THE INTERNET OF THINGS

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The Internet has experienced a tremendous growth in the past three decades, evolving from a network of a few hundred hosts to a platform linking billions of "things" globally, including individual people as well as enterprises of various sizes, through computers and computerized devices of any conceivable size and capability and the applications running on them. The growth of the Internet shows no signs of slowing down and it steadily becomes the cause of a new pervasive paradigm in computing and communications. This new paradigm enhances the traditional Internet into a smart *Internet of Things* (IoT) created around intelligent interconnections of diverse objects in the physical world, such as vehicles, cell phones, habitats, and habitat occupants. It utilizes low-cost information gathering and dissemination devices, such as sensors and RFID tags, that facilitate fast-paced interactions among the objects themselves as well as the objects and persons in any place and at any time. IoT will usher in a wide range of smart applications and services to cope with many of the challenges individuals and organizations face in their everyday lives. For example, remote healthcare monitoring systems could aid in managing costs and alleviating the shortage of healthcare personnel; intelligent transportation systems could aid in reducing traffic congestion and inevitably the ills caused by it such as air pollution; smart distribution systems from utility grids to supply chains could aid in improving the quality and reducing the cost of their respective goods and services; tagged objects could result in more systematic recycling and effective waste disposal, and so on.

These applications would dramatically change the way our societies function and thus have a big impact on many aspects of people's lives in the years to come. IoT is not a mere extension of today's Internet or an internet of Internet systems. It represents intelligent end-to-end systems that enable smart solutions, and, as such, it covers a diverse range of technologies, including sensing, communications, networking, computing, information processing, and intelligent control technologies. To make IoT a reality, significant research needs to be conducted within and across these technological aspects of IoT. This has recently motivated a voluminous amount of research activities in the hot field, and this Feature Topic intends to capture and expose it to the *IEEE Communications Magazine* readership.

The Feature Topic includes a collection of five articles that cover a diversity of topics on the Internet of Things. We hope that you will find them timely, informative, and enjoyable.

In the first article, "Mobile Crowdsensing: Current State and Future Challenges," R. Ganti *et al.* examine mobile crowdsensing where individuals with sensing and computing devices collectively share data and extract information to measure and map phenomena of common interests. They, then, present a brief overview of existing mobile crowdsensing applications, explain their unique characteristics, describe various research challenges, and discuss possible solutions.

In the second article, "SPITFIRE: Toward a Semantic Web of Things," D. Pfisterer *et al.* describe their vision and architecture of a Semantic Web of Things. It refers to a service infrastructure that makes the deployment and use of semantic applications involving Internet-connected sensors practically as easy as building, searching, and reading a Web page today.

In the third article, "IMS-Enabled Management Platform for MTC-based Metropolitan Traffic Management in IoT," L. Foschini *et al.* consider the interoperability problem between machine type communications (MTC) techniques, and widespread Internet protocols and applications. They describe a practical design experience derived from the development of an IMS-enabled platform for the management of an MTC-based retractable bollard system to restrict vehicular access to limited vehicular traffic areas for the city of Bologna.

In the fourth article, "A Survey on Facilities for Experimental Internet of Things Research," A. Gluhak *et al.* identify the requirements for the next generation of IoT experimental facilities, and survey currently available research testbeds, identify existing gaps, and suggest new directions based on experiences from recent efforts in this field.

In the last article, "Smart Community: An Internet of Things Application," X. Li *et al.* introduce an Internet of Things application, Smart Community, which refers to a class of cyber-physical systems with cooperating objects (i.e., networked smart homes). They define the smart community architecture and describe how to realize secure and robust networking among individual homes. Moreover, they present two smart community applications, neighborhood watch and pervasive healthcare, with supporting techniques and associated challenges, and envision a few value-added smart community services.

In closing, we would like to acknowledge all those who contributed to our Feature Topic. First of all, we would like to congratulate the authors of the five featured articles for their fine contributions. We would also like to extend our many thanks to the authors of all articles that were submitted to our Feature Topic but, unfortunately, could not be accom-

modated in our issue. We are extremely grateful to our reviewers for their time and effort in reviewing the submitted articles and providing us and the authors valuable review comments. Many thanks go to *IEEE Communications Magazine* for giving us the opportunity to serve the community by putting together this Feature Topic. We are appreciative of the support that the Editor-in-Chief and his Senior Technical Editors gave us with their guidance during the whole process. We are also thankful to the entire IEEE ComSoc publication staff for their support and excellent work in producing this Feature Topic.

