Editorial

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A breakthrough in multi-hop wireless multimedia sensor networking protocols

Beyond the conventional wireless sensor networks (WSNs) transmitting mainly small sensed and non-time-constrained data, the emerging hardware technologies such as complementary metal-oxide semiconductor (CMOS) cameras and microphones have fostered the development of wireless multimedia sensor networks (WMSNs), that is, networks of wirelessly interconnected heterogeneous devices that are able to ubiquitously retrieve multimedia content such as video and audio streams, still images, and scalar sensor data from the environment. Because of such enhanced capabilities, WMSN has been considered as an essential new technology with great potential for strengthening the traditional WSN applications, as well as creating new multimedia-data-oriented applications such as multi-camera surveillance, visual target/location tracking, location-based multimedia services, and situation/context awareness. Furthermore, as tactical and mission critical environment intends to utilize more unmanned systems such as unmanned vehicles, aerial vehicles, drones, and robots, importance of reliable WMSNs is increasing. Recently, the standard activities for fifth-generation (5G) cellular communication, officially named "IMT-2020," has been actively in progress and it plans to specify various communication/networking technologies for supporting a Massive Machine Type Communication (mMTC) targeting on Internet of Things (IoT) services and ultra-reliable and low-latency communications (uRLLC) targeting multimedia communications. With the deployment of IMT-2020 which provides the majority of hardware infrastructure support for mMTC and uRLLC, WMSN has become an important supportive platform for sensing and transmission of Internet of Multimedia Things (IoMT). Many applications in IoMT benefit from WMSN technology, such as massive or wearable sensing devices.

The recent survey paper, named "Routing in wireless multimedia sensor networks: A survey and challenges ahead," shows that according to the Google, the research activities with video sensors and camera sensors are continuously increasing.

In spite of aforementioned trends heading toward for WMSN, WMSN needs lots of issues to be resolved and enhanced. The objective of this Special Issue is to answer various open issues to provide more practical feasibility on WMSN.

Due to the great effort made in publicity, we received 14 submissions from both academia and industry in the relevant fields. Following a strict review process, we accepted only five papers for this Special Issue. Each of the papers was peer-reviewed by at least two experts in the field. In the following, we provide a brief introduction to each paper.

Multimedia data are playing an increasing role in WSN applications including target tracking, environmental video/imaging surveillance, telemedicine, video vehicle detection, and battlefield intelligence, in which users have specific quality of service (QoS) requirements on bandwidth, delay, and/or packet loss. Software-defined networking (SDN) primarily moves network control functions away from traditional routers to an external software entity called the controller. This simple abstraction makes for easy optimal path detection and on-demand resource allocation through the centralized control plane, thereby offering new opportunities for addressing QoS supporting problems in WMSNs. The paper "QoS-Aware Routing Mechanism in OpenFlow-Enabled Wireless Multimedia Sensor Networks" by L Han et al. introduces SDN technology (e.g. OpenFlow-enabled wireless networking) to design QoS-aware routing mechanism for cluster-based WMSNs. In the proposed routing scheme, OpenFlow-enabled nodes (OFNs) act as cluster headers, maintain connections with neighbor OFNs, and forward packets on behalf of sensor nodes. Each OFN also detects link states among OFNs and determines flow's QoS requirements. The SDN controller then seeks the feasible paths that satisfy QoS requirements of a flow. If there is no path which satisfies the required QoS, the path will be decided by the proposed algorithms depending on the flow types, such as delay-sensitive, bandwidth-sensitive, or best-effort traffic. An SDN overlay network testbed is built with OFNs using Open vSwitch and an SDN controller using Ryu controller. A series of experiments

are conducted to compare the routing performances for multimedia data transmission. The experimental results show that the proposed routing algorithm has an overall advantage in QoS satisfaction for different types of multimedia flows.

