when updating data in cloud.

A Reliability Benchmark for Big Data Systems on JointCloud
Yingying Zheng (Institute of Software, Chinese Academy of Sciences), Lijie Xu (Institute of Software, Chinese Academy of Sciences), Wei Wang (Institute of Software, Chinese Academy of Sciences), Wei Zhou (KSYUN), Ying Ding (Changchun University of Science and Technology)

JointCloud provides a flexible and elastic computing resource platform. Big data systems such as MapReduce and Spark are widely deployed on this platform for big data processing. These frameworks have high scalability, but the applications running atop them often generate runtime errors, such as out of memory errors, IOExceptions, and task timeouts. For users, they want to know whether the developed applications have potential application faults. For system designers and managers, they want to know whether the deployed/upated frameworks have potential system faults. Current performance benchmarking can choose suitable clouds platform for customers. However, they do not consider reliability of applications deployed on the cloud. In addition, current benchmarks for big data system are also only designed for performance testing. To fill this gap, we propose a reliability benchmark, which contains representative applications, an abnormal data generator, and a configuration combination generator. Different from performance benchmarks, this benchmark (1) generates abnormal test data according to the application characteristics, and (2) reduces the configuration combination space based on configuration features. Currently, we implemented this benchmark on Spark framework. In our preliminary test, we found three types of errors (i.e., out of memory error, timeout and wrong results) in five SQL, Machine Learning, and Graph applications.

UCPR:User Classification and Influence Analysis in Social Network
Cong Zha (Tsinghua University), Yongqiang Lv (Tsinghua University)

There are vigorous developments of social network which affect out life greatly. User influence is an important reason to pro-mote the interaction in social network. When we analyze user influence, single value can’t indicate the user influence in different domains. This paper puts forward the design of User Classification PageRank (UCPR) to solve this problem. Firstly, we classify users according to the content they forwarded. Then, we use space mapping to set up several subnets. Finally, we analyze user influence in every specific subnet by Domain Mapped Network (DMN) which is based on PageRank algorithm and we improve this algorithm to analyze the user influence in different domains. Through the work of this paper, we used a vector to present user influence rather than a single number and we test and verified the long-tailed distributions of social net-work in experiments.

Adaptive Routing Algorithm for Joint Cloud Video Delivery
Zexun Jiang (Tsinghua University), Hao Yin (Tsinghua University)

As the Internet keeps growing, online video has become a great part of the current Internet data traffic, which will take over 80% of Internet traffic according to Ciscos report. Also, new and more heavyweight applications keep developing to fulfill people’s growing requirements, like 4k resolution and visual reality videos. However, one single service provider, like a Content Delivery Network (CDN), can not meet the performance requirements completely. To employ the potential of Joint Cloud, this paper designs and implements a new request routing algorithm that can make video delivery utilize multiple clouds and servers. On the premise of guaranteeing the quality of video playing, this algorithm minimizes the cost of service resources based on different infrastructures service quality, cost, and cover
areas. Based on this algorithm, we implement a practical video delivery system using light-weight, flash-based terminals. And this system provides live video and video-on-demand delivery service for China Future Networks Industry Summit 2014 on June 4th. The actual user data was gathered and analyzed to verify the effectiveness of this algorithm. 90.2% of the total VOD requests were completed smoothly without pause, and the video traffic was optimized by the algorithm.

Towards Efficient Resource Management in Virtual Clouds
Bo An (Peking University), Junming Ma (Peking University), Donggang Cao (Peking University), Gang Huang (Peking University)

The use of multiple clouds brings many advantages: cost optimization, Quality-of-Service (QoS) improvements, high availability, avoidance of vendor lock-in, disaster recovery and so on. However, currently the cloud vendor is largely proprietary and different cloud vendors have their own heterogeneous infrastructure, making it difficult for users to utilize resource from multiple cloud vendors. As a result, users have to manage distributed applications spanning multiple clouds and take into consideration the services migration for reasons like best cost efficiency. In this paper, we introduces the notion of Virtual Cloud and focus on the issues related to multi-cloud resource management in Virtual Cloud. Virtual Cloud is a customized cloud by aggregating resources and services of different clouds and aims to provide end users with a specific cloud working environment. It will ease users’ burden of resource and distributed application management as well as the workload migration across cloud.

