Guest Editorial
Special Section on Advances and Applications of Internet of Things for Smart Automated Systems

IN 1999, Kevin Ashton envisioned a novel paradigm named Internet of Things (IoT), in which all things could see, hear, and smell the world for themselves, and interact with each other and cooperate with their neighbors to reach some common desired goals. In the following years, the IoT ideas started to spread rapidly due to the technology advancements in the fields of microelectromechanical systems and most recently, nanoelectromechanical systems, computers, and wireless communications, resulting in autonomous everyday thing augmented with sensing/actuation, storage, processing, and network capabilities. Their new applications emerged daily from smart homes to smart cities, from automobiles to high-speed trains, from new-born care devices to patient operating rooms and entire hospitals, and from manufacturing factories to agricultural food plants. IoT is one of the fastest growing technical areas across almost all engineering disciplines and touches almost all verticals of the World Economy. It represents major investments in commercial and government initiatives. We expect to have over 40% Compound Annual Growth Rate year over year in the commercial marketplace and to dominate "traffic" on the Internet within the next decade.

According to IEEE IoT Initiative Steering Committee, the IoT refers to a world-wide network of interconnected heterogeneous objects (sensors, actuators, smart devices, smart objects (SOs), radio frequency identification (RFID), embedded computers, etc.) uniquely addressable, based on standard communication protocols. Beyond such a networking-oriented definition, IoT can be seen as a loosely coupled, decentralized system of cooperating SOs. An SO is an autonomous, physical digital object augmented with sensing/actuating, processing, storing, and networking capabilities. SOs are able to sense/actuate, store, and interpret information created within themselves and around the neighboring external world, where they are situated, act on their own, cooperate with each other, and exchange information with other kinds of electronic devices and human users.

Similar concepts have been proposed in different application domains and with different focuses: GE's Industrial Internet and M2M focusing on machine-to-machine interactions; automotive industry's Connected Car and V2V focusing on vehicle-to-vehicle communication and collaboration; and a People-to-People collaboration concept being proposed and used in the e-commerce and social network worlds. After the Web and mobile accessibility, IoT has been hailed as another technological revolution of our lifetime, even more promising with smart automated systems (such as Smart Cities, Smart Grid, Smart Factories, Smart Buildings, Smart Homes, and Smart Cars). In such systems and related applications, it is important to effectively propose methods and architectures able to effectively collect, manage, and process large/complex data sets and processes, and ultimately to manage and control IoT-enabled systems at different levels (from local to global), as they are composed of many networked entities of different scales (sensors and actuators, embedded computers, mobile devices, machines, factories, buildings, and people).

The large-scale nature of IoT-enabled systems raises a number of specific challenges including: effective data collection, cleaning, and storage; data latency and real-time Big Data analytics; novel methods for global system control; effective development of large-scale management platforms; well-defined control interfaces for IoT technologies; and various IoT standards. Moreover, such new findings, development and implementation need to ensure IoT system safety, security, and privacy.

The goal of this Special Section is to address these challenges and concerns in order to develop advanced technologies for effectively managing and controlling future IoT systems, to provide insights into real-time Big Data and process management in large-scale IoT contexts, and recent applications to manufacturing, supply chain management, transportation, environment monitoring, energy management, and healthcare. We have collected a set of outstanding works that address the following research issues and applications:

– Theoretical foundations of controlling/managing/monitoring IoT systems
– System design methodologies for IoT systems
– Control interfaces in IoT systems
– Software platforms for managing IoT systems
– Cyber-security in IoT systems
– Validation of large-scale IoT systems control
– Data latency and real-time Big Data analytics
– Sensor networks for smart automation
– Networks of robots

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– IoT applications to automotive, manufacturing, supply chain management, transportation and logistics, energy and environment, and healthcare.

The first paper "Efficient Distributed Query Processing" by Kolcun *et al.* answers how to perform speedy distributed queries in the IoT environment. As the number of peripheral devices and sensors grow exponentially in IoT systems, so will the number of queries and message traffic. Conventional "hub and spoke" architectures of wireless sensor networks will be increasingly overwhelmed and their main detraction as a single point of failure will be increasingly highlighted. This paper presents a new distributed computing architecture that drastically reduces the messaging overhead on the network as a result of sensor queries. The performance of the architecture is compared with the state-of-the-art along practical metrics like network traffic volume and execution time. Two easy to understand examples from an oil field services application are considered to describe the response of typical queries posed to sensor networks. The performance of the platform for sparse, medium dense, and dense network topologies is considered. This paper is also easy to read and positions itself relative to related work in an easy to understand manner.

