Guest Editorial Special Issue on Emerging Social Internet of Things: Recent Advances and Applications

THE CONCEPT of Social Internet of Things (SIoT) has emerged from the integration of social networking into the core of the Internet of Things (IoT). It envisions IoT objects and devices to have social interactions with each other autonomously, cooperate with other agents, and exchange information with human users and surrounding computing devices. These objects are able to sense/actuate, store, and interpret information in an opportunistic and loosely coupled fashion. The objects in the SIoT paradigm can exhibit multiple forms of social relationships derived from their collaborative activities or functional, temporal and spatial dependencies to meet a particular need of human users, which signify the difference between the SIoT domain to that of social-based mobile networks or sensor networks. The social interaction among the SIoT objects contribute a huge volume of data to be processed and used by various applications such as social VANET, social connected health, SIoT-based recommendation service, traffic service, policing, energy management etc, in the area of Smart Cities, Smart Homes, Smart Grid, and Smart Factories to satisfy human needs, interests, and objectives. Such a dynamic landscape with billions of social communities of objects and devices requires new models, theories, and approaches of interaction and collaboration, which could be established by referring to the experience that people have already gained in social networking domain over the past few years.

Despite all the possibilities offered by SIoT, there are several critical challenges that need further attention from the industry and academic communities. Until now, it remains unclear how to efficiently address the application of social concepts into the IoT paradigm, how to discover and utilize SIoT services and applications in certain industrial areas, how to handle complex interactions in a dynamic SIoT environment, how to perceive a social object's autonomy, and how to handle the darker aspects of SIoT such as security, privacy and trust issues, and so on.

The response to our Calls for Papers for this Special Issue, which aimed to foster the dissemination of high-quality research in terms of theory and practice related to IoT and its social aspects, was overwhelming, with 35 papers submitted from around the world. During the review process, each paper was assigned to and reviewed by multiple experts in the relevant areas, with a rigorous two-round review process. Thanks to the courtesy of the Editor-in-Chief of this JOURNAL, Prof. Xuemin (Sherman) Shen, we were able to accept nine excellent papers covering various aspects of SIoT: edge/smart middleware, high-level machine-to-machine protocols, security and privacy, quality-aware services, big data integration, and topical applications (multimedia healthcare, Internet of Vehicles, Smart Grid). In the following, we will summarize these papers, highlighting their main contributions.

In the paper "Privacy-Preserving and Lightweight Key Agreement Protocol for V2G in the Social Internet of Things," Shen *et al.* consider the vehicle-to grid (V2G) networks as an important domain for SIoT. They in fact address issues of security and privacy in V2G networks. Specifically, the authors propose a robust key agreement protocol that can achieve mutual authentication without exposing the real identities of users. The proposed protocol based on hash functions and bitwise exclusive-OR operations, is more efficient than pairing-based protocols. A formal security model is also defined for the proposed protocol. According to such model, the protocol is demonstrated to be secure through a formal security analysis. The protocol can notably withstand different types of attacks.

The paper "Nonreciprocity Compensation Combined With Turbo Codes for Secret Key Generation in Vehicular Ad Hoc Social IoT Networks" by Epiphaniou *et al.*, focuses on security in vehicular ad-hoc SIoT networks and, specifically, on the generation of highly random and symmetric cryptographic keys on the basis of the physical attributes of the dynamic vehicle-to-vehicle propagation channel. A main issue for a physical-layer key agreement scheme, is the nonreciprocity that is due to inherent channel noise and hardware impairments that can propagate bit disagreements. Authors therefore proposed a novel scheme to tackle such an important issue, incorporating temporal variability attributes such as 3-D scattering and scatterers' mobility, so defining a key generation process by combining nonreciprocity compensation with turbo codes. Results show a significant improvement when using turbo codes in bit mismatch rate and key generation rate in comparison to sample indexing techniques.