BIOGRAPHIES

JUN ZHENG [SM] (junzheng@seu.edu.cn) is a full professor with the National Mobile Communications Research Laboratory, Southeast University (SEU), Nanjing, China. He received his Ph. D. degree in electrical and electronic engineering from the University of Hong Kong, China. Before joining SEU, he was with the School of Information Technology and Engineering, University of Ottawa, Canada. He has conducted extensive research in the field of communications and communication networks. The scope of his research includes design and analysis of network architectures and protocols for efficient and reliable communications and their application to different types of networks. He co-authored the books *Optical WDM Networks: Concepts and Design Principles* (Wiley-IEEE Press, 2004) and *Wireless Sensor Networks: A Networking Perspective* (Wiley-IEEE Press, 2009), and has published over 100 technical papers in refereed journals and magazines, and peer-reviewed conference proceedings. His current research interests include mobile ad hoc networks, wireless sensor networks, and mobile communication networks, focused on network architectures and protocols. He serves as an Associate Technical Editor of *IEEE Communications Magazine* and an editorial board member of several other refereed journals, including Springer *Wireless Networks and Applications*, Elsevier *Ad Hoc Networks Journal*, and Wiley *Wireless Communications and Mobile Computing*. He was an Editor of *IEEE Communications Surveys & Tutorials* and an Associate Editor of *IEEE/OSA Journal of Optical Communications and Networking*. He has co-edited 10 Special Issues for different refereed journals and magazines, including Special Issues of *IEEE Network* on Wireless Sensor Networking and Advances in Broadband Access Networks, and Special Issues of *IEEE JSAC* on Network Coding for Wireless Communication Networks, and Broadband Access Networks: Architectures and Protocols, all as Lead Guest Editor. He has served as the founding General Chair of AdHocNets '09, General Chair of AccessNets '07, and TPC Co-Chair and Symposium Co-Chair of several international conferences and symposia, including IEEE GLOBECOM '08, '10, and '12, and ICC '09 and '11. He has also served on the TPCs of a number of international conferences and symposia. He is a member of the Expert Committee on the Internet of Things of the Chinese Institute of Electronics.

DAVID SIMPLOT-RYL (David.Simplot-Ryl@inria.fr) is director of the Lille — Nord Europe Inria research center. He was nominated as a member of the Institut Universitaire de France in 2009 and scientific head of the POPS project-team (joint project of Inria, Université Lille1, and CNRS from 2004 to 2011) which is focused on small computing devices like smartcards, electronic tags and sensor networks. After a Ph.D. (1997) in theoretical computer science, he joined the Université Lille1 — Sciences et Technologies, where he has been a full professor since 2004. His research interests include sensor and mobile ad hoc networks, mobile and distributed computing, embedded operating systems, smart objects, and RFID technologies. He is involved in numerous international conferences and workshops (e.g., recently AdHocNets 2010–2011, IEEE MASS 2010–2011, IEEE INFOCOM 2011–2012), and editorial activities (e.g., Special Issues of *IEEE Network* and *IEEE Communication Magazine*, and Associate Editor of *IEEE Transactions on Parallel and Distributed Systems*). Together with his research group, he contributed to the implementation of SensLab sensor networks, which led to the creation of FIT — Future Internet (of Things) — as part of the excellence-in-equipment (EquipEx) project. In the Lille — Nord Europe Inria research center, he served from 2008 to 2011 as scientific deputy in charge of the development and evaluation of research activities of the research center. In particular, he is involved in regional entities like CITC-EuraRFID, Picom or Maud.

