

**NSDI '17: 14th USENIX Symposium on Networked Systems  
Design and Implementation  
March 27–29, 2017  
Boston, MA**

Message from the Program Co-Chairs..... vii

**Monday, March 27, 2017**

**Storage Systems**

**The Design, Implementation, and Deployment of a System to Transparently Compress  
Hundreds of Petabytes of Image Files for a File-Storage Service .....1**  
Daniel Reiter Horn, Ken Elkabany, and Chris Lesniewski-Lass, *Dropbox*; Keith Winstein, *Stanford University*

**Decibel: Isolation and Sharing in Disaggregated Rack-Scale Storage .....17**  
Mihir Nanavati, Jake Wires, and Andrew Warfield, *Coho Data and University of British Columbia*

**vCorfu: A Cloud-Scale Object Store on a Shared Log .....35**  
Michael Wei, *University of California, San Diego, and VMware Research Group*; Amy Tai, *Princeton University and VMware Research Group*; Christopher J. Rossbach, *The University of Texas at Austin and VMware Research Group*; Ittai Abraham, *VMware Research Group*; Maithem Munshed, Medhavi Dhawan, and Jim Stabile, *VMware*; Udi Wieder and Scott Fritchie, *VMware Research Group*; Steven Swanson, *University of California, San Diego*; Michael J. Freedman, *Princeton University*; Dahlia Malkhi, *VMware Research Group*

**Curator: Self-Managing Storage for Enterprise Clusters .....51**  
Ignacio Cano, *University of Washington*; Srinivas Aiyar, Varun Arora, Manosiz Bhattacharyya, Akhilesh Chaganti, Chern Cheah, Brent Chun, Karan Gupta, and Vinayak Khot, *Nutanix Inc.*; Arvind Krishnamurthy, *University of Washington*

**Packet Processing**

**Evaluating the Power of Flexible Packet Processing for Network Resource Allocation .....67**  
Naveen Kr. Sharma, Antoine Kaufmann, and Thomas Anderson, *University of Washington*; Changhoon Kim, *Barefoot Networks*; Arvind Krishnamurthy, *University of Washington*; Jacob Nelson, *Microsoft Research*; Simon Peter, *The University of Texas at Austin*

**APUNet: Revitalizing GPU as Packet Processing Accelerator .....83**  
Younghwan Go, Muhammad Asim Jamshed, YoungGyoun Moon, Changho Hwang, and KyoungSoo Park, *Korea Advanced Institute of Science and Technology (KAIST)*

**Stateless Network Functions: Breaking the Tight Coupling of State and Processing .....97**  
Murad Kablan, Azzam Alsudais, and Eric Keller, *University of Colorado Boulder*; Franck Le, *IBM Research*

**mOS: A Reusable Networking Stack for Flow Monitoring Middleboxes .....113**  
Muhammad Asim Jamshed, YoungGyoun Moon, Donghwi Kim, Dongsu Han, and KyoungSoo Park, *Korea Advanced Institute of Science and Technology (KAIST)*

**Security and Privacy**

**One Key to Sign Them All Considered Vulnerable: Evaluation of DNSSEC in the Internet .....131**  
Haya Shulman and Michael Waidner, *Fraunhofer Institute for Secure Information Technology SIT*

(Continues on next page)

**Enhancing Security and Privacy of Tor’s Ecosystem by Using Trusted Execution Environments . . . . .145**  
Seongmin Kim, Juhyeng Han, and Jaehyeong Ha, *Korea Advanced Institute of Science and Technology (KAIST)*;  
Taesoo Kim, *Georgia Institute of Technology*; Dongsu Han, *Korea Advanced Institute of Science and Technology (KAIST)*

**ViewMap: Sharing Private In-Vehicle Dashcam Videos . . . . .163**  
Minho Kim, Jaemin Lim, Hyunwoo Yu, Kiyeon Kim, Younghoon Kim, and Suk-Bok Lee, *Hanyang University*

**A System to Verify Network Behavior of Known Cryptographic Clients . . . . .177**  
Andrew Chi, Robert A. Cochran, Marie Nesfield, Michael K. Reiter, and Cynthia Sturton, *The University of North Carolina at Chapel Hill*

## **Wireless Networking**

**FlexCore: Massively Parallel and Flexible Processing for Large MIMO Access Points . . . . .197**  
Christopher Husmann, Georgios Georgis, and Konstantinos Nikitopoulos, *University of Surrey*; Kyle Jamieson, *Princeton University and University College London*

**Facilitating Robust 60 GHz Network Deployment by Sensing Ambient Reflectors . . . . .213**  
Teng Wei, *University of Wisconsin—Madison*; Anfu Zhou, *Beijing University of Posts and Telecommunications*;  
Xinyu Zhang, *University of Wisconsin—Madison*

**Skip-Correlation for Multi-Power Wireless Carrier Sensing . . . . .227**  
Romil Bhardwaj, Krishna Chintalapudi, and Ramachandran Ramjee, *Microsoft Research*