Lippi *et al.* in their paper entitled "An Argumentation-Based Perspective Over the Social IoT," focuses on social interactions between smart objects in the SIoT. Smart objects, named "speaking objects," can interact through argumentation, showing how different forms of human dialogue naturally fit cooperation and coordination requirements of the SIoT. Specifically, authors show how speaking objects can

Digital Object Identifier 10.1109/JIOT.2018.2860339

exchange arguments to seek for information, negotiate over an issue, persuade others, deliberate actions, and so forth, namely, striving to reach consensus about the status of affairs and their goals. How argumentation naturally enables such a form of conversational coordination is demonstrated through traffic management and assisted living use cases scenarios.

In the era of big data, the SIoT data is increasing continuously. Algorithmic trading is beginning to develop rapidly in the trading market, which attracts plenty of attention from academic and industry. The paper "Self-Evolving Trading Strategy Integrating Internet of Things and Big Data," by Xiao *et al.*, propose a machine-learning-based approach to establish a futures algorithm trading strategy, which can make transaction decisions autonomously or assisting, and get considerable results. Through the adequate experiments, it shows that the back propagation (BP) neural network can predict the futures price trend accurately, while the proposed self-evolving trading strategy based on BP neural network is superior to the other four representative approaches. Overall, this paper is significant to the research of the futures market and it provides a novel approach for the application of machine learning in algorithmic trading.

The paper "A Cooperative Quality-Aware Service Access System for Social Internet of Vehicles" by Ning *et al.*, is in the SIoT-related topical application domain of Social Internet of Vehicle (SIoV), addressing road safety and driving experience issues. The contribution of this paper is on the design of a service access system in SIoVs, focusing on a reliability assurance strategy and quality optimization method. A dynamic access service evaluation scheme for constructing social relationships among vehicles is first proposed; then, a trajectory-based interaction time prediction algorithm is defined, which deals with an unstable network topology and high rate of disconnection, which are typical issues in SIoVs. Finally, a cooperative quality-aware system model is proposed for service access in SIoVs. The proposal is evaluated through simulation, showing the effectiveness of the scheme.

In the paper by Rahman and Hossain entitled "m-Therapy: A Multisensor Framework for in-Home Mobile Therapy Management: A Social Therapy of Things Perspective," SIoT concepts are exploited to provide health services, specifically in-home therapy. In-home therapy environments have several distinctive characteristics, mainly low-cost medical devices and noncontinuity of health monitoring, differentiating them from in-hospital environments based on expensive medical devices and the constant presence of therapists. This paper proposes the m-Therapy framework, in which multiple gesture-tracking sensors and environmental sensors are used to collect therapy and ambient data, which can be then analyzed on a big data server. m-Therapy uses a purposely defined therapy model to guide a patient's self-performing therapy. The framework analytics provide live or statistical kinematic data, including rotational and angular range of motion of the joints of interest, and ambient environmental data, which can be shared with therapists and caregivers. m-Therapy monitoring system was actually deployed and evaluated in real use cases.

In the paper "Toward a Smart Society Through Semantic Virtual-Object Enabled Real-Time Management Framework in the Social Internet of Things," Shamszaman and Ali focus on defining a new cognitive middleware for SIoT management. Specifically, they propose a framework providing abstractions to define smart objects like virtual objects and their "social" composition (to build new services) through composite virtual objects. Moreover, abstract objects are introduced to model special skills such as expertise, and/or willingness to help others. The performance of virtual object selection mechanism was evaluated to analyze the resource consumption and latency involved in the management process.

"Edge Computing and Social Internet of Things for Large-Scale Smart Environments Development" by Cicirelli *et al.* refers to large-scale smart environments (LSE) as open and dynamic systems extending over a wide area and including a huge number of interacting and heterogeneous devices. The authors propose a new an agent-based approach, relying on edge computing and SIoT, for the deployment and management of LSE. Specifically, the approach is fully realized through the *iSapiens* framework, providing all necessary abstractions to develop SIoT applications. The effectiveness of such an approach is assessed through a real case study involving a smart commercial road environment.