Monitoring and Billing of A Lightweight Cloud System Based on Linux Container
Yujian Zhu (Peking University), Junming Ma (Peking University), Bo An (Peking University), Donggang Cao (Peking University)

Nowadays, more and more enterprises and research institutes choose to build mini-datacenters and deploy private cloud environments to meet growing business and research needs. To make users can run different application frameworks on the same datacenter, Cao et al. proposed a new service model named ClaaS (Cluster as a Service) and developed a lightweight prototype system named Docklet which is based on LXC (Linux Container). Docklet faces a problem of resources waste and abuse due to our free policy. This paper introduces the monitoring and billing modules of Docklet in order to solve this problem. Monitoring module provides users and administrators with a clear, real-time and detailed monitoring interface to understand the statues of running applications and the usage of physical resources. Billing module uses these data to remind users to release unnecessary resources. An experiment and observations show that our proposed monitoring method is effective and lightweight and our proposed billing model increases the utilization of physical resources of a mini-datacenter.

Building emulation framework for non-volatile memory
Guoliang Zhu (National University of Defense Technology), Kai Lu (National University of Defense Technology), Xiaoping Wang (National University of Defense Technology)

Currently, researchers use simulators to experiment their innovation on emerging non-volatile memory. Unfortunately, simulation method is both time-consuming and are hard to debug. In this paper, we present a non-volatile memory emulator which enables system-level research on emerging memory. Our emulator uses performance monitoring units on off-the-shelf processors to implement an accurate performance model.

Seflow: Efficient Flow Scheduling for Data-Parallel Jobs
Qiao Zhou (National Lab for Parallel and Distributed Processing), Ziyang Li (National Lab for Parallel and Distributed Processing), Ping Zhong (Central South University), Tian Tian (National Lab for Parallel and Distributed Processing), Yuxing Peng (National Lab for Parallel and Distributed Processing)

Data-parallel jobs transfer massive amounts of data between a series of successive stages. The coflow abstraction is proposed to represent a group of parallel flows between two stages and efficiently improves stagelevel performance. However, state-of-the-art coflow scheduling techniques are agnostic to the jobs’ intercoflow semantics and thus are suboptimal in reducing the average job completion times (JCT). To address this problem, in this paper we present the “semantic flow” (seflow) abstraction to express the job-level intercoflow semantics. A seflow comprises not only all the coflows of a job but also the relationship between the coflows. We design an efficient seflow scheduler which utilizes the rich seflow semantics of jobs to achieve better performance than seflow-agnostic scheduling for data parallel jobs.

Online Encoding for Erasure-Coded Distributed Storage Systems
Fangliang Xu (National University of Defense Technology), Yijie Wang (National University of Defense Technology), Xingkong Ma (National University of Defense Technology)

Many large-scale distributed storage systems deploy erasure coding to protect data from frequent server failures for cost reason. In most of these systems, newly inserted data is first replicated across different storage nodes and then migrated to erasure coded. Although this offline encoding manner can improve performance of data access before erasure coding for some systems, it helps little and wastes many network resources and disk resources for many other systems. In this study, we propose an online encoding method, which encodes data as soon as it is inserted into the system. By eliminating the migration process, our online encoding can significantly reduce network transfer and data read; by caching the intermediate parity blocks into memory, our online encoding also significantly reduce data write. Analysis show that our online encoding can reduce data transfer by more than 25%, reduce data write by 57% at least and eliminate all data read, compared to traditional offline encoding.
PED 2017 Workshop Abstracts