**FM Backscatter: Enabling Connected Cities and Smart Fabrics . . . . .243**  
Anran Wang, Vikram Iyer, Vamsi Talla, Joshua R. Smith, and Shyamnath Gollakota, *University of Washington*

## **Tuesday, March 28, 2017**

### **Privacy and Security**

**Prio: Private, Robust, and Scalable Computation of Aggregate Statistics . . . . .259**  
Henry Corrigan-Gibbs and Dan Boneh, *Stanford University*

**Opaque: An Oblivious and Encrypted Distributed Analytics Platform . . . . .283**  
Wenting Zheng, Ankur Dave, Jethro G. Beekman, Raluca Ada Popa, Joseph E. Gonzalez, and Ion Stoica, *University of California, Berkeley*

**Splinter: Practical Private Queries on Public Data . . . . .299**  
Frank Wang, Catherine Yun, Shafi Goldwasser, and Vinod Vaikuntanathan, *MIT CSAIL*; Matei Zaharia, *Stanford InfoLab*

### **SDN and Network Design**

**VFP: A Virtual Switch Platform for Host SDN in the Public Cloud . . . . .315**  
Daniel Firestone, *Microsoft*

**SCL: Simplifying Distributed SDN Control Planes . . . . .329**  
Aurojit Panda and Wenting Zheng, *University of California, Berkeley*; Xiaohe Hu, *Tsinghua University*;  
Arvind Krishnamurthy, *University of Washington*; Scott Shenker, *University of California, Berkeley, and International Computer Science Institute*

**Robust Validation of Network Designs under Uncertain Demands and Failures . . . . .347**  
Yiyang Chang, Sanjay Rao, and Mohit Tawarmalani, *Purdue University*

(Continues on next page)

## Data-Driven Systems

- Encoding, Fast and Slow: Low-Latency Video Processing Using Thousands of Tiny Threads** .....363  
Sadjad Fouladi, Riad S. Wahby, and Brennan Shacklett, *Stanford University*; Karthikeyan Vasuki Balasubramaniam, *University of California, San Diego*; William Zeng, *Stanford University*; Rahul Bhalerao, *University of California, San Diego*; Anirudh Sivaraman, *Massachusetts Institute of Technology*; George Porter, *University of California, San Diego*; Keith Winstein, *Stanford University*
- Live Video Analytics at Scale with Approximation and Delay-Tolerance** .....377  
Haoyu Zhang, *Microsoft and Princeton University*; Ganesh Ananthanarayanan, Peter Bodik, Matthai Philipose, and Paramvir Bahl, *Microsoft*; Michael J. Freedman, *Princeton University*
- Pytheas: Enabling Data-Driven Quality of Experience Optimization Using Group-Based Exploration-Exploitation** .....393  
Junchen Jiang, *Carnegie Mellon University*; Shijie Sun, *Tsinghua University*; Vyas Sekar, *Carnegie Mellon University*; Hui Zhang, *Carnegie Mellon University and Conviva Inc.*

## Datacenter Networking

- Let It Flow: Resilient Asymmetric Load Balancing with Flowlet Switching** .....407  
Erico Vanini and Rong Pan, *Cisco Systems*; Mohammad Alizadeh, *Massachusetts Institute of Technology*; Parvin Taheri and Tom Edsall, *Cisco Systems*
- Flowtune: Flowlet Control for Datacenter Networks** .....421  
Jonathan Perry, Hari Balakrishnan, and Devavrat Shah, *Massachusetts Institute of Technology*
- Flexplane: An Experimentation Platform for Resource Management in Datacenters** .....437  
Amy Ousterhout, Jonathan Perry, and Hari Balakrishnan, *MIT CSAIL*; Petr Lapukhov, *Facebook*

## Cloud and Distributed Systems

- I Can't Believe It's Not Causal! Scalable Causal Consistency with No Slowdown Cascades** .....453  
Syed Akbar Mehdi, Cody Littlely, and Natacha Crooks, *The University of Texas at Austin*; Lorenzo Alvisi, *The University of Texas at Austin and Cornell University*; Nathan Bronson, *Facebook*; Wyatt Lloyd, *University of Southern California*
- CherryPick: Adaptively Unearthing the Best Cloud Configurations for Big Data Analytics** .....469  
Omid Alipourfard, *Yale University*; Hongqiang Harry Liu and Jianshu Chen, *Microsoft Research*; Shivaram Venkataraman, *University of California, Berkeley*; Minlan Yu, *Yale University*; Ming Zhang, *Alibaba Group*
- AdaptSize: Orchestrating the Hot Object Memory Cache in a Content Delivery Network** .....483  
Daniel S. Berger, *University of Kaiserslautern*; Ramesh K. Sitaraman, *University of Massachusetts Amherst and Akamai Technologies*; Mor Harchol-Balter, *Carnegie Mellon University*

