Guest Editorial 5G and Beyond Mobile Technologies and Applications for Industrial IoT (IIoT)

Summaries of Accepted Papers

FOLLOWING the tremendous success of 2G and 3G mobile networks and the fast growth of 4G, the next generation mobile networks (5G) was proposed aiming to provide infinite networking capability to mobile users. Differentiated from 4G, a benefit offered by 5G is much more than the increased maximum throughput. It aims to involve and benefit from many current technical advances including industrial Internet of Things (IIoT). As the IIoT integrates many heterogeneous networks, such as wireless sensor networks, wireless local area networks, mobile communication networks (3G/4G/LTE/5G), wireless mesh networks, and wearable health care systems, it is critical to design self-organizing and smart protocols for heterogeneous ad hoc networks in various IoT applications, such as cyber-physical systems, cloud computing for heterogeneous ad hoc networks, large-scale sensor networks, data acquisition from distributed smart devices, green communication and applications, environmental monitoring and control. Moreover, based on the survey conducted by the World Health Organization, the world will lack 12.9 million healthcare workers by 2035. Hence, it is important to develop wearable healthcare systems to perform self-health monitoring. In general, wearable healthcare systems demand low power consumption and high measurement accuracy. Smart technologies including green electronics, green radios, fuzzy neural approaches, and intelligent signal processing techniques play important roles in the developments of the wearable healthcare systems. Therefore, this special issue provides a forum to discuss the recent advances on 5G and beyond mobile technologies and applications for IIoT.

This special issue of the IEEE TRANSACTION ON INDUSTRIAL INFORMATICS includes different aspects of 5th generation/beyond 5th generation (5G/B5G) technologies for the industrial Internet of Things (IIoT) [1]–[8]. This issue intends to bring together all mobile stakeholders, academic, and industry, to identify and promote technical challenges and recent results related to 5G/B5G IIoT. This theme reflected in the large number of papers (37 papers were submitted, out of which we have selected the top 14 research articles).

In the first article, "Smartphone-Powered Electrochemical" by Guo, the author presents a medical dongle powered by the Smartphone as a miniaturized electrochemical analyzer for blood glucose and uric acid monitoring. The family doctor can access the related biomedical information of his patient and give the precise, personalized, and preventive health care consults. In addition, the accuracy and reliability of the proposed system were verified with the good agreement as compared to the bulky biochemical analyzer in clinical use.

In the second article, "Dynamic Compressive Wide-Band Spectrum Sensing Based on Channel Energy Reconstruction in the Cognitive Internet of Things" by Li *et al.*, the authors propose a novel dynamic compressive wide-band spectrum sensing method based on channel energy reconstruction.

In the third article, "Joint Subcarrier and Power Allocation in the Energy-Harvesting-Aided device to device communication (D2D) Communication" by Saleem *et al.*, the authors investigate resource allocation for the energy-harvesting-aided D2D communication underlying cellular network. The authors formulate a joint subcarrier assignment and power allocation problem for multiple cellular and energy harvesting direct D2D links to maximize the overall sum rate subject to the quality of service, subcarrier reuse, power, and energy harvesting constraints.

In the fourth article, "Energy-Efficient Resource Allocation for Industrial Cyber-Physical IoT Systems in 5G Era" by Li *et al.*, the authors propose a communication framework based on 5G to support the deployment of cyber-physical internet of things system (CPIoTS) with a central controller. Based on this framework, multiple sensors and actuators can establish communication links with the central controller in full-duplex mode.

In the fifth article, "SDN-Enabled Multiattribute-Based Secure Communication for Smart Grid in an IIoT Environment" by Chaudhary *et al.*, a software-defined network (SDN) enabled multiattribute secure communication model for an IIoT environment is designed. The proposed scheme works in three phases: 1) an SDN-IIoT communication model is designed using a cuckoo-filter based fast-forwarding scheme; 2) an attribute-based encryption scheme is presented for secure data communication; and 3) a peer entity authentication scheme using a third party authenticator, Kerberos.

In the sixth article, "Massive MIMO for Industrial Internet of Things in Cyber-Physical Systems" by Lee *et al.*, the authors investigate the feasibility of utilizing massive multiple-input-multiple-output (MIMO) as such a wireless technology. The authors analyze the performance of a massive MIMO base station deployed at a data center to provide massive connectivity to a large number of devices. In addition, they discuss the related research challenges for deploying massive MIMO in industrial

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Internet applications of cyber-physical systems (CPS), such as device scheduling and power control, energy-efficient design and radio frequency energy transfer/harvesting, signaling techniques for drones and mobile robots, and the applications of the underwater industrial Internet.

