THE INTERNET of Things (IoT) provides enormous connections of devices and sensors with different applications. It is an enabling technology for smart city, intelligent transportation systems, environmental monitoring, security surveillance, smart homes, satellite and space information network, ocean monitoring, and unmanned border awareness systems, just to name a few. IoT as a high-density network will take the burden of massive data generated by different kinds of terminals and sensors. Dramatic growth in IoT has created a shortage in the available radio spectrum. Wireless communications services in IoT such as cellular phones, tablets, and wireless Internet access have to compete with existing users in radar, government and military communications, environmental monitoring, and other IoT applications. The strategy to increase the efficiency of spectrum sharing among the enormous users in IoT. Besides, the IoT applications demand more and better functionality and performance from new electronic devices; these demands translate into greater energy consumption demands. The gap between energy storage and demand continues to grow and the battery technologies for energy storage are not expected to increase tremendously in the coming years. Furthermore, reducing signal transmission power can lessen interference among devices in IoT. Energy-efficient protocols and network architectures will further reduce the number of transmissions and extend the battery life of IoT devices (IoTDs). Therefore, it is essential to pursue fundamental research on new components, techniques, and architectures to achieve energy-efficient sensing, communications, and networking in a shared spectrum environment for IoT.

The response to our Call for Papers on this special issue was overwhelming, with 110 articles 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 or three rounds of review process. Thanks to the great support from the Editor-in-Chief of IEEE INTERNET OF THINGS JOURNAL, Dr. Xuemin (Sherman) Shen, we were able to accept 31 excellent articles covering various aspects of spectrum and energy efficient communications for IoT.

IoT has been recognized as the next technological revolution. It faces two challenges: 1) how to achieve energy efficient communication for battery-constrained devices, and 2) how to connect a very large number of devices to the Internet with low latency, high efficiency, and high reliability. To address these problems, the article “EPKF: Energy Efficient Communication Schemes Based on Kalman Filter for IoT” proposes two methods based on Kalman filter, termed as extensions of predicable Kalman filter (EPKF). They locally reduce the unnecessary transmission (access) of end devices to the network (Internet) utilizing the spatial and temporal correlations with low algorithmic overhead.

The performance of a vehicle detection system is often affected by both internal and external noise. In the article “Research on Multiple Sensors Vehicle Detection With EMD-Based Denoising” a novel vehicle detection scheme called vehicle detector based on EMD-HT and multichannel GLRT (V-EHMG) is proposed, which is composed of a signal denoising part based on empirical mode decompositon (EMD) and a signal detection part that takes advantage of the spatial–temporal relationship acquired by multiple sensors.

The expected influx of IoT in 5G will provide new opportunities for uplink traffic offloading. In general, base stations with proximity require lower transmission power of the IoTD, thus saving energy consumption as spectral efficiency (SE) of the transmissions increase. By letting IoTDs send to base stations with better link conditions, the IoTDs’ battery lifetime is prolonged. The article “Distributed Uplink Offloading for IoT in 5G Heterogeneous Networks Under Private Information Constraints” presents a many-to-many offloading scheme for uplink traffic. The scheme works when link conditions are private information and gives incentives to all involved players to participate.

Massive device connectivity is a crucial communication challenge for IoT networks, which consist of a large number of devices with sporadic traffic. In each coherence block, the serving base station needs to identify the active devices and estimate their channel state information for effective communication. By exploiting the sparsity pattern of data transmission, the article “Joint Activity Detection and Channel Estimation for IoT Networks: Phase Transition and Computation-Estimation Tradeoff” develops a structured group sparsity estimation method to simultaneously detect the active devices and estimate the corresponding channels. This method significantly reduces the signature sequence length while supporting massive IoT access.

Many future wireless sensor networks (WSNs) will feature very high node density and low data rates per node as well as the desire for low latency and high network dependability. Existing medium access control (MAC) layer
protocols, namely IEEE 802.15.4, may not be suitable for these networks due to their reliance on carrier sense multiple access with collision avoidance (CSMA-CA) contention processing. A modified IEEE 802.15.4 MAC protocol that supports a receiver-assigned code division multiple access (RA-CDMA) contention mechanism is modeled in the article “Network Scalability Comparison of IEEE 802.15.4 and Receiver-Assigned CDMA.” It focuses on a comparison of the contention mechanisms and the network scalability of IEEE 802.15.4 nonbeacon enabled mode and RA-CDMA, along with a MATLAB simulation framework used for end-to-end simulations of the protocols.

