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EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: INTELLIGENT SYSTEMS FOR THE INTERNET OF THINGS

The underlying concept of the Internet of Things (IoT) is simply to connect all devices and systems together via the Internet so that more suitable services can be provided to users. Many infrastructures, systems, and devices of the IoT have matured while some are still being developed. This is why several recent studies have claimed that IoT will dramatically change our lives. Today, we can find research topics driven by IoT technologies and can imagine that the era of smart homes and cities will be coming in the foreseeable future. The development of the IoT has reached a crossroad. One of the current research trends is to make this kind of system smarter, by using intelligent technologies to provide a much more convenient environment for humans. Among the intelligent technologies, how to handle the massive amount of data generated by the systems and devices of the IoT has been widely considered. Many other technologies, such as data mining, big data analytics, statistical and other analysis technologies, have also been used for analyzing data generated from the IoT. In addition to the analysis technologies, intelligent system technologies also provide many possibilities for the IoT because they can be used to enhance not only the performance of a system and its devices, but they can also be aware of events that have occurred.

The focus of this Special Section in IEEE Access is on intelligent technologies for the IoT and their applications. With great support from a large number of reviewers from different disciplines, different organizations, and different countries, we finally accepted 59 articles out of 130 submissions from 22 countries. The research focus of the articles in this Special Section can be divided into six categories: (1) applications of smart home, (2) applications of smart city, (3) advanced technologies for IoT infrastructure, (4) effective energy technologies for IoT environment, (5) security and privacy, and (6) survey. A brief summary of these articles is given below.

The first category is about the applications of smart homes, some of which are focused on recognizing and understanding human behavior in a home or particular region while some of which are focused on establishing the healthcare system based on IoT technologies. Using position and posture information to recognize and understand user behavior is critical in this research. For example, Li, *et al.*, in "R&P: an low-cost device-free activity recognition for e-health," used commercial passive radio frequency identification devices (RFID) to differentiate six different activities in different environments. Another example can be found in "Development of home intelligent fall detection IoT system based on feedback optical flow convolutional neural network," in which Hsieh and Jeng used convolutional neural networks (CNN) to provide an intelligent fall detection system to avoid accidents at home. These two examples show that IoT technologies will be very useful for understanding human behavior in a home. Similar applications can also be found in the following articles. In "IoT-based wireless polysomnography intelligent system for sleep monitoring," Lin, *et al.*, explain that IoT technologies can be used to monitor sleep of people in their homes. In "Who Used My Smart Object? A Flexible Approach for the Recognition of Users," Amroun and Ammi explain how IoT technologies can be used for recognition of human activities (e.g., sitting, standing, walking, and lying down) and in "Sensor network oriented human motion segmentation with motion change measurement," Liu, *et al.*, the authors explain how to understand the human motion sequence. Finally, it is explained how IoT technologies can be used to track human motion in an invited article, "Rule-based human motion tracking for rehabilitation exercises: realtime assessment, feedback, and guidance," by Zhao, *et al.* Other applications using IoT technologies further show that they have an unlimited number of possibilities. For example, in "Anomaly detection for civil aviation pilots using step-sensors," Yuan, *et al.*, use the step-sensor to avoid anomaly behavior of a pilot. In "Thing relation modeling in the Internet of Things," Li. *et al.*, use an ontology-based mechanism to formulate social attributes and analyze the role of relations. In "A weighted evidence combination approach for target identification in wireless sensor networks," Zhang, *et al.*, present a contradiction measure for body of evidence (BOE) in wireless sensor networks (WSN). In "Trajectory mining using uncertain sensor data," Muzammal, *et al.*, use uncertain sensor data and proposed dynamic programming-based algorithms to find out interesting trajectories.

Different from smart home applications, the focus of the second category is on smart city, which is used for a large number of users in a city. The studies on internet of vehicles (IoV) in this Special Section show that we can integrate