WED-SQL: A Relational Framework for Design and Implementation of Process-Aware Information Systems
Bruno Padilha (University of Sao Paulo), André Luis Schwerz (Federal University of Technology), Rafael Liberato Roberto (Federal University of Technology)

Despite the significant evolution of the design and implementation of business process models, a transactional approach that evolves an incremental and adaptive strategy remains an important challenge to be overcome. Traditional frameworks such as BPEL, Process Algebra, and Petri Net require an additional software layer or some third party toolkits to be able to enforce a data-state based transaction control and deal with semantic exceptions. However, the complexity of implementation based on these traditional frameworks, especially to treat exceptions, is too high. In this paper, we present the WED-SQL, a distributed framework that provides a reliable and efficient way to design and implement business processes. Our main contribution is the integration of WED-flow concepts into the PostgreSQL RDBMS. This integration enables the WED-SQL to take full advantage of transactional properties and also benefit from the SQL language to specify the WED-flow definitions.

Querying Workflow Logs
Yan Tang (University of California at Santa Barbara), Jianwen Su (University of California at Santa Barbara)

A business process (BP or workflow) is an assembly of tasks to accomplish a business goal. Business process management (BPM) is a study to provide support for the design, configuration/implementation, enactment and monitoring, diagnose/analysis, and re-design of workflow. Business analytics or intelligence (BI) is a necessary step towards re-design/improvement. The traditional methodology for BI is the well known sequence of ETL, data/process warehouse, and OLAP tools. In this paper, we focus on the problem of ad hoc querying process enactments for data-centric business processes. We develop an algebraic query language based on “incidents” to allow the user to formulate ad hoc queries directly on workflow logs. A formal semantics and an preliminary query evaluation algorithm are provided.

On the integration of event-based and transaction-based architectures for Supply Chains
Zhijie Li (Indiana University–Purdue University Indianapolis), Haoyan Wu (Indiana University–Purdue University Indianapolis), Brian King (Indiana University–Purdue University Indianapolis), Zina Ben-Miled (Indiana University–Purdue University Indianapolis), John Wassick (The Dow Chemical Company), Jeffrey Tazelaar (The Dow Chemical Company)

Affordable and reliable supply chain visibility is becoming increasingly important as the complexity of the network underlying supply chains is becoming orders of magnitudes higher compared to a decade ago. Moreover this increase in complexity is starting to reflect on the cost of goods and their availability to the consumers. This paper addresses two key issues in the distribution phase of the supply chain, namely, affordability and pseudo real-time visibility of truck load activities. The proposed framework creates a digital thread that tracks the pseudo real-time status of the shipment making the physical distribution process completely transparent to the stakeholders. The architecture of the framework is based on a dynamic hybrid peer-to-peer network and a private/public blockchain data model that leverages emergent sensor technologies.

CacheDOCS: A Dynamic Key-Value Object Caching Service
Julien Gascon-Samson (University of British Columbia), Michael Coppinger (McGill University), Fan Jin (McGill University), Jörg Kienzle (McGill University), Bettina Kemme (McGill University)

Caching plays an important role in many domains, as it can lead to important performance improvements. A key-value based caching system typically stores the results of popular queries in efficient storage location. While caching enjoys widespread usage in the context of dynamic web applications, most mainstream caching systems store static binary items, which makes them impractical for many real-world applications that would benefit from storing dynamic items. In this paper, we propose CacheDOCS, a dynamic key-value object caching service that allows for caching arbitrary objects. As part of our model, CacheDOCS provides an API that supports the execution of operations against cached objects, and allows for clients to seamlessly subscribe to keep their local copies in sync with cached remote objects. CacheDOCS supports multiple update dissemination strategies in order to optimize performance, and proposes a versioning mechanism to ensure consistency. We implemented a full version of CacheDOCS and we ran several performance-related experiments under three use-case scenarios.
A novel game-theoretic model for content-adaptive image steganography
Qi Li (Hunan University), Xin Liao (Hunan University), Guoyong Chen (Hunan University), Liping Ding (Guangzhou Branch of Institute of Software, Chinese Academy of Science)