The second paper entitled "Smart Configuration of Smart Environments" by Mayer *et al.* addressed the issues related to the dynamic composition of heterogeneous services in arbitrary environments within the IoT context. It is well known that the manual composition of Web services is a time-consuming, inflexible, and error-prone operation. This paper proposes a fully automatic services composition system that allows users to graphically configure smart environments through a goal-driven approach. The proposed system enables the on-the-fly inference of service mashups, avoiding therefore a static linkage of services. The desired properties of a target environment are defined by the user through a visual interface that exploits the embedded semantic descriptions of the single services, expressed in RESTDesc and formalized in the first-order logic. Simulation results show that the proposed system is flexible, reliable, scalable, user-friendly, as well as highly customizable and autonomous.

In the third paper "Energy-Centered and QoS-Aware Services Selection for Internet of Things" Khanouche *et al.* focus on an important issue in large-scale service-oriented IoT systems: the development of efficient service selection algorithms for optimal management of energy and quality-of-service (QoS) in the context of composition of IoT services. Specifically, they propose EQSA, an energy-centered and QoS-aware services selection algorithm, which considers a preselection of services providing user-satisfying QoS levels by also reducing energy consumption. A lexicographic optimization technique is exploited for preselection, whereas the concept of relative dominance of services in the sense of Pareto is used for energy consumption reduction. The effectiveness of the proposed approach is assessed through extensive simulations. Results confirm that the EQSA has good performance in terms of selection time, relative dominance, QoS-based dominance, energy consumption, composition lifetime, and optimality. The algorithm also performs better than related algorithms that deal separately with QoS and energy consumption.

IoT data and system security represents a huge challenge to many IoT applications. In particular, in such IoT environment, most IoT devices are resource-constrained. Consequently, they either use the symmetric cryptography with preshared key mode or asymmetric cryptography with raw public keys mode. These modes require a preprovisioning of all expected trusted clients in individual nodes before deployment or requires out-of-band validation of raw public keys. If the number of clients that a node would communicate with varies dynamically, this would demand frequent reprovisioning of each trusted client to the individual nodes. The approach based on preprovisioning and reprovisioning of trusted keys is certainly not scalable and requires a continuous management of security policies. In the paper "S3K: Scalable Security With Symmetric Keys—DTLS Key Establishment for the Internet of Things" Raza *et al.* deal with this challenging problem. They propose a novel solution that is scalable and does not require preprovisioning or reprovisioning the individual nodes with keys for all future trusted clients. Their idea is to establish shared keys between resource servers and a trust anchor. When a client wants to establish a trust relationship with a resource server, it requests a key from a trust anchor. The trust anchor asserts a secret key or a public key of the client that can be conveyed to the resource server. Their evaluation shows that S3K is feasible in constrained environment and scalable to a large number of IoT devices.

The next security-related paper entitled "On Secure Wireless Communications for IoT Under Eavesdropper Collusion" by Zhang *et al.* studies the issue of secure wireless communications in an IoT system in the presence of eavesdropper collusion. It conducts a theoretical analysis, along with simulations, to study two scenarios. In the first one, the eavesdroppers do not collude but operate independently, while in the second one, they collude to conduct such attacks. Secrecy outage probability (SOP) is proposed as a metric to evaluate the security of the wireless communications. SOP is the probability of a secret message being successfully decoded by eavesdroppers. The work derives SOP for both the cases, i.e., colluding and noncolluding eavesdroppers. It argues that the traditional security mechanisms, such as encryption, may be vulnerable in the future due to the increasing computing capability, e.g., quantum computing technology. Therefore, it makes a case for physical layer security, where the inherent characteristics of the physical medium can be exploited to increase the security. Such cooperative jamming techniques combined with other security methods can greatly increase security while reducing the costs typically associated with encryption.

Applications of IoT have emerged rapidly since its inception. We have collected the following four IoT application papers.

The first application paper "Enhanced Fingerprinting and Trajectory Prediction for IoT Localization in Smart Buildings" by Lin *et al.* deals with indoor location technologies by using IoT. Such technologies are critically important in enabling various services for smart indoor environments, including smart homes, smart buildings, and smart factories. One key challenge is to achieve high localization accuracy with low infrastructure investment and easy implementation. This work proposes an interesting localization approach that uses neighbor relative received signal strength (NR-RSS) to build a fingerprint database and adopts a Markov chain prediction model to assist positioning. The NR-RSS fingerprint database is used to build a radio signal map instead of absolute RSS, while the Markov chain model is applied to conduct the trajectory analysis of mobile devices. The proposed approach has been validated in a real building environment.