Frustaci *et al.* in their paper "Evaluating Critical Security Issues of the IoT World: Present and Future Challenges" deal with security and privacy issues that are a great challenge for SIoT. The intrinsic vulnerabilities of IoT devices, with limited resources and heterogeneous technologies, together with the lack of specifically designed IoT standards, represent a fertile ground for the proliferation of specific cyber threats. In this paper, the authors systematize the IoT security panorama by providing a taxonomic analysis from the perspective of the three main key layers of the IoT system model: 1) perception; 2) transportation; and 3) application levels. As a result of the analysis, the most critical issues with the aim of guiding future research directions are also highlighted.

To conclude, we first would like to acknowledge all the authors for their support and excellent contributions. We also would like thanking all the reviewers for their efforts in the paper review phase, and for their valuable comments and constructive suggestions that allowed improving the quality of the papers. Finally, we appreciate the advice and support of the Editor-in-Chief of this JOURNAL, Prof. Xuemin (Sherman) Shen, along with the Editorial Office staff, for his help during the entire publication process.

GIANCARLO FORTINO, *Leading Guest Editor*
University of Calabria
Rende, Italy
e-mail: g.fortino@unical.it

MOHAMMAD MEHEDI HASSAN, *Guest Editor*
King Saud University
Riyadh, Saudi Arabia
e-mail: mmhassan@ksu.edu.sa

MENGCHU ZHOU, *Guest Editor*
New Jersey Institute of Technology
Newark, NJ, USA
e-mail: mengchu.zhou@njit.edu

ANDRZEJ M. GOSCINSKI, *Guest Editor*
Deakin University
Geelong, VIC, Australia
e-mail: andrzej.goscinski@deakin.edu.au

MD ZAKIRUL ALAM BHUIYAN, *Guest Editor*
Fordham University
New York, NY, USA
e-mail: mbhuiyan3@fordham.edu

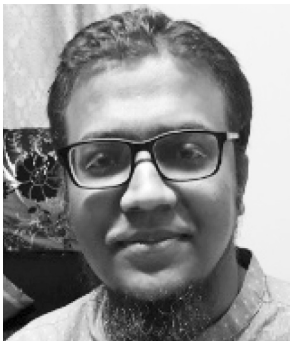
JIANQIANG LI, *Guest Editor*
Beijing University of Technology
Beijing, China
e-mail: lijianqiang@bjut.edu.cn

SOURAV BHATTACHARYA, *Guest Editor*
Nokia Bell Labs – Dublin
Dublin, Ireland
e-mail: sourav.bhattacharya@bell-labs.com

Giancarlo Fortino (SM'12) received the Laurea (B.S. and M.S.) and Ph.D. degrees in computer engineering from the University of Calabria, Rende, Italy, in 1995 and 2000, respectively.

He is currently a Professor of computer engineering with the Department of Informatics, Modeling, Electronics and Systems, University of Calabria. He holds the Scientific Italian Habilitation for Full Professor and is also an Adjunct Full Professor of computer engineering with the Wuhan University of Technology, Wuhan, China, in the framework of High-End Foreign Experts in China and an Adjunct Senior Researcher with the Italian National Research Council, Rome, Italy. He has authored over 350 publications in journals, conferences, and books. He is currently the Scientific and Technical Project Manager of the EU-funded H2020 INTER-IoT project on heterogeneous IoT platform interoperability. He is the co-founder and CEO of SenSysCal S.r.l., a spin-off of the University of Calabria, engaged in advanced applied research and development of IoT systems. His current research interests include distributed computing, wireless sensor networks, body area networks, software agents, Internet of Things technology, and cloud computing.