Broadband power line communication (BPLC) and television white space (TVWS) are regarded as promising candidates for indoor broadband applications of the IoT. However, they share access to the very-high frequency (VHF) band, which could cause harmful interference and performance degradation to each other. In the article “TV White Space Regulated Broadband Power Line Communication for Point-to-Multipoint Downlink IoT Networks: A Standard Perspective,” a TVWS regulated BPLC system is proposed for point-to-multipoint downlink communication, which integrates the requirement of primary user sensing and the permissible transmission power spectral density (PSD) for TVWS users into the BPLC standard, regarding VHF band access.

Military surveillance events and rescue activities are vital missions for the IoT. To this end, foliage penetration for human detection plays an important role. However, although the feasibility of that mission has been validated, we observe that it still cannot perform promisingly under severe weather conditions, such as rainy, foggy, and snowy days. Therefore, in the article “Cost-Effective Foliage Penetration Human Detection Under Severe Weather Conditions Based on Auto-Encoder/Decoder Neural Network” experiments are conducted under severe weather conditions based on a proposed deep learning approach.

Wireless body area networks (WBANs) that offer various medical applications have received considerable attention in recent years. Due to limited energy of sensors, duty-cycling technique is employed to prolong the network lifetime. However, it results in long delivery delay and suffers from reliability issues. The article “Energy-Efficient Sleep Scheduling in WBANs: From the Perspective of Minimum Dominating Set” introduces an efficient and reliable sleep scheduling scheme from the perspective of constructing an $m$-fold dominating set (DS), where $m$ is the number of links from a node outside DS to those in DS.

The article “Effective Energy Detection for IoT Systems Against Noise Uncertainty at Low SNR” deals with spectrum sensing for cognitive radio (CR)-based IoT systems and their coexistence with long-term evolution (LTE) systems. Due to the sparsity of the covariance matrix of IoT/LTE signals, it is revealed that the likelihood ratio test approximates to energy detection (ED) at low signal-to-noise ratio. However, the noise (power) uncertainty can degrade the performance of ED severely, especially when low-cost IoTDs are employed for spectrum sensing.

The isochronous channel is a new feature of the next version of Bluetooth 5.0 and has been developed to enable audio transmission using Bluetooth low energy (LE). This feature will include a scheme for audio broadcasting in public areas and in homes and office environments. However, this paper has only employed an $n$-repetition scheme for the broadcast method. In the article “Broadcast Audio Transmission for Bluetooth LE on an Interfered ISM Band,” an ED-based broadcast scheme is proposed using an appropriate analysis model based on a stochastic method to find the optimal retransmission number, where heterogeneous Wi-Fi communications coexist on the same 2.4-GHz band.

To enable ultrareliable low-latency wireless communications required in the industrial IoT, the article “Energy-Efficient and Low-Latency Massive SIMO Using Noncoherent ML Detection for Industrial IoT Communications” develops an energy-based modulation [i.e., non-negative pulse amplitude modulation (PAM)] constellation design framework for noncoherent detection in massive single-input–multiple-output (SIMO) systems.

IoT involves trillions of devices to collect information data and exchange data with one another, which could congest the IoT networks. Orbital-angular-momentum (OAM) multiplexing optical wireless communications (OWCs) enable to provide ultralong capacity, high-speed, low-latency, low-energy consumption, and secure and reliable communications, thus being one of the most promising wireless access techniques for the deployment of IoT networks. However, the imperfect alignment of free-space optics systems and air channel conditions pose formidable challenges to the OWC. Crosstalk among the parallel OAM mode channels will be induced. The article “Orbital-Angular-Momentum Multiplexing Optical Wireless Communications With Adaptive Modes Adjustment in Internet-of-Things Networks” presents an adaptive modes adjustment scheme to mitigate the deleterious impacts.

The performance of a UAV is determined by the performance of both its sensing and transmission processes, which are influenced by the trajectory of the UAV. However, it is challenging for UAVs to design their trajectories efficiently, since they work in a dynamic environment. To tackle this challenge, the article “Reinforcement Learning for Decentralized Trajectory Design in Cellular UAV Networks With Sense-and-Send Protocol” adopts the reinforcement learning framework to solve the UAV trajectory design problem in a decentralized manner. To coordinate multiple UAVs performing real-time sensing tasks, the authors propose a sense-and-send protocol, and analyze the probability for successful valid data transmission using nested Markov chains.

Future IoT should contain a space segment and a terrestrial segment. In addition, multibeam satellite communication systems, especially working in S shared band, have gained more attention, and play a significant role in providing direct-to-user satellite mobile services. Due to the limited on-board resources, it is increasingly urgent to improve resource utilization. Taking the interbeam interference, channel conditions, delay factor, capacity, and bandwidth utilization variance into consideration, a novel joint resource allocation algorithm is proposed in the article “Interbeam Interference Constrained...