the information from sensors and appliances with intelligent methods to enhance the performance of a transportation system. For example, in ''Establishing an intelligent transport system with a network security mechanism in an Internet of vehicle environment,'' Wu and Horng present an intelligent transportation system with a network security mechanism in an IoV environment. Kato and Shinkuma, in ''Priority control in communication networks for accuracy-freshness tradeoff in realtime road-traffic information delivery,'' propose effective road-traffic information to improve the accuracy of such systems. In ''Rapid-response framework for defensive driving based on Internet of vehicles using message-oriented middleware,'' Lai, *et al*. present a framework based on internet of vehicles technologies to achieve the target of safe driving. Some interesting research can be found in ''A real-time bicycle record system of ground conditions based on Internet of Things,'' in which Zhao, *et al*., used smartphones and embedded systems to establish a bicycle record system for storing information for sport training. The applications of IoT, of course, can also be found in different environments, such as underwater sensor networks (UWSNs), ''Distributed receiver-oriented adaptive high performance multi-channel MAC for underwater sensor networks,'' by Feng, *et al*., or online social network (OSNs) in ''Balancing user profile and social network structure for anchor link inferring across multiple online social networks,'' by Ma, *et al.* According to our observations, more studies are attempting to integrate IoT devices, web, hypermedia, and machine learning to understand user behavior, in orderto provide the needed information to the user. In ''Tianji: implementation of an efficient tracking engine in mobile Internet era,'' Chen, *et al*., present a web service tracking engine to provide relevant information for the user on mobile Internet environment. Martins, *et al*., in ''Hypermedia APIs for the web of things,'' compare six hypermedia application programming interfaces (APIs) to explain critical things for creating efficient hypermedia-enriched APIs and their relationships with physical things. In ''Mining Efficient taxi operation strategies from large scale geo-location data,'' Rong, *et al*., present an effective system by using geo-location data to guide taxi drivers to passenger hotspots with the right timing. Anjomshoa, *et al*., in ''Social behaviometrics for personalized devices in the Internet of Things era,'' present an intelligent system to improve the security of mobile smart devices by using behavior patterns of users on social network applications. Also, in ''A semi-automatic numerical algorithm for turing patterns formation in a reaction-diffusion model,'' Campagna, *et al*., present semi-automatic numerical algorithm for IoT environments. In ''Practical incentive mechanisms for IoT-based mobile crowdsening systems,'' Duan, *et al*., present online and online incentive mechanisms for IoT-based mobile crowdsensing systems.

As for the advanced technologies for IoT infrastructure, the articles in this category are typically aimed at providing more efficient or effective methods to enhance the performance of an IoT environment. These methods contain: (1) a general evaluation framework for mobile peer-to-peer (MP2P) systems, in ''Multi-reciprocity policies co-evolution based incentive evaluating framework for mobile P2P systems,'' by Lu, *et al*., (2) an intelligent planning algorithm to provide an efficient authorization decision in a manufacturing internet of things (MIoT) in ''An access control model for resource sharing based on the role-based access control intended for multi-domain manufacturing Internet of Things,'' by Liu, *et al*., (3) a distributed time-division multiple-access (TDMA) slot scheduling algorithm in ''A distributed tdma scheduling algorithm based on energy-topology factor in Internet of Things,'' by Li, *et al*., (4) a multi-attribute decision fusion model based on intuitionistic fuzzy set for the monitoring target in ''Multiple attributes decision fusion for wireless sensor networks based on intuitionistic fuzzy set,'' by Zhang, *et al*., (5) a network mobility supporting scheme based on a novel Locator/ID separation architecture in ''Network mobility in a locator/id separation context,'' by Yan, *et al*., (6) a parallel mosaicking algorithm based on Apache Spark as presented in ''A model of parallel mosaicking for massive remote sensing images based on spark,'' by Jing, *et al*., and (7) using genetic algorithms for service-oriented virtual machine (VM) placement strategy in cloud data center and IoT platform in ''Service oriented cloud VM placement strategy for Internet of Things,'' by Chen, *et al*. Moreover, different resource allocation problems for an IoT environment have attracted the attention of researchers in recent years. How to provide an efficient method to solve these problems has become a critical research issue in some IoT studies. For example, in ''Soft-GORA: soft constrained globally optimal resource allocation for critical links in IoT backhaul communication,'' Iqbal, *et al*., presented a backtracking search algorithm for solving the resource allocation problem of IoT backhaul communication. In ''distributed large-scale co-simulation for IoT-aided smart grid control,'' Li, *et al*., presented a co-simulator, which is useful for scheduling the jobs of electrical appliances of IoT. Han, *et al*., in ''An effective multi-objective optimization algorithm for spectrum allocations in the cognitive-radio-based Internet of Things,'' also focus on the allocation problem. They use the non-dominated sorting genetic algorithm II (NSGA-II) to solve the multiobjective spectrum allocation problem of IoT. In ''Fast discrepancy identification for RFID-enabled IoT networks,'' Gu presents two discrepant tag identification protocols to enhance the performance of IoT environments. Zhao, *et al*., in ''Interference graph based channel assignment algorithm for D2D cellular networks,'' present a novel channel assignment algorithm to provide ways to improvecommunication for device-to-device (D2D) environments. In ''Efficient and agile carrier sense multiple access in capillary machine-to-machine communication networks,'' Ashrafuzzaman and Fapojuwo present an intelligent collision avoidance mechanism to enhance the performance of machine-to-machine communication networks. A smart High-Speed Backbone Path (HSBP) construction approach in ''A smart high-speed backbone path construction approach

for energy and delay optimization in WSN,'' is presented by Liu, *et al*., to improve network performance of WSN.