The second application paper entitled "Point-n-Press: An Intelligent Universal Remote Control System for Home Appliances" by Teng *et al.* presents an important application of the IoT, i.e., smart home. With the increase of the number and complexity of smart appliances and devices in a home environment, an easy-to-use remote controller becomes more and more important. This paper presents an intelligent universal remote control system called Point-n-Press for home appliances. It takes the advantage of directional infrared to enable intuitive control of a target appliance. By leveraging the state dependences of home device/appliance operations, only functional buttons that are relevant to the current context are utilized. The feasibility of the proposed approach is validated through the implementation of two prototype systems. The presented results are expected to produce lasting impact in the area of smart homes.

The recent IoT developments provide us with enormous opportunities for smart manufacturing with real-time traceability, visibility, and interoperability in production planning, execution, and control. The next work "IoT enabled Real-Time Production Performance Analysis and Exception Diagnosis Model" by Zhang *et al.* successfully constructs an IoT-based real-time production performance analysis and exception diagnosis model. Their work is motivated by the strong need to deal with any exceptions that may occur during a complex product production stage. These exceptions can aggravate the disturbances of a production system. The authors innovatively combine IoT technologies, including RFID and Bluetooth, hierarchical-timed-colored Petri net with a decision tree algorithm to achieve their goal. With their proposed model, they present a solution to monitor production performance and analyze any exceptions in real time. Their application to manufacturing shop-floor monitoring and control is well illustrated.

The last application paper "An Active RFID Tag-Enabled Locating Approach With Multipath Effect Elimination in AGV" contributed by Lu *et al.* illustrates how Auto-ID technologies like RFID is used in an automated guided vehicle (AGV) system for product warehouse and manufacturing factories. RFID technologies have received wide acceptance and applications in various industrial to achieve desired tracking, logistics tracing, and supply chain visibility. Their advantages include noncontact sensing, antidust-pollution, and multi-identification capability. Most of the RFID-enabled localization systems are based on passive tags that are limited in reading distances when implementing in real-life environments. In order to enhance the reading distances and accuracy, active RFID tags become more popular. This paper introduces an active RFID tag-enabled locating method for AGV systems used in warehouses or factories. The proposed system uses magnetic field lines for precise coverage locating based on the errors suppression positioning method. Dolph–Chebyshev antenna array is used to enable AGV with more precise location implementation. The system design and implementation are conducted. Both simulation and laboratory testing results are presented.

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MENGCHU ZHOU
New Jersey Institute of Technology
Department of Electrical and Computer Engineering
Newark, NJ 07102 USA
zhou@njit.edu

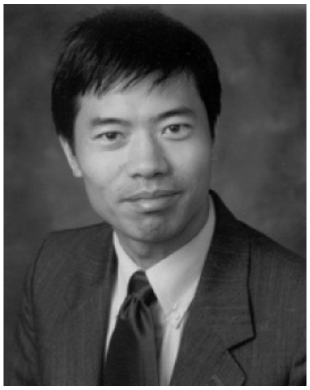
GIANCARLO FORTINO
University of Calabria
Department of Computer Engineering
87036 Arcavacata, Rende CS, Italy
g.fortino@unical.it

WEIMING SHEN
National Research Council, Canada
Ottawa, ON K1A 0R6, Canada
wshen@ieee.org

JIN MITSUGI
Keio University
Department of Environment and Information Studies
Fujisawa, Kanagawa, 252-0882, Japan
mitsugi@sfc.wide.ad.jp

JAMES JOBIN
GE Global Research
San Ramon, CA 94583 USA
jobin@ge.com

RAHUL BHATTACHARYYA
Massachusetts Institute of Technology
Auto-ID Labs
Cambridge, MA 02139 USA
rahul_b@mit.edu



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 the Rensselaer Polytechnic Institute, Troy, NY, USA, in 1990.

He joined the New Jersey Institute of Technology (NJIT), Newark, NJ, USA, in 1990, and is now a Distinguished Professor of Electrical and Computer Engineering. He has authored over 640 publications, including 12 books, 330+ journal papers (240+ in IEEE TRANSACTIONS), and 28 book chapters. His research interests are in Petri nets, Internet of Things, Big Data, Web services, manufacturing, transportation, and energy systems.