Content-adaptive image steganography means that steganographer chooses security embedding positions based on image textures. Steganalyst can also focus on detecting these positions according to image textures. Game theory is preferred to analyze the above situation. However, in previous game models, steganalyst will mistakenly identify that no bit is embedded, when the secret bit is the same as the least significant bit of cover image. In this paper, a novel game-theoretic model based on secondary embedding is proposed to correct the judgment drawback for a better Nash equilibrium by steganalyst. However, steganalyst's choice disturbs previous equilibrium and steganographer will change his choice to find new equilibrium by Game theory. Co-occurrence matrix and point deviation degree are utilized for describing steganalyst's choices. The occurrence number of each pixel pairs is calculated to constitute co-occurrence matrix, and then Euclidean distance between one point and adjacent points is computed to locate embedding positions. In content-adaptive image steganography, we can draw a conclusion that steganographer should select embedding positions from both image edge areas and smooth areas.

A Fine-grained Access Control Scheme for Big Data Based on Classification Attributes
Tengfei Yang (State Key Laboratory of Information Security, Institute of Information Engineering, Chinese Academy of Sciences), Peisong Shen (State Key Laboratory of Information Security, Institute of Information Engineering, Chinese Academy of Sciences), Xue Tian (State Key Laboratory of Information Security, Institute of Information Engineering, Chinese Academy of Sciences), Chi Chen (State Key Laboratory of Information Security, Institute of Information Engineering, Chinese Academy of Sciences)

In order to protect the security and privacy of big data, the cloud storage service needs to enforce effective access control mechanism on user requests. Attribute-Based Encryption is a promising cryptographic access control technique to ensure the end-to-end security of data in cloud. However, the existing ABE researches mainly focus on the efficiency decryption, while the flexibility of policy, the communication cost, and the metadata management of ciphertexts are still challenging issues in the big data environment. In this paper, for the first time, we propose a new distributed, scalable and fine-grained access control scheme based on classification attributes for the cloud object storage. The classification attributes and threshold policies are integrated into an access structure, and then the objects are encrypted with the integrated access structure. The constant-size ciphertext components related to attributes can be managed as the corresponding metadata. As a result the encryption complexity and ciphertext storage are reduced. In addition, we present a new label-based access control model with multi-authorities to describe the detailed relationships of entities in our scheme. Besides, the proposed scheme is proved to be secure under IBDHE assumption, and the system implementation demonstrates the practical feasibility and good performance.

Social-Aware Decentralization for Efficient and Secure Multi-Party Computation
Yuzhe Tang (Syracuse University), Sucheta Soundarajan (Syracuse University)

This work studies the problem of MPC scheduling that is, identifying a set of computing nodes to execute secure multi-party computation protocols (MPC) over a distributed private dataset. Our primary contribution is in estimating the risk of collusion between nodes to whom the computation is scheduled. This work has potential in enabling efficient privacy-preserving data sharing in emerging platforms of big-data federation, in healthcare, finance, and other marketplaces. In our methods, we assume that the MPC computing nodes exist in a social network, and present two models for estimating the risk of collusion, as well as algorithms for finding the MPC nodes such that the risk of collusion is minimized. We evaluate our methods on several real-world network datasets, and show that they are effective in minimizing the risk levels.

Statistical Anomaly Detection on Metadata Streams via Commodity Software to Protect Company
Christine Chen (University of Portland), James Gurganus (Micro Systems Engineering, Inc.)

As a company grows, its infrastructure naturally must grow to support it. The resulting mountains of infrastructure metadata contain valuable information on the health and wellbeing of the systems throughout the company. For example, an abnormally low disk write rate to a file server may indicate that a regularly scheduled task has failed to start, or an abnormally high disk write rate may indicate the presence of a malicious threat such as ransomware. The hypothesis of this case study is that such metadata streams can be effectively utilized by implementing statistical anomaly detection methods via commodity software (Splunk, in this case). These methods were tested primarily on server metadata in a ransomware simulation and also on server metadata from file servers and production servers in active use.