In the seventh article, "Coalition Formation Game Based Access Point Selection for long term evaluation in unlicensed band (LTE-U) and Wi-Fi Coexistence" by Zhang *et al.*, the authors emulate the coexistence of the LTE-U networks and Wi-Fi networks, and experimentally evaluate their mutual interference relying on deploying time division duplex based OpenWrt wireless routers. Moreover, an LTE-U and Wi-Fi coexistence mechanism are proposed, where users with diverse traffic demands are capable of accessing either the public LTE-U network or its nearby Wi-Fi network.

In the eighth article, "Optimized Cooperative Multiple Access in Industrial Cognitive Networks" by Li *et al.*, the authors find both analytical solutions as well as solutions based on experiments through the time-sharing strategy between the primary and secondary system and the transmit power allocation strategy at the secondary transmitter. The authors show the performance improvements of exploiting analog network coding and the impacts of cooperative schemes and user geometry on achievable rates and resource sharing strategies.

In the ninth article, "A Console GRID Leveraged Authentication and Key Agreement Mechanism for LTE/SAE" by Arul *et al.*, the authors propose a public key cryptosystem named "International mobile subscriber identity protected console grid-based authentication and key agreement protocol" to address the vulnerabilities related to weak key management.

In the tenth article, "5G Enabled Codesign of Energy-Efficient Transmission and Estimation for Industrial IoT Systems" by Lyu *et al.*, the authors propose a hierarchical transmission-estimation approach to improve the transmission reliability and estimation accuracy according to system dynamics. The proposed approach is then optimized by formulating a constrained minimization problem, which is mixed integer nonlinear programming and solved efficiently with a block-coordinate-descent-based decomposition method.

In the eleventh article, "Energy-Efficient Industrial Internet of UAVs for Power Line Inspection in Smart Grid" by Zhou *et al.*, the authors investigate how to apply industrial internet of thing for unmanned aerial vehicles (IIoUAVs) for power line inspection in the smart grid from an energy-efficiency perspective. First, the energy consumption minimization problem is formulated as a joint optimization problem, which involves both the large-timescale optimization, such as trajectory scheduling, velocity control, and frequency regulation, and the small-timescale optimization, such as relay selection and power allocation. Then, the original non-deterministic polynomial (NP)-hard problem is transformed into a two-stage suboptimal problem by exploring the timescale difference and the energy magnitude difference between the large-timescale and the small-timescale optimizations and is solved by combining dynamic programming, auction theory, and matching theory. Finally, the proposed algorithm is verified based on the real-world map and realistic power grid topology.

In the twelfth article, "Space-Reserved Cooperative Caching in 5G Heterogeneous Networks for Industrial IoT" by Duan *et al.*, the authors propose an algorithm to obtain the optimal proportion between the two parts of the cache space for the purpose of reducing the average energy consumption.

In the thirteenth article, "An named data networking (NDN) IoT Content Distribution Model With Network Coding Enhanced Forwarding Strategy for 5G" by Lei *et al.*, the authors design a probability-based multipath forwarding strategy for network coding to make full use of its potential. To quantify performance benefits of applying network coding in 5G NDN, this paper also integrates network coding into an NDN streaming media system implemented in the NS-3 based named data networking simulator (ndnSIM) simulator.

In the last article, "Context-Sensitive Access in Industrial Internet of Things (IIoT) Healthcare Applications" by Fadi *et al.*, the authors propose a context-sensitive seamless identity provisioning (CSIP) framework for the IIoT. The CSIP proposes a secure mutual authentication approach using hash and global assertion value to prove that the proposed mechanism can achieve the major security goals of the wireless medical sensor networks (WMSN) in a short time period.

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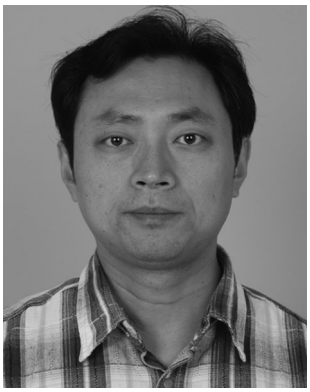

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