Prof. Zhou 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 and the American Association for the Advancement of Science. He is a recipient of the Humboldt Research Award for the U.S. Senior Scientists, the Franklin V. Taylor Memorial Award, and the Norbert Wiener Award from the IEEE Systems, Man and Cybernetics Society. He is the Founding Editor of the *IEEE Press Book Series on Systems Science and Engineering*.

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

He has been an Associate Professor of Computer Engineering with the Department of Informatics, Modeling, Electronics and Systems, University of Calabria, since 2006. He holds the Scientific National Italian Habilitation for Full Professor and is also an Adjunct Full Professor of Computer Engineering at 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. He is 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 Internet of Things (IoT) systems. He authored about 300 publications in journals, conferences, and books. His research interests include distributed computing, wireless sensor networks, software agents, IoT technology, and cloud computing.

Dr. Fortino is an Associate Editor of the IEEE TRANSACTIONS ON AFFECTIVE COMPUTING, the IEEE TRANSACTIONS ON HUMAN-MACHINE SYSTEMS, *Information Fusion*, *Engineering Application of Artificial Intelligence*, and the *Journal of Network and Computer Applications*. He is the Chair of the IEEE SMC Italian Chapter.

Weiming Shen (M'98–SM'02–F'13) received the Ph.D. degree from the University of Technology of Compiègne, Compiègne, France, in 1996.

He was a Lecturer at Beijing Jiaotong University, Beijing, China, from 1986 to 1992. He is currently a Senior Research Scientist with the National Research Council Canada, Ottawa, ON, Canada. He is an Adjunct Professor with the University of Western Ontario, London, ON, Canada, and Tongji University, Shanghai, China. He has been working on intelligent software agents, Internet of Things and Big Data, and their applications to different engineering domains for many years. He has published several books and over 400 papers in scientific journals and international conferences in the related areas, with 8500+ citations and has an h-index of 43.

Dr. Shen is a Fellow of the Engineering Institute of Canada, and a Registered Professional Engineer in Ontario, Canada.

Jin Mitsugi (M'05) received the B.S. degree from Nagoya University, Nagoya, Japan, and the M.S. and Ph.D. degrees from the University of Tokyo, Tokyo, Japan, all in aerospace engineering.

He joined Nippon Telegraph and Telephone Corporation, Tokyo, in 1987, where he was involved in the satellite communications system. He joined Keio University, Minato, Japan, in 2004. He is currently a Professor with the Faculty of Information and Environmental Studies. His research interests include wireless communications technology and computational mechatronics and applied wireless system, such as supply chain management, logistics system, environmental monitoring, and disaster communications.

Dr. Mitsugi is a member of the Institute of Electronics, Information and Communication Engineers (IEICE), the Japan Society of Mechanical Engineers (JSME), and ASASS.

James Jobin (M'00) received the Ph.D. degree in computer science from the University of California at Riverside, Riverside, CA, USA, in 2003, where his research focused on the systematization of the modeling and simulation of wireless networks.

He is currently a Researcher with GE Global Research, San Ramon, CA, USA, where he works on challenging technological problems in a variety of domains (energy, transportation, oil and gas, healthcare, etc.). He has experience in tackling problems from both technology and business perspectives and leading projects from a research concept stage through functional PoC prototype to final production. He has been building his own desktop computers (running Linux, of course) for 16+ years and enjoys experimenting with open source technology.

Dr. Jobin is a member of the Association for Computing Machinery (ACM), the IEEE Computer Society, the IEEE Communications Society, and the IEEE Education Society.

Rahul Bhattacharyya (M'11) received the bachelor's and master's integrated dual degree in civil engineering from the Indian Institute of Technology Bombay, Mumbai, India, in 2006, and the Ph.D. degree in systems engineering from the Massachusetts Institute of Technology (MIT), Cambridge, MA, USA, in 2012.

He is a Research Scientist with Auto-ID Labs, MIT. His research interests broadly encompass the development and integration of technologies that form the framework for the Internet of Things. He is particularly interested in low-cost, pervasive wireless sensor design using smart materials and predictive analytics for fault detection using machine-learning techniques.

Dr. Bhattacharyya is a member of the International Society for Structural Health Monitoring of Intelligent Infrastructure. He has served various roles on the Organizing Committee of the IEEE International Conference on RFID 2010–2016 and was the Technical Program Co-Chair of the Fourth International Conference on the Internet of Things.