CHATSCHIK BISDIKIAN [F] (bisdik@us.ibm.com) holds a Ph.D. degree in electrical engineering from the University of Connecticut, Storrs. He is a research staff member with the Network Management Department at IBM T. J. Watson Research Center, Hawthorne, New York. He has been with IBM Research since 1989 and has worked in numerous projects covering a variety of research topics in communications, networking, pervasive computing, IPTV services, computer system management, quality of information for sensor networks, and so on. In 2004 he was elected IEEE Fellow for his contributions to the development, modeling, and analysis of communication protocols and wireless personal area networks. He has authored over 120 peer-reviewed papers, holds several patents in the aforementioned areas, and co-authored the book *Bluetooth Revealed* (Prentice Hall). He has served as Editor-in-Chief of *IEEE Network*, where he currently serves as Senior Technical Editor. He also serves on the editorial board of the *Pervasive and Mobile Computing* journal and has served on the editorial boards of *IEEE Journal on Selected Areas in Communications* and the *Telecommunication Systems* journal; he has also guest edited several Special Issues on various topics. He served as Technical Program Chair for IEEE PerCom '09, and as Chair of the IEEE International Workshop on Information Quality and Quality of Service (IQ2S '10 and '11), the First IEEE Workshop on Quality of Information (QoI) for Sensor Networks (QoISN '08), and the Workshop on End-to-End, Sense-and-Respond Systems, Applications, and Services (EESR '05). He has been involved with the development of the Bluetooth specification from its early stages and has served as vice-chair of the IEEE 802.15.1 task group that developed a standard for personal area networks adapted from the Bluetooth specification. He received the 2002 best tutorial award from IEEE Communications Society for his paper titled "An Overview of the Bluetooth Wireless Technology" and the IEEE RTSS best paper award for "Quality Tradeoffs in Object Tracking with Duty-Cycled Sensor Networks." He is a 1995 finalist of the Eta Kappa Nu Honor Society's Outstanding Young Electrical Engineer Award Program and a 2004 inductee of the Academy of Distinguished Engineers and Hall of Fame of the School of Engineering of the University of Connecticut. He is a lifelong member of the Eta Kappa Nu and Phi Kappa Phi Honor Societies, and a member of ACM.

HUSSEIN T. MOUFTAH [F'90] (mouftah@site.uottawa.ca) started his academic career as an assistant professor in the Department of Electrical and Computer Engineering at Queen's University in 1979. In 1988 he became a full professor there, and from 1998 until 2002 he was associate head of the department. In 2002 he became a Tier 1 Canada Research Chair Professor at the University of Ottawa School of Information Technology and Engineering, where in 2006 he became a Distinguished University Professor. During his sabbatical leaves, he did consulting work for BNR and Nortel Networks (1986–1987; 1993–1994; and 2000–2001). He has published over 850 technical papers, 6 books, and 30 book chapters. To his credit he has 10 patents and 138 industrial reports. He has received research grants and contracts totaling close to $30 million and has supervised more than 200 highly qualified personnel, of which 88 are Master graduates, 59 are Ph.D. graduates, and 22 are post-doctoral fellows. He has served the IEEE Communications Society as Editor-in-Chief of *IEEE Communications Magazine* (1995–1997), Director of Magazines (1998–1999), Chair of the Awards Committee (2002–2003), Director of Education (2006–2007), and member of the Board of Governors (1997–1999 and 2006–2007). Also, he is the founding Chair of two of IEEE Communications Society's Technical Committees: Optical Networking (2002–2004) and Ad Hoc and Sensor Networks (2005–2007). He has been a Distinguished Speaker of the IEEE Communications Society (2000–2007). He is the recipient of the 1989 Engineering Medal for Research and Development from the Association of Professional Engineers of Ontario and the 2002 Ontario Distinguished Researcher Award of the Ontario Innovation Trust. He has also received eight Outstanding/Best Paper Awards (two at ISCC '08; ICC '05; CITO Innovators Showcase '04; *IEEE Communications Magazine* in 1993; SPECTS '02; HPSR '02; and ISMVL '84), the IEEE Canada Outstanding Service Award (1995), and the CSIM Distinguished Service Award of the IEEE Communications Society (2006). In 2004 he received the IEEE Communications Society Edwin Howard Armstrong Achievement Award and the George S. Glinski Award for Excellence in Research from the Faculty of Engineering, University of Ottawa. In 2006 he was honored with the IEEE McNaughton Gold Medal and the Engineering Institute of Canada Julian Smith Medal. In 2007 he was the recipient of the Royal Society of Canada (RSC) Thomas W. Eadie Medal. Most recently, he received the University of Ottawa 2007–2008 Award for Excellence in Research and the ORION Leadership Award of Merit (2008). He is a Fellow of the Canadian Academy of Engineering (2003), the Engineering Institute of Canada (2005), and RSC: The Academies of Canada (2008).