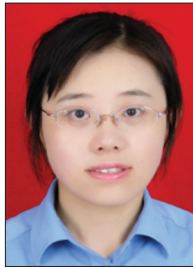


THE INTERNET OF THINGS FOR SMART CITIES: TECHNOLOGIES AND APPLICATIONS



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Smart cities are creating emerging innovation in academia, industry, and government. A city may be called “smart” when investments in human and social capital and traditional and modern communication infrastructure fuel sustainable economic growth and a high quality of life, with wise management of natural resources through participatory governance. A smart city is also defined as a city connecting the physical infrastructure, the ICT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city. Smart cities are usually established relying on both advanced infrastructures and modern information and communication technologies.

In particular, the Internet of Things (IoT) plays an important role in connecting everything together and to the Internet through specific protocols for information exchange and communications, achieving intelligent recognition, location, tracking, monitoring, and management. Extensive research on IoT is taking place on sensing and automatic control, network infrastructure and communication, and big data analytics. This facilitates a multidisciplinary approach for developing integrated solutions and creating novel applications to build a sustainable society. By interconnecting physical and virtual worlds with huge amounts of electronic devices distributed in houses, vehicles, streets, buildings, and many other public environments, IoT-based smart cities can provide various kinds of services for both citizens and administrators. These include smart homes, smart parking lots, weather systems, vehicular traffic, environmental pollution, surveillance systems, smart energy, and smart grids. Therefore, it is necessary to further research the technologies and applications in the domain of IoT-based smart cities.

The objective of this Special Issue is to cover the most recent research and development on the enabling technologies for IoT-based smart cities and to stimulate discussions on state-of-the-art and innovative aspects in the field. The response to our Call for Papers on this Special Issue was good. During the review process, each paper was assigned to and reviewed by at least three experts in the relevant area, with a rigorous two-round review process. This issue accommodates 15 excellent articles covering various aspects of IoT-based smart cities involving IoT-based architecture and infrastructure, IoT-based services for smart and green cities, IoT-based networks and communications protocol, and IoT-based applications, business, and social issues.

The first article, “HybridIoT: Integration of Hierarchical Multiple Access and Computation Offloading for IoT-Based Smart Cities,” by Qian *et al.*, propose a new architecture, HybridIoT, in order to efficiently transmit, compute, and cache big data generated from the massive distributed IoT devices deployed in a smart city.

In the second article, “UAV Aided Aerial-Ground IoT for Air Quality Sensing in Smart City: Architecture, Technologies, and Implementation,” Hu *et al.* present a real-time, fine-grained, and power-efficient air quality monitoring system based on aerial and ground sensing. The architecture of this system consists of four layers: the sensing layer to collect data, the transmission layer to enable bidirectional communications, the processing layer to analyze and process the data, and the presentation layer to provide graphic interface for users.

The third article, “Demystifying the Crowd Intelligence in Last Mile Parcel Delivery for Smart Cities,” by Wang *et al.*, studies how the rich IoV resources further enable intelligent vehicle scheduling and management, opening new opportunities toward efficient and elastic last mile delivery for smart cities.

In the fourth article, “Optimal Edge Resource Allocation in IoT-Based Smart Cities,” Zhao *et al.* study how to allocate edge resources for average service response time minimization. Besides the proposed algorithms, extensive numerical results are also presented to validate their efficacy.

In the fifth article, “When UAV Swarm Meets Edge-Cloud Computing: The QoS Perspective,” by Chen *et al.*, the authors design a novel hybrid computing framework to provide powerful resources to support resource-intensive applications and real-time tasks at edge networks, and then study a joint task placement and routing problem for latency-critical applications as a case study.

The sixth article, “A Lightweight Authentication Scheme for Cloud-based RFID Healthcare Systems,” by Fan *et al.*, proposes a lightweight authentication scheme based on quadratic residuals and a pseudo random number generator to guarantee the security of a cloud-based RFID healthcare system. It ensures data privacy and is resistant to typical attacks in mobile communications.

The seventh article, “Toward Edge-Assisted Internet of Things: From Security and Efficiency Perspectives,” by Ni *et al.*, studies the security, privacy, and efficiency challenges in data processing for mobile edge computing, and discuss the opportunities to enhance data security and improve computational efficiency.

In the eighth article, “Smart-Edge-CoCaCo: AI-Enabled Smart Edge with Joint Computation, Caching, and Communication in Heterogeneous IoT,” Hao *et al.* propose a new AI-enabled smart edge with heterogeneous IoT architecture that combines edge computing, caching, and communication, and propose the Smart-Edge-CoCaCo algorithm.

The ninth article, “Toward Integrating Vehicular Clouds with IoT for Smart City Services,” by Ali Khattak *et al.*, provides deep insights for different real-world application scenarios — smart homes, intelligent traffic lights, and smart city — using IoT-VC

for general control and automation along with their associated challenges.

The tenth article, “Edge Computing-Based Security Framework for Big Data Analytics in VANETs,” by Garg *et al.*, proposes an advanced vehicular communication technique where RSUs are proposed to be replaced by edge computing platforms. Then secure vehicle-to-vehicle and vehicle-to-edge communication is designed using quotient filter, a probabilistic data structure.

