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MobiSys'19

Proceedings of the 17th Annual International Conference on
Mobile Systems, Applications, and Services

Sponsored by:

ACM SIGMOBILE

General Co-Chairs:

Junehwa Song (Korea Advanced Institute of Science and Technology)
Minkyong Kim (Samsung Electronics)



Association for
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Advancing Computing as a Science & Profession

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General Chairs' Welcome

On behalf of the organizing committee, it is our great pleasure to welcome you to Seoul, South Korea and the *17th ACM International Conference on Mobile Systems, Applications, and Services (MobiSys 2019)*. MobiSys has been the premier venue for cutting-edge research in mobile systems and applications since its inception in 2003. We are delighted that the steering committee, led by Victor Bahl, has decided to bring the conference to Seoul this year.

We are proud that the program committee, led by the co-chairs, Rajesh K. Balan and Nicholas D. Lane, has compiled an excellent technical program. The committee has done a fabulous job in selecting 39 excellent papers from 172 submissions. We would like to acknowledge the tremendous efforts of these individuals for making the outstanding program.

In addition to the regular sessions of the main conference, we host a number of exciting adjunct programs. First, we have significantly enhanced poster as well as demo and video sessions, featuring 72 posters, 24 demos, and 7 video presentations. We expect that these sessions will serve as a valuable venue for open discussion and communication among the presenters and audience on interesting on-going works and future research directions. We are thankful to the poster chairs, Karthik Dantu, Dongsu Han, and Inseok Hwang, and the demo and video chairs, Chulhong Min and Mi Zhang, for their enormous efforts to compose and organize these sessions.

We continue the tradition of having multiple workshops on emerging and evolving topics, which bring the MobiSys community to discuss potential new directions for future mobile systems. The workshop chairs, Z. Morley Mao and Seungwoo Kang, have done an excellent work and deserve a special acknowledgment for coordinating five interesting workshops. We also thank all the individual workshop chairs for their efforts in organizing their workshops. We are proud to feature the Rising Stars Forum, a venue for young scholars, including Ph.D. students as well as fresh Ph.D.'s, to present their recent works and get useful advices for their early career. This special forum has come true by the dedication of the two rising stars forum chairs, Hsin-Mu Tsai and Chenren Xu.

MobiSys 2019 hosts three impressive keynote speakers: Professor Kang G. Shin from the University of Michigan will give a talk titled "Marriage of Smart Phones with Smart Cars", and Professor Gregory D. Abowd from Georgia Institute of Technology will speak on "The Material of the 21st Century: Moving beyond Moore and Weiser," and Roy Want from Google, the winner of the SIGMOBILE Outstanding Contribution Award (OCA), will share his valuable experiences and vision in his OCA talk.

We will continue to host the ACM Open IoT Day, which started in 2018. The IoT Day is a venue to foster stimulating and inspiring discussions on future evolutions of the IoT ecosystem. This year, we emphasize industrial views and experiences on real-world issues, and thereby aim to build valuable insights on the future of IoT. We invite a number of speakers from leading companies including two keynote speakers, Feng Zhao at Haier and Jaeyeon Jung at Samsung Electronics. We also host exciting talks by the startup leaders. We deeply thank the IoT Day program committee and the chairs, Yunxin Liu and Fahim Kawsar, for their consistent efforts to make this exciting program happen.

Putting together MobiSys 2019 has been a huge team effort. I would like to thank the organizing committee for their tireless work, including the local arrangement chairs, Kyungsik Han and JeongGil Ko, the publicity chairs, Kyunghan Lee and Tam Vu, the finance chair, Jeongyeup Paek, the publication chair, Chungkuk Yoo, the registration chair, Jihoon Ryoo, the Web chairs, Jun Han

and Jemin Lee, the student volunteer chair, Youngjin Kwon, and the startup friends chair, Yunseok Rhee. A special thanks goes to the student travel grants chairs, Brad Campbell and Song Min Kim, for the hard work acquiring funds and making it possible for dozens of students to come to MobiSys 2019. We would like to thank the steering committee chair, Victor Bahl, and the SIGMOBILE chair, Marco Gruteser, for their supports in putting the conference together.