Dr. Fortino is an Associate Editor of the IEEE TRANSACTIONS ON AFFECTIVE COMPUTING, the IEEE TRANSACTIONS ON HUMAN–MACHINE SYSTEMS, the IEEE INTERNET OF THINGS JOURNAL, IEEE SENSORS JOURNAL, IEEE ACCESS, *Information Fusion*, *Engineering Application of Artificial Intelligence*, and the *Journal of Network and Computer Applications*. He is the founding Co-Chair of SMC TC on Interactive and Wearable Computing and Devices and the Chair of the Italian Chapter of the IEEE SMC Society and a Member-at-Large of the IEEE SMCS BoG.



Mohammad Mehedi Hassan (M'11) received the Ph.D. degree in computer engineering from Kyung Hee University, Seoul, South Korea, in 2011.

He is currently an Associate Professor with the Information Systems Department, College of Computer and Information Sciences (CCIS), King Saud University (KSU), Riyadh, Saudi Arabia. He has authored or co-authored over 100 research papers in the journals and conferences of international repute. His current research interests include cloud federation, multimedia cloud, sensor-cloud, Internet of Things, big data, mobile cloud, cloud security, IPTV, sensor network, 5G network, social networks, publish/subscribe systems, and recommender systems.

Dr. Hassan was a recipient of the Best Paper Award of the CloudComp Conference in China in 2014 and the Excellence in Research Award from CCIS, KSU, in 2015 and 2016, respectively. He has served as the Chair and Technical Program Committee member of numerous international conferences/workshops such as IEEE HPCC, ACM BodyNets, IEEE ICME, IEEE ScalCom, ACM Multimedia, ICA3PP, IEEE ICC, TPMC, and IDCS. He has also been the Guest Editor of several international ISI-indexed journals.

MengChu Zhou (S'88–M'90–SM'93–F'03) received the B.S. degree in control engineering from the Nanjing University of Science and Technology, Nanjing, China, in 1983, the M.S. degree in automatic control from the Beijing Institute of Technology, Beijing, China, in 1986, and the Ph.D. degree in computer and systems engineering from Rensselaer Polytechnic Institute, Troy, NY, USA, in 1990.

He joined the New Jersey Institute of Technology, Newark, NJ, USA, in 1990, where he is currently a Distinguished Professor of electrical and computer engineering. He has over 700 publications, including 12 books, over 400 journal papers (over 300 in IEEE TRANSACTIONS), 11 patents, and 28 book chapters. His current research interests include Petri nets, intelligent automation, Internet of Things, big data, Web services, and intelligent transportation.

Dr. Zhou was a recipient of the Humboldt Research Award for U.S. Senior Scientists from Alexander von Humboldt Foundation, the Franklin V. Taylor Memorial Award, and the Norbert Wiener Award of the IEEE Systems, Man and Cybernetics Society for which he serves as a VP for Conferences and Meetings. He is the Founding Editor of IEEE Press Book Series on Systems Science and Engineering and the Editor-in-Chief of the *IEEE/CAA Journal of Automatica Sinica*. He is a Life Member of the Chinese Association for Science and Technology–USA and served as its President in 1999. He is a Fellow of the International Federation of Automatic Control, American Association for the Advancement of Science, and Chinese Association of Automation.

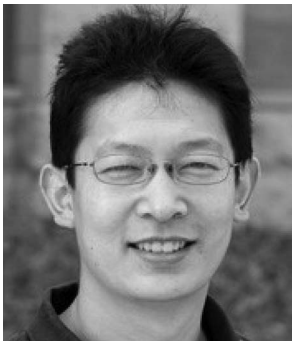
Andrzej M. Goscinski received the Ph.D. degree in computer science and automatic control from the University of Science and Technology, Kraków, Poland, in 1973.