In the eleventh article, “Challenges of Multi-Factor Authentication for Securing Advanced IoT (A-IoT) Applications,” Ometov *et al.* advocate for the adoption of multi-factor authentication for A-IoT, such that multiple heterogeneous methods — both well-established and emerging — are combined intelligently to grant or deny access reliably.

In the twelfth article, “A Computing and Content Delivery Network in Smart City: Scenario, Framework and Analysis,” Chen *et al.* deal with this issue and propose a novel network framework based on content delivery and computing deployment in order to make a network smart and clever.

The thirteenth article, “UAV Network and IoT in the Sky for Future Smart Cities,” by Zhu *et al.*, develops a 5G IoT network with unmanned aerial vehicles (UAVs) for future smart city architecture.

In the fourteenth article, “Visual IoT: Enabling Internet of Things Visualization in Smart Cities,” Ji *et al.* present a systemic analysis for the requirements of visual IoT from the perspective of smart cities.

The fifteenth article, “Intelligent Edge Computing for IoT-Based Energy Management in Smart Cities,” by Liu *et al.*, proposes the framework and software model of the IoT-based system with edge computing.

In closing, we would like to thank all the authors for their excellent contributions. We also thank the reviewers for their dedication in reviewing the papers and providing valuable comments and suggestions for refining the quality of the articles. We appreciate the advice and support of the Editor-in-Chief of *IEEE Network*, Dr. Mohsen Guizani, and Joseph Milizzo, Jennifer Porcello, and Cathy Kemelmacher for their tremendous help in the publication process. Finally, we hope that the readership will find this Special Issue interesting and informative. We also hope that the readership will stay tuned for new developments in this research area.

BIOGRAPHIES

YI QIAN [M’95, SM’07, F’19] (yqian@ieee.org) received a Ph.D. degree in electrical engineering from Clemson University, South Carolina. He is currently a professor in the Department of Electrical and Computer Engineering, University of Nebraska-Lincoln (UNL). Prior to joining UNL, he worked in the telecommunications industry, academia, and government. Some of his previous professional positions include serving as a senior member of scientific staff and a technical advisor at Nortel Networks, a senior systems engineer and a technical advisor at several startup companies, an assistant professor at the University of Puerto Rico at Mayaguez, and a senior researcher at the National Institute of Standards and Technology. His research interests include communications and systems, and information and communication network security. More specifically, he has research and industry experience in wireless communications and systems, information assurance and network security, sensing and sensor networks, vehicular communications, smart

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WEI BAO received his B.E. degree in communications engineering from Beijing University of Posts and Telecommunications, China, in 2009; his M.A.Sc. degree in electrical and computer engineering from the University of British Columbia, Canada, in 2011; and his Ph.D. degree in electrical and computer engineering from the University of Toronto, Canada, in 2016. He is currently a lecturer at the School of Information Technologies, University of Sydney, Australia. His research covers the area of network science, with emphasis on 5G systems, the Internet of Things, and mobile computing. His research has solved challenging and important problems that widely exist in practical networks. New solutions that achieve drastic performance improvement and support a variety of new applications are proposed. He served as a Local Chair for Passive and Active Measurement Conference 2017, and Publicity Co-Chair for the Australasian Symposium on Parallel and Distributed Computing (AusPDC). He was a TPC member for the IEEE Wireless Communications and Networking Conference (WCNC) and the IEEE Conference on Pervasive Intelligence and Computing, and has been a Guest Editor for Special Issues of the *IEEE Journal on Selected Areas in Communications*. He was a reviewer for a number of IEEE, ACM, and Elsevier conferences and journals. He received the Best Paper Awards at the ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems in 2013 and the IEEE International Symposium on Network Computing and Applications in 2016.

PASCAL LORENZ [SM] received his M.Sc. (1990) and Ph.D. (1994) from the University of Nancy, France. Between 1990 and 1995 he was a research engineer at WorldFIP Europe and at Alcatel-Alstom. He has been a professor at the University of Haute-Alsace, France, since 1995. His research interests include QoS, wireless networks, and high-speed networks. He is the author/co-author of three books, three patents, and 200 international publications in refereed journals and conferences. He was a Technical Editor on the IEEE Communications Magazine Editorial Board (2000–2006), Chair of the Vertical Issues in Communication Systems Technical Committee Cluster (2008–2009), Chair of the Communications Systems Integration and Modeling Technical Committee (2003–2009), and Chair of the Communications Software Technical Committee (2008–2010). He has served as Co-Program Chair of IEEE WCNC 2012, ICC 2004, and ICC 2017, Tutorial Chair of VTC-Spring 2013 and WCNC 2010, Track Chair of PIMRC 2012, and Symposium Co-Chair of GLOBECOM 2007–2011, ICC 2008–2010, and ICC 2014 and 2016. He has served as Co-Guest Editor for Special Issues of *IEEE Communications Magazine*, *IEEE Network*, *IEEE Wireless Communications*, *Telecommunications Systems*, and *LNCs*. He is Associate Editor for the *International Journal of Communication Systems* (Wiley), the *Journal on Security and Communication Networks* (SCN-Wiley), the *International Journal of Business Data Communications and Networking*, and the *Journal of Network and Computer Applications* (Elsevier). He is an IARIA Fellow and a member of many international program committees. He has organized many conferences, chaired several technical sessions, and given tutorials at major international conferences. He was an IEEE ComSoc Distinguished Lecturer during 2013–2014.