In the ransomware simulation, the alerting system detected the ransomware behavior five minutes after an encryption event began in the simulation environment and alerted steadily for the duration of the simulation. In the week-long experiment over 11 file servers and production servers, a total of 1,484 alerts were generated. Applying simple correlation techniques created a more concentrated information stream with 77 events. These results confirm the value of metadata in identifying system anomalies and providing another layer of defense against malicious threats. The relatively simple anomaly detection techniques utilized in this case study also highlight the increasing practicality of behavioral analytics—it can only be a matter of time before such techniques will be ubiquitous.

Computational improvements in parallelized k-anonymous microaggregation of large databases
Ahmad Mohamad Mezher (Universitat Politècnica de Catalunya), Alejandro García Álvarez (Universitat Politècnica de Catalunya), David Rebollo-Monedero (Universitat Politècnica de Catalunya), Jordi Forné (Universitat Politècnica de Catalunya)

The technical contents of this paper fall within the field of statistical disclosure control (SDC), which concerns the postprocessing of the demographic portion of the statistical results of surveys containing sensitive personal information, in order to effectively safeguard the anonymity of the participating respondents. The concrete purpose of this study is to improve the efficiency of a widely used algorithm for k-anonymous microaggregation, known as maximum distance to average vector (MDAV), to vastly accelerate its execution without affecting its excellent functional performance with respect to competing methods. The improvements put forth in this paper encompass algebraic modifications and the use of the basic linear algebra subprograms (BLAS) library, for the efficient parallel computation of MDAV on CPU.
WoSC 2017 Workshop Abstracts

Ripple: Home Automation for Research Data Management
Ryan Chard (Argonne National Laboratory), Kyle Chard (University of Chicago and Argonne National Lab), Jason Alt (National Center for Supercomputing Applications), Dilworth Parkinson (Lawrence Berkeley National Laboratory), Steve Tuecke (University of Chicago and Argonne National Lab), Ian Foster (Argonne National Laboratory & The University of Chicago)

Exploding data volumes and acquisition rates, plus ever more complex research processes, place significant strain on research data management processes. It is increasingly common for data to flow through pipelines comprised of dozens of different management, organization, and analysis steps distributed across multiple institutions and storage systems. To alleviate the resulting complexity, we propose a home automation approach to managing data throughout its lifecycle, in which users specify high-level rules the actions that should be performed on data at different times and locations. To this end, we have developed RIPPLE, a responsive storage architecture that allows users to express data management tasks via a rules notation. RIPPLE monitors storage systems for events, evaluates rules, and uses serverless computing techniques to execute actions in response to these events. We evaluate our solution by applying RIPPLE to the data lifecycles of two real-world projects, in astronomy and light source science, and show that it can automate many mundane and cumbersome data management processes.

Pipsqueak: Lean Lambdas with Large Libraries
Edward Oakes (University of Wisconsin-Madison), Leon Yang (University of Wisconsin-Madison), Kevin Houck (University of Wisconsin-Madison), Tyler Harter (Microsoft Gray Systems Lab), Andrea C. Arpaci-Dusseau (University of Wisconsin-Madison), Remzi H. Arpaci-Dusseau (University of Wisconsin-Madison)

Microservices are usually fast to deploy because each microservice is small, and thus each can be installed and started quickly. Unfortunately, lean microservices that depend on large libraries will start slowly and harm elasticity. In this paper, we explore the challenges of lean microservices that rely on large libraries in the context of Python packages and the OpenLambda serverless computing platform. We analyze the package types and compressibility of libraries distributed via the Python Package Index and propose PipBench, a new tool for evaluating package support. We also propose Pipsqueak, a package-aware compute platform based on OpenLambda.