He is currently a Chair Professor of computing with Deakin University, Geelong, VIC, Australia. He is recognized as one of the leading researchers in distributed systems, distributed and cluster operating systems, and service and cloud computing. He has authored or co-authored over 180 refereed papers with many of them featuring in first-class international refereed journals such as *Parallel Computing*, the *International Journal of Cloud Computing*, *Genomics*, *Cluster Computing*, *The Computer Journal*, the *Journal of Parallel and Distributed Computing*, the *Journal of Systems and Software*, *Computer Communications*, and *Microcomputers and Microsystems* and first-class international refereed conference proceedings such as the IEEE International Conference on Clouds, Web Services, Services, Parallel and Distributed Processing, International Conference on Technology of Object-Oriented Languages and Systems, IEEE International Conference on Algorithms and Architectures for Parallel Processing, International Conference on Parallel and Distributed Systems, IEEE International Conference on Computation Science, and the IEEE/ACM International Symposium on Cluster Computing and the Grid. The results of his research have been published in international refereed journals and conference proceedings and presented at specialized conferences. His current research interests include high-level abstractions of cloud computing, cloud's service publication, selection, and discovery, grid, and the development and deployment of services-based clouds.

Md Zakirul Alam Bhuiyan (M'14) received the M.Eng. and Ph.D. degrees in computer science and technology from Central South University (CSU), Changsha, China, in 2013 and 2009, respectively.

He has been an Assistant Professor with Temple University, Philadelphia, PA, USA. He is currently an Assistant Professor with the Department of Computer and Information Sciences, Fordham University, New York, NY, USA. He was a Post-Doctoral Research Fellow with the School of Software and the School of Information Science and Engineering, CSU, from 2010 to 2011. He was a Research Assistant with the Department of Computing, Hong Kong Polytechnic University, Hong Kong, from 2010 to 2011 and a Software Engineer with several international software companies. His papers have appeared in prestigious journals/conferences. His current research interests include dependable cyber-physical system design and development in multi-disciplinary research fields (networked and distributed sensing systems, monitoring software/tool design, data mining, and security), fault-tolerance and reliability, and cloud computing.

Dr. Bhuiyan was a recipient of the Youth Scientific Fund (2015–2017) of the NSF of China and the Best Ph.D. Thesis Award at both the provincial and the university levels, the 2012 Top-Notch Ph.D. Student Award of CSU, the 2012 Hunan Province Innovative Engineering Research Fund Award, the Outstanding Master Degree Dissertation Award at both the provincial and the university levels, the Best Paper Award of IEEE ISPA 2013, Melbourne, VIC, Australia, and the Best Academic Paper Award 2012. He is a member of the ACM.



Jianqiang Li received the B.S. degree in mechatronics from the Beijing Institute of Technology, Beijing, China, in 1996, and the M.S. and Ph.D. degrees in control science and engineering from Tsinghua University, Beijing, in 2001 and 2004, respectively.

He was a Researcher with the Digital Enterprise Research Institute, National University of Ireland, Galway, Ireland, from 2004 to 2005. From 2005 to 2013, he was with NEC Laboratories China, Beijing, China, as a Researcher, and the Department of Computer Science, Stanford University, Stanford, CA, USA, as a Visiting Scholar from 2009 to 2010. He joined the Beijing University of Technology, Beijing, in 2013, as a Beijing Distinguished Professor. He has authored or co-authored over 70 publications and 42 international patent applications (22 of them have been granted in China, U.S., or Japan). His current research interests include Petri nets, enterprise information system, social computing, predicative data mining, Internet of Things, privacy protection, and big data.

Dr. Li served as a Program Committee member of multiple international conferences and organized the IEEE Workshop on Medical Computing 2014. He served as the Guest Editor to organize special issues on Emerging Information Technology for Enhanced Healthcare in Computer in Industry and Telecommunication for Remote Medicine in China Communication.

Sourav Bhattacharya received the Ph.D. degree in computer science from the University of Helsinki, Helsinki, Finland.

He was a Post-Doctoral Researcher with Aalto University, Espoo, Finland. He is a Technical Staff Member with Nokia Bell Labs – Dublin, Dublin, Ireland, where he is involved in developing novel inference techniques using deep learning and bringing new inference capabilities to mobile and wearable platforms. He is part of a dynamic team, which focuses on broader Internet of Things research.