In future IoT networks, sensors or even access points can be mounted on ground/aerial vehicles for smart-city surveillance or environment monitoring. A technique called over-the-air-computation (AirComp) was recently developed which enables a data-fusion to receive a desired function of sensing data from concurrent transmissions by exploiting the superposition property of a multiaccess channel. The article “MIMO Over-the-Air Computation for High-Mobility Multimodal Sensing” aims at further developing AirComp for next-generation multiantenna multimodal sensor networks. Specifically, it designs beamforming and channel-feedback techniques for multifunction AirComp.

The massive usage of IoT devices in various smart applications results in spectrum scarcity issues. In order to enhance the dynamic spectrum capability, the CR network (CRN) is considered as a key technology to address the spectrum scarcity problem. However, the establishment of a common communication channel in CRN by considering the unlicensed heterogeneous devices in an asynchronous environment is a challenging problem. In the article “Spectrum Allocation With Guaranteed Rendezvous in Asynchronous Cognitive Radio Networks for Internet of Things,” a novel asymmetric asynchronous channel hopping (AACH) mechanism is designed, where secondary users have different sets of available channels and can enter into the network without any global clock synchronization.

With the rapid development of Internet of Vehicles (IoV), more available resources and energy-efficient optimizations in resources scheduling are required for large-scale network implementation for sustainable development. In the article “Parked Vehicular Computing for Energy-Efficient Internet of Vehicles: A Contract Theoretic Approach,” it is observed that parked vehicles (PVs) have rich and underutilized resources for task execution. By scheduling them as general computing nodes to undertake computation tasks, a new computing paradigm is introduced, named parked vehicular computing (PVC).

Due to their wide application range and attractive features, WBANs are considered as a revolutionary technology which is envisaged to change how people manage and think about their health and their lifestyles. In the article “A Self-Organized Dynamic Clustering Method and Its Multiple Access Mechanism for Multiple WBANs,” a self-organized dynamic clustering (SDC) method and its multiple access mechanism to mitigate the interference and improve the QoS in multiple WBANs environment is proposed.

Compared with conventional narrowband radar, ultrawideband (UWB) radar has strong anti-interference performance, low-frequency and wide-frequency characteristics, a good penetrating ability, a high-resolution range, and good target-recognition ability. The article “Classification of Data Stream in Sensor Network With Small Samples” proposes an adaptive incremental recursive least-squares regression parameter estimation method based on an adaptive variable sliding window, which performs Gaussian function fitting on the data streams and adapts to the mean square error and self-adaptation variable sliding window threshold comparison to adaptively block dynamic data streams.

The sensing application of space surveillance has put forward challenges to the IoT. However, current moving algorithms in IoT rarely aim for target surveillance. In view of energy efficiency for multimodal signals in IoT, the article “Collaborative Energy-Efficient Moving in Internet of Things: Genetic Fuzzy Tree Versus Neural Networks” mainly investigates three typical target trajectories: 1) line; 2) square; and 3) circle. On a basis of target learning, two types of collaborative sensor movement algorithms are proposed and compared. One approach is based on genetic fuzzy tree (GFT) and the other is based on the neural network (NN).

Recently, visual IoT (VIoT) has become a fast-growing field based on various applications. The article “Hybrid Cross Deep Network for Domain Adaptation and Energy Saving in Visual Internet of Things” focuses on two critical challenges for applications in VIoT, i.e., domain adaptation and energy saving. The images captured by various visual sensors in VIoT appear quite different due to changes in visual sensor locations, visual sensor settings, and image resolutions and illuminations.

The IoT has gradually changed the way of peoples’ lives due to its ability of connecting everything together, and meanwhile accurate location sensing plays a crucial role in achieving this goal. Up to now, as one of the most representative outdoor localization systems, the global positioning system (GPS) has been widely used, but its performance may be dramatically declined in indoor environments due to the serious multipath effect and signal attenuation caused by the complicated indoor structure. The article, “Calibrated Data Simplification for Energy-Efficient Location Sensing in Internet of Things” proposes to use an information-theoretic lens to construct the energy-efficient location fingerprint database for localization in IoT.

The machine-to-machine (M2M) communications, which achieve the implementation of IoT, can be carried over wireless cellular networks. The article “Learning Automata-Based Access Class Barring Scheme for Massive Random Access in Machine-to-Machine Communications” studies the massive access problem in M2M traffic-centered scenarios where M2M and H2H traffic can apply for all available preambles without distinction. Utilizing the self-adaptive learning property of learning automata, it further proposes a novel learning automata-based ACB scheme (LA-ACB).