Leveraging the Serverless Architecture for Securing Linux Containers
Nilton Bila (IBM), Paolo Dettori (IBM), Ali Kanso (IBM), Yuji Watanabe (IBM), Alaa Youssef (IBM)

Linux containers present a lightweight solution to package applications into images and instantiate them in isolated environments. Such images may include vulnerabilities that can be exploited at runtime. A vulnerability scanning service can detect these vulnerabilities by periodically scanning the containers and their images for potential threats. When a threat is detected, an event may be generated to (1) quarantine or remove the compromised container(s) and optionally (2) remedy the vulnerability by rebuilding a secure image. We believe that such event-driven process is a great fit to be implemented in a serverless architecture. In this paper we present our design and implementation of a serverless security analytics service based on OpenWhisk and Kubernetes.

Serverless Computing: Design, Implementation, and Performance
Garrett McGrath (University of Notre Dame), Paul R. Brenner (University of Notre Dame)

We present the design of a novel performance-oriented serverless computing platform implemented in .NET, deployed in Microsoft Azure, and utilizing Windows containers as function execution environments. Implementation challenges such as function scaling and container discovery, lifecycle, and reuse are discussed in detail. We propose metrics to evaluate the execution performance of serverless platforms and conduct tests on our prototype as well as AWS Lambda, Azure Functions and IBM’s deployment of Apache OpenWhisk. Our measurements show the prototype achieving greater throughput than other platforms at most concurrency levels, and we examine the scaling and instance expiration trends in the implementations. Additionally, we discuss the gaps and limitations in our current design, propose possible solutions, and highlight future research.
Accelerating Big Data Infrastructure and Applications
Kevin Brown (Tokyo Institute of Technology), Tianqi Xu (Tokyo Institute of Technology), Keita Iwabuchi (Tokyo Institute of Technology), Kento Sato (Lawrence Livermore National Laboratory), Adam Moody (Lawrence Livermore National Laboratory), Kathryn Mohror (Lawrence Livermore National Laboratory), Nikhil Jain (Lawrence Livermore National Laboratory), Abhinav Bhattele (Lawrence Livermore National Laboratory), Martin Schulz (Lawrence Livermore National Laboratory), Roger Pearce (Lawrence Livermore National Laboratory), Maya Gokhale (Lawrence Livermore National Laboratory), Satoshi Matsuoka (Tokyo Institute of Technology)

High-performance computing (HPC) systems are increasingly being used for data-intensive, or "Big Data", workloads. However, since traditional HPC workloads are compute-intensive, the HPC-Big Data convergence has created many challenges with optimizing data movement and processing on modern supercomputers. Our collaborative work addresses these challenges using a three-pronged approach: (i) measuring and modeling extreme-scale I/O workloads, (ii) designing a low-latency, scalable, on-demand burst-buffer solution, and (iii) optimizing graph algorithms for processing Big Data workloads. We describe the three areas of our collaboration and report on their respective developments.

Disaster Network Evolution Using Dynamic Clustering of Twitter Data
Krishna Kant (Temple University), Yilang Wu (Aizu University), Shanshan Zhang (Temple University), Junbo Wang (Aizu University), Akitangshu Pal (Temple University)

Ad hoc smartphone networks can be used to augment communications degraded by disasters provided that the individual ad hoc clusters can reach some “connection gateways” to get out to the Internet via connected devices in the surrounding area (in addition to connectivity via any specially deployed emergency equipment). The disconnected areas are not known until they are back online; however, we need a mechanism to determine them so that the gateway device can be best recruited to provide the connectivity. This needs to be done in a dynamic environment because of disaster related mobility. In this paper we propose a mechanism to solve this problem by estimating regions that are likely to be dense but disconnected with significant number of connected devices around them. Because of lack of direct information on people (or smartphone) density, we attempt to do this by analyzing the twitter data. By virtue of its efficiency, the algorithm can be used on a dynamically evolving data set and thus allows dynamic tracking.