## Wednesday, March 29

### Mobile Systems and IoT

- Bringing IoT to Sports Analytics** .....499  
Mahanth Gowda, Ashutosh Dhekne, Sheng Shen, and Romit Roy Choudhury, *University of Illinois at Urbana-Champaign*; Xue Yang, Lei Yang, Suresh Golwalkar, and Alexander Essanian, *Intel*
- FarmBeats: An IoT Platform for Data-Driven Agriculture** .....515  
Deepak Vasisht, *Microsoft and Massachusetts Institute of Technology*; Zerina Kapetanovic, *Microsoft and University of Washington*; Jongho Won, *Microsoft and Purdue University*; Xinxin Jin, *Microsoft and University of California, San Diego*; Ranveer Chandra, Ashish Kapoor, Sudipta N. Sinha, and Madhusudhan Sudarshan, *Microsoft*; Sean Stratman, *Dancing Crow Farm*

(Continues on next page)

**Enabling High-Quality Untethered Virtual Reality . . . . .**531  
Omid Abari, Dinesh Bharadia, Austin Duffield, and Dina Katabi, *Massachusetts Institute of Technology*

**Improving User Perceived Page Load Times Using Gaze. . . . .**545  
Conor Kelton, Jihoon Ryoo, Aruna Balasubramanian, and Samir R. Das, *Stony Brook University*

## **Networking in the Datacenter**

**RAIL: A Case for Redundant Arrays of Inexpensive Links in Data Center Networks. . . . .**561  
Danyang Zhuo, *University of Washington*; Monia Ghobadi, Ratul Mahajan, Amar Phanishayee, and Xuan Kelvin Zou, *Microsoft Research*; Hang Guan, *Columbia University*; Arvind Krishnamurthy and Thomas Anderson, *University of Washington*

**Enabling Wide-Spread Communications on Optical Fabric with MegaSwitch . . . . .**577  
Li Chen and Kai Chen, *The Hong Kong University of Science and Technology*; Zhonghua Zhu, *Omnisensing Photonics*; Minlan Yu, *Yale University*; George Porter, *University of California, San Diego*; Chunming Qiao, *University at Buffalo*; Shan Zhong, *CoAdna*

**Passive Realtime Datacenter Fault Detection and Localization . . . . .**595  
Arjun Roy, *University of California, San Diego*; Hongyi Zeng and Jasmeet Bagga, *Facebook*; Alex C. Snoeren, *University of California, San Diego*

## **Big Data Systems**

**Clipper: A Low-Latency Online Prediction Serving System . . . . .**613  
Daniel Crankshaw, Xin Wang, and Guilio Zhou, *University of California, Berkeley*; Michael J. Franklin, *University of California, Berkeley, and The University of Chicago*; Joseph E. Gonzalez and Ion Stoica, *University of California, Berkeley*

**Gaia: Geo-Distributed Machine Learning Approaching LAN Speeds . . . . .**629  
Kevin Hsieh, Aaron Harlap, Nandita Vijaykumar, Dimitris Konomis, Gregory R. Ganger, and Phillip B. Gibbons, *Carnegie Mellon University*; Onur Mutlu, *ETH Zurich and Carnegie Mellon University*

**Efficient Memory Disaggregation with INFISWAP . . . . .**649  
Juncheng Gu, Youngmoon Lee, Yiwen Zhang, Mosharaf Chowdhury, and Kang G. Shin, *University of Michigan*

**TuX<sup>2</sup>: Distributed Graph Computation for Machine Learning . . . . .**669  
Wencong Xiao, *Beihang University and Microsoft Research*; Jilong Xue, *Peking University and Microsoft Research*; Youshan Miao, *Microsoft Research*; Zhen Li, *Beihang University and Microsoft Research*; Cheng Chen and Ming Wu, *Microsoft Research*; Wei Li, *Beihang University*; Lidong Zhou, *Microsoft Research*

## **Network Verification and Debugging**

**Correct by Construction Networks Using Stepwise Refinement . . . . .**683  
Leonid Ryzhyk, *VMware Research*; Nikolaj Bjørner, *Microsoft Research*; Marco Canini, *King Abdullah University of Science and Technology (KAUST)*; Jean-Baptiste Jeannin, *Samsung Research America*; Cole Schlesinger, *Barefoot Networks*; Douglas B. Terry, *Amazon*; George Varghese, *University of California, Los Angeles*

**Verifying Reachability in Networks with Mutable Datapaths . . . . .**699  
Aurojit Panda, *University of California, Berkeley*; Ori Lahav, *Max Planck Institute for Software Systems (MPI-SWS)*; Katerina Argyraki, *École Polytechnique Fédérale de Lausanne (EPFL)*; Mooly Sagiv, *Tel Aviv University*; Scott Shenker, *University of California, Berkeley, and International Computer Science Institute*

**Automated Bug Removal for Software-Defined Networks . . . . .**719  
Yang Wu, Ang Chen, and Andreas Haeberlen, *University of Pennsylvania*; Wenchao Zhou, *Georgetown University*; Boon Thau Loo, *University of Pennsylvania*

**Delta-net: Real-time Network Verification Using Atoms . . . . .**735  
Alex Horn, *Fujitsu Labs of America*; Ali Kheradmand, *University of Illinois at Urbana-Champaign*; Mukul Prasad, *Fujitsu Labs of America*