Phase-sensitive optical time-domain reflectometry (Φ-OTDR), which utilizes the phase information of Rayleigh scattered lightwaves inside optical fiber, could turn a fiber cable into a massive sensor array for distributed acoustic sensing (DAS), i.e., an emerging infrastructure for IoT. Given a certain fiber length, there are tradeoffs among the sensing bandwidth, the sensitivity, and the spatial resolution. In the article “Distributed Acoustic Sensing Based on Pulse-Coding Phase-Sensitive OTDR,” the concept of linearization and Golay pulse-coding for heterodyne Φ-OTDR is proposed and experimentally verified for the first time.

Efficient processing of large-scale multimodal sensor data is a key issue for applying the IoT. Accurate cloud classification
is critical for weather and climate monitoring which are parts of IoT applications. The article “Multimodal GAN for Energy Efficiency and Cloud Classification in Internet of Things” proposes a novel generative deep model named multimodal generative adversarial network (Multimodal GAN) to improve both the energy efficiency and the cloud classification accuracy in IoT. The proposed Multimodal GAN is composed of a discriminator and a generator, each of which is devised to a two-stream network.

In order to overcome the shortcomings of orthogonal frequency division multiplexing (OFDM) and prolong the battery life of devices in the IoT, a joint subcarrier and subsymbol allocation-based Simultaneous Wireless Information and Power Transfer (SWIPT) scheme for multiuser generalized frequency division multiplexing (GFDM) system is proposed in the article “Joint Subcarrier and Subsymbol Allocation-Based Simultaneous Wireless Information and Power Transfer for Multiuser GFDM in IoT.”

Recent advances of deep learning have produced encouraging results comparable to and in some cases superior to human experts. However, the large amount of data input has been a daunting task for deep learning to be widely applied in IoT with real-time processing. The article “Smart and Fast Data Processing for Deep Learning in Internet of Things: Less Is More” proposes to apply SVD-QR algorithm to preprocessing of deep learning for large-scale data input. For the mass data input, it applies limited memory subspace optimization for SVD (LMSVD)-QR algorithm to increase the data processing speed.

IoT is facing a shortage of spectrum resources due to the rapid growth of IoT terminals and big data services. Fifth generation (5G) network owns sufficient spectrum resources and supplies large data volume business, which can help to expand the communication resources of the IoT by combining IoT with 5G network. In the article “Rate and Energy Efficiency Improvements for 5G-Based IoT With Simultaneous Transfer,” a 5G-based IoT is designed to transfer both 5G and IoT information simultaneously.

In the 5G mobile networks, GFDM is expected as the candidate waveform which can flexibly meet the requirements of diverse applications and scenarios for the IoT because of its advantages over OFDM. In order to achieve reliable data transmission in GFDM-based IoT systems, channel estimation is a prerequisite. However, the 2-D block modulation and the nonorthogonality between subcarriers for GFDM make it almost impossible that the conventional channel estimation methods suitable for OFDM are directly applied to GFDM. To cope with this problem, a soft decision control strategy-based iterative channel estimation (SDC-ICE) method is proposed in the article “Soft Decision Control Iterative Channel Estimation for the Internet of Things in 5G Networks.”

IoT as an essential integrated part of the future wireless communication system provides ubiquitous connectivity and information exchange to enable a range of applications and services, which has triggered spectrum resource pressure, multiple access, bandwidth efficiency, and security issues. Focusing on these issues, a high SE secure access (HSESA) scheme based on dual nonorthogonal is proposed first in the article “High Spectral Efficiency Secure Communications With Nonorthogonal Physical and Multiple Access Layers.”

The shortage of spectrum resources has limited the development of IoT. 5G network can flexibly support a variety of devices and services, which makes it possible to combine 5G with IoT. In the article “A Novel Multichannel Internet of Things Based on Dynamic Spectrum Sharing in 5G Communication,” a novel multichannel IoT is proposed to dynamically share the spectrum with 5G communication, where an IoT node, including transmitter and receiver, is designed to perform 5G communication and IoT communication simultaneously.

The Guest Editors express our gratitude to the authors for their excellent contributions to this special issue. We are also grateful for all the reviewers dedicating their efforts in reviewing these papers, and for their valuable comments and suggestions that significantly improved the quality of the articles. We hope that this special issue will serve as a good reference for researchers, scientists, engineers, and academicians in the field of spectrum and energy-efficient communications for IoT.

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