Single-epoch supernova classification with deep convolutional neural networks
Akisato Kimura (NTT), Ichiro Takahashi (Kavli IPMU, The University of Tokyo), Masaomi Tanaka (National Astronomical Observatory of Japan), Naoki Yasuda (Kavli IPMU, The University of Tokyo), Naonori Ueda (NTT), Naoki Yoshida (Kavli IPMU, The University of Tokyo)

Supernovae Type-Ia (SNeIa) play a significant role in exploring the history of the expansion of the Universe, since they are the best-known standard candles with which we can accurately measure the distance to the objects. Finding large samples of SNeIa and investigating their detailed characteristics has become an important issue in cosmology and astronomy. The current photometric supernova surveys produce vastly more candidates than can be followed up spectroscopically, highlighting the need for effective classification methods. Existing methods relied on a photometric approach that first measures the luminance of supernova candidates precisely and then fits the results to a parametric function of temporal changes in luminance. However, it inevitably requires a lot of observations and complex luminance measurements. In this work, we present a novel method for detecting SNeIa simply from single-shot observation images without any complex measurements, by effectively integrating the state-of-the-art computer vision methodology into the standard photometric approach. Our method first builds a convolutional neural network for estimating the luminance of supernovae from telescope images, and then constructs another neural network for the classification, where the estimated luminances and observation dates are used as features for classification. Both of the neural networks are integrated into a single deep neural network to classify SNeIa directly from observation images. Experimental results show the effectiveness of the proposed method and reveal classification performance comparable to existing photometric methods with many observations.

Enabling Large Scale Deliberation using Ideation and Negotiation-Support Agents
Katsuhide Fujita (Tokyo University of Agriculture and Technology), Takayuki Ito (Nagoya Institute of Technology), Mark Klein (MIT)

This paper describes an ongoing Japan-US project that is developing the kind of advanced computer support for online crowd-scale deliberation that is needed to enable smarter and more connected communities. Our shared work has focused on addressing both these problems: (1) ideation: helping crowds more effectively develop potential win-win solutions, and (2) decision-making: helping crowds get to pareto-optimality in the solutions they select. In Japan, a discussion support system called COLLAGREE that facilitates free text discussions to achieve consensus has been developing. In US, an online tool called the Deliberatorium that integrates argumentation theory and social computing techniques to enable more effective crowd-scale deliberation has been developing. One of our immediate joint work is to integrate the facilitated free-text discussions of COLLAGREE with the structured deliberations provided by the Deliberatorium. We will also develop automated agents that enable better ideation as well as better decision-making.
Local Information

Maps
Restaurants in/near Lenox Mall

**Sprinkles Cupcakes and Ice Cream**

#493 of 2,662 Restaurants in Atlanta

![Sprinkles Cupcakes and Ice Cream](image1)

3393 Peachtree Rd NE
0.0 miles from Lenox Square

“Very Average” 04/02/2017
“arype of a average cupcake” 03/31/2017

Cuisines: American

**True Food Kitchen**

#104 of 2,662 Restaurants in Atlanta

![True Food Kitchen](image2)

3393 Peachtree Rd NE Lenox Square Mall
0.0 miles from Lenox Square

“Excellent food!” 05/01/2017
“Deliciously Fresh” 04/30/2017

Cuisines: American

**The Cheesecake Factory**

#85 of 2,662 Restaurants in Atlanta

![The Cheesecake Factory](image3)

3393 Peachtree Rd NE Suite 3076A, Lenox Square Mall
0.0 miles from Lenox Square

“Hostess” 04/15/2017
“Food ok, cheesecake paradise” 04/07/2017

Cuisines: Italian, American

**Zinburger Wine & Burger Bar**

#107 of 2,662 Restaurants in Atlanta

![Zinburger Wine & Burger Bar](image4)