Some articles also aimed at enhancing the performance of IoT; the focus, however, is on prolonging the lifetime of IoT devices or reducing the power consumption of IoT environment. As a consequence, we put them in a separate category to explain that the focus is on providing effective energy technologies for IoT environment. How to develop an effective mechanism to reduce the energy consumption is one of the main research directions. The mechanisms are: (1) how to fill sensing holes in ''A mechanism filling sensing holes for detecting the boundary of continuous objects in hybrid sparse wireless sensor networks,'' by Xiang, *et al*., (2) how to identify energy holes in ''Identifying energy holes in randomly deployed hierarchical wireless sensor networks,'' by Naureen, *et al*., and (3) how to balance energy with concerns about the coverage of sensors in ''Energy balance-based steerable arguments coverage method in WSNs,'' by Wei, *et al*., lifetime of sensors in ''Balanced energy consumption based adaptive routing for IoT enabling underwater WSNs,'' by Javaid, *et al*., and data transmission in ''Energy-balanced transmission with accurate distances for strip-based wireless sensor networks,'' by Xin and Liu. Li, et al. explore effective IoT-based energy management systems by using a fuzzy comprehensive evaluation method in ''Fuzzy comprehensive evaluation method for energy management systems based on an Internet of Things.'' Kazmi, *et al*., explore metaheuristic algorithms in ''Towards optimization of metaheuristic algorithms for IoT enabled smart homes targeting balanced demand and supply of energy.'' Some other studies present an energy-efficient way to transmit data between devices of IoT that consider the routing protocol; for example, in ''An efficient centroid-based routing protocol for energy management in WSN-assisted IoT,'' by Shen, *et al*. In in ''Energy-efficient optimization for concurrent compositions of WSN services,'' Zhou, *et al*., explain candidate WSN services selection. Zhang, et al. explore the lifetime of sensors in ''System-level energy balance for maximizing network lifetime in WSNs.''

Since security and privacy issues have attracted the attention of researchers, companies, organizations, and governments, several articles in this Special Section are focused on providing better mechanisms for security and privacy of IoT environments. Huang, *et al*., in ''Secure data access control with ciphertext update and computation outsourcing in fog computing for Internet of Things,'' presented a secure and fine-grained data access control scheme with ciphertext update and computation outsourcing in fog computing for IoT. Another interesting example can be found in our second invited article, ''BIDaaS: blockchain based ID as a service,'' in which Lee used a blockchain-based ID as a service (BIDaaS) and explained how the proposed BIDaaS works as an identity and authentication management infrastructure for mobile users. Moreover, several technologies that are used for these studies for security and privacy issues of IoT environments are: semantic ontology in ''Network security situation awareness based on semantic ontology and user-defined rules for Internet of Things,'' by Xu, *et al.,* blockchain in ''A software defined fog node based distributed blockchain cloud architecture for IoT,'' by Sharma, *et al*., game theoretic methodology in ''Intelligent gaming for mobile crowd-sensing participants to acquire trustworthy big data in the Internet of Things,'' by Pouryazdan, *et al*., fault-tolerant mechanism in ''Secure and fault-tolerant distributed location management for intelligent 5g wireless networks,'' by Munir, *et al*., dynamic game model-based secure collaborative spectrum sensing strategy in ''A secure collaborative spectrum sensing strategy in cyber-physical systems,'' by Hui, *et al*., common database forensic investigation processes in ''CDBFIP: common database forensic investigation processes for Internet of Things,'' by Al-Dhaqm, *et al*., decentralized, semantics-based service discovery in ''A decentralized trustworthy context and qos-aware service discovery framework for the Internet of Things,'' by Li, *et al*., and anonymous credential systems in ''Integration of anonymous credential systems in IoT constrained environments,'' by Canovas Sanchez, *et al*.

The last category is the survey article, which attempt to provide a brief review for the IoT on a particular research issue. In ''Security and privacy in fog computing: challenges,'' Mukherjee, *et al*., provide an overview of existing security and privacy concerns for fog computing. In ''Internet of Things for disaster management: state-of-the-art and prospects,'' Ray, *et al*., provide a brief survey of existing approaches to relevant issues with disasters, such as early warning, notification, and data analytics. In ''Routing protocols based on ant colony optimization in wireless sensor networks: a survey,'' Liu provides a brief review on ant colony optimization based routing protocols for WSNs.

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