We would like to express our deep gratitude to the MobiSys 2019 sponsors, ACM and ACM SIGMOBILE, and the generous supporters, KAIST (Korea Advanced Institute of Science and Technology), KIISE (Korean Institute of Information Scientists and Engineers), Google, Samsung, NSF, Naver, Nokia Bell Labs, HP Labs, Microsoft, KT (Korea Telecom), Korea Tourism Organization, Polariant, Ezfarm, and YBRAIN. Finally, we thank KAIST for its consistent support to host this great conference.

We sincerely hope that this year's conference provides you with a valuable opportunity to share ideas and experiences with researchers and practitioners from institutions around the world, and you find it interesting, useful and enjoyable.

ACM MobiSys 2019 General Co-chairs

Junehwa Song

Korea Advanced Institute of Science and Technology

Minkyong Kim

Samsung Electronics

ACM IoT Day Chairs' Welcome

Remarkable advancement of wireless networking, artificial intelligence and sensing devices is causing a seismic shift, in that we are experiencing the realization of a long-sought vision of the Internet of Things. Naturally, numerous industrial stakeholders are embracing this connected technology, instigating a paradigm shift that we refer to as the fourth industrial revolution. However, as this shift starts entering the mainstream and disrupting a multitude of business dynamics, it also uncovered myriads of challenges—some are technical, some are political, and some are ethical. These are thus exciting and unique times for devising and proposing novel ideas that will shape the evolution of the IoT ecosystem in the coming years.

To support a continuous, active and stimulating exchange in this space, ACM is organizing the Open IoT Day, an initiative supported by the ACM President aimed at increasing ACM's visibility with IoT industry and practitioners. In 2018, ACM hosted the first edition of the IoT day in conjunction with MobiSys 2018 at Munich. The program that included seminal talks by Vint Cerf, Mahadev Satyanarayanan and several other leading thought leaders from the industry, made a striking beginning of this initiative.

Building on the success of the first edition, we are delighted to organize the second edition of the ACM IoT Day and bring you a fascinating program looking at the Internet of Things from many perspectives. In particular, this year's program includes insightful keynotes from Feng Zhao, CTO, Haier and Jaeyeon Jung, Corporate Vice President, Samsung Electronics, discussing their experiential lessons from building real-world IoT products. Next, a set of established thought leaders from the industry including IBM, ARM, Nokia, Samsung, Alibaba, and Naver will share, discuss, and challenge the status-quo of IoT by bringing their views into the program. Finally, the program ends with an exciting panel focusing on “The Convergence of 5G, AI and IoT and its Impact on Human Productivity”.

We owe many thanks to the program committee members. The success of this year's IoT Day would not be possible without their hard work, and their professional contributions to maintain the high standards of this year's technical program. We are also grateful to all the Steering Committee members for their helpful advice and constant support. Several organizations provided financial and logistical assistance, and we are thankful for their support.

Finally, we extend a sincere “Thank You” to all the speakers and to everyone who attended the IoT Day and enjoyed the program we helped to assemble. Your continuous contribution, participation and support to this event make this entirely volunteer effort worthwhile.

Junehwa Song

KAIST

South Korea

Minkyong Kim

Samsung Electronics

South Korea

Fahim Kawsar

Nokia Bell Labs

UK

Yunxin Liu

Microsoft Research

China

MobiSys 2019 Welcome Message from the PC Chairs

Welcome to the 17th ACM International Conference on Mobile Systems, Applications, and Services (MobiSys 2019) held at the InterContinental Hotel Seoul Coex, Seoul, South Korea. ACM MobiSys 2019 is a highly selective, single-track conference seeking to present innovative and significant research on all aspects of mobile systems, applications, and services. The conference values technical contributions with working implementations and practical evaluations. This year's program includes 39 papers covering topics ranging from secure and trustworthy mobile systems to new human computer interfaces, from virtual and augmented reality to novel ideas in wireless, and from localization to acoustic sensing. The program committee carefully evaluated the most creative and interesting ideas in mobile systems among the submissions, and discussed them during a one-day PC meeting. Each paper accepted was shepherded by a program committee member to clarify the feedback and to help the authors improve their final papers. We are very pleased with the quality and creativity found in the final list of papers. We hope you enjoy the program.

Nicholas D. Lane

*Program Committee Co-Chairs
University of Oxford*

Rajesh Krishna Balan

*Program Committee Co-Chairs
Singapore Management University*

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