3393 Peachtree Rd NE Lenox Mall
0.0 miles from Lenox Square

“Very good burger” 04/27/2017
“Very good, but pricey burgers!” 04/24/2017

Cuisines: American, Bar, Wine Bar
<table>
<thead>
<tr>
<th>Restaurant</th>
<th>Rating</th>
<th>Reviews</th>
<th>Address</th>
<th>Distance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dantanna’s</td>
<td>4.5</td>
<td>266</td>
<td>3400 Around Lenox Rd NE</td>
<td>0.1 miles</td>
<td>“Great burgers!” 05/03/2017 “Love this place” 05/02/2017</td>
</tr>
<tr>
<td>Lenox Square</td>
<td>3.5</td>
<td>24</td>
<td>3333 Peachtree Rd NE</td>
<td>0.1 miles</td>
<td>“...mall” 01/17/2017 “Business” 10/25/2016</td>
</tr>
<tr>
<td>Garrett Popcorn Shops</td>
<td>3.5</td>
<td>17</td>
<td>3333 Peachtree Rd NE Lenox Square Mall</td>
<td>0.1 miles</td>
<td>“Love the pecan popcorn” 04/12/2017 “It’s ok. Not like Chicago’s!” 01/05/2017</td>
</tr>
<tr>
<td>Haagen-Dazs Shop</td>
<td>4.5</td>
<td>1</td>
<td>3333 Peachtree Rd NE</td>
<td>0.1 miles</td>
<td>“O melhor sorvete do mundo” 05/24/2014</td>
</tr>
</tbody>
</table>
Bantam + Biddy
#1,334 of 2,662 Restaurants in Atlanta
4.00 out of 5 stars 19 reviews
3393 Peachtree Rd NE Unite 3065B
0.1 miles from Lenox Square
"Well prepared food, and though..." 02/21/2017
"Banana pecan waffles...yum!" 02/19/2017

Corner Bakery Cafe
#1,450 of 2,662 Restaurants in Atlanta
4.00 out of 5 stars 22 reviews
3393 Peachtree Rd NE #4033
0.1 miles from Lenox Square
"Excellent breakfast" 02/25/2017
"Dessert" 02/19/2017
Cuisines: American, Cafe, Healthy, Soups

Taziki's
#1,520 of 2,662 Restaurants in Atlanta
4.00 out of 5 stars 6 reviews
3393 Peachtree Rd NE # 10008
0.1 miles from Lenox Square
"Good choice of salads" 01/22/2017
"Consistently quite good meals..." 01/19/2017

Seven Lamps
#151 of 2,662 Restaurants in Atlanta
4.00 out of 5 stars 176 reviews
3400 Around Lenox Rd NE
0.1 miles from Lenox Square
"Say 'No" to the oysters" 05/01/2017
"Great place!" 04/26/2017
Cuisines: American
Farmer's Basket
#1,263 of 2,662 Restaurants in Atlanta
5.00 stars 12 reviews
3393 Peachtree Rd NE Ste 1012
0.1 miles from Lenox Square
“Really good food court option...” 04/29/2017
“Great quality and quantity!” 04/08/2017
Cuisines: Fast Food

Zinburger Wine and Burger Bar
#2 of 5 Restaurants in Buckhead
4.50 stars 7 reviews
3393 Peachtree Road NE, Room 3065A outside entrance - Lenox Mall
0.1 miles from Lenox Square
“Great burgers, wine and salads...” 04/13/2017
“Disappointed” 03/05/2017

Panera Bread
#876 of 2,662 Restaurants in Atlanta
4.50 stars 22 reviews
3393 Peachtree Rd NE
0.1 miles from Lenox Square
“dined with jade and chantel 3...” 03/29/2017
“Good Visit” 02/12/2017
Cuisines: Soups, Cafe

Cinnabon
#989 of 2,662 Restaurants in Atlanta
4.50 stars 5 reviews
3393 Peachtree Rd NE Ste 1004
0.1 miles from Lenox Square
“Great cinnamon rolls! Not to b...” 02/26/2017
“ME ENCANTA!” 11/17/2015