To support multimedia traffic in WSNs, high data rates network interfaces are required. IEEE 802.11 is a popular standard which is using wide bandwidth to achieve high data rates. Mobile sensor nodes in WMSNs can be equipped with multiple network interface cards (NICs) to support multiple channels and data rates. Clearly, concurrent transmissions over multiple nonoverlapping channels can improve the capacity of WMSNs substantially. However, the number of available channels is limited in IEEE 802.11. Moreover, a node cannot use a number of channels larger than the number of equipped NICs. These facts severely decrease the number of concurrent transmissions and the capacity of WMSNs. To address this problem, the paper "Exploiting channel and interface heterogeneity for rate separating channel assignment in IEEE 802.11 wireless multimedia sensor networks" by T-S Kim et al. develops a novel channel assignment protocol, called heterogeneity-aware mesh (HMesh), to exploit channel and interface heterogeneity for rate separation in IEEE 802.11 multiradio multirate WMSNs. In HMesh, each node is equipped with multiple NICs and forms a tree architecture rooted at a sink node to deal with the traffic distribution of WMSNs. Parent nodes have higher priority than child nodes since they serve more traffic than child nodes. Each node joins a parent on the tree using the proposed channel assignment and routing metric, called heterogeneity-aware transmission time. After tree join, each node provides Internet paths to its child nodes. Once a parent receives a request from a new child node to join the tree, it runs an efficient algorithm, called heterogeneity-aware rate separating algorithm that separates different data rate links between the parent and its child nodes by exploiting the channel and interface heterogeneity. Simulation and experimental results show that HMesh can significantly improve performance compared with existing channel assignment protocols designed for WMSNs.

As mentioned above, WMSNs have been widely used for collecting and delivering multimedia content. Congestion control is a fundamental problem in WMSNs, which has been intensively studied in the literature. However, existing solutions cannot achieve network congestion control stability, that is, maximizing network throughput while at the same time maintaining network parameters stable at the optimal states.

In the paper "A Robust Congestion Control Scheme for Cluster Wireless Multimedia Sensor Networks with Propagation Delay and External Interference" authored by Xi Hu and Wei Guo, a new robust congestion control model is proposed using Lyapunov–Krasovskii functionals in Lur'e dynamical network. Global cluster synchronization with the performance of robust congestion control using the random early detection (RED) algorithm at source side is extended to realize global network re-stabilization. A weighted fair scheduling scheme is also developed to achieve network congestion control stability with consideration of propagation delay and external interference. Numerical results show the effectiveness of the proposed scheme.

Cognitive radio networks (CRNs) have emerged as a promising solution to address the spectrum shortage problem, which allow secondary users (SUs) to opportunistically access available licensed channels and thus significantly improve spectrum utilization. Recently, WMSNs have been trying to adopt CRN technologies to enhance their performances over massive IoT environments, in which networks experience lack of channel resources. However, in order for the networks to collect more accurate sensing data and perform spectrum allocation efficiently, SUs have to share their locations with untrusted entities such as fusion center, which will raise serious privacy concerns.

To protect SUs' location privacy in CRNs, the paper "Location Privacy-Preserving Channel Allocation Scheme in Cognitive Radio Networks" authored by Hongning Li, Qingqi Pei, and Wenjing Zhang proposes a new location privacy-preserving channel allocation scheme. The scheme uses hash matching for authentication without leaking identities of SUs. It also breaks the connection between SUs' location and register data in database while allocating channels with self-coexistence mechanisms. Simulation results show the efficiency of the proposed scheme in terms of location privacy protection and spectrum utility maximization.

Based on the previous researches, it has been proved that using nonregenerative untrusted relay in multi-hop networks can help achieve a higher secrecy rate than simply treating it as an eavesdropper. Therefore, the paper "Cooperative Secure Transmission in the Presence of Untrusted Relay" by D Chen et al. investigates secret levels of WMSN with nonregenerative untrusted relay networks with three different transmission strategies. The three strategies are noncooperative strategy, conventional amplify-and-forward (AF) strategy, and cooperative jamming (CJ) strategy. For the extensive evaluations for the secrecy performance achieved by the three strategies, the paper derives the closed-form expressions for the connection outage probabilities and secrecy outage probabilities for the three strategies. Based on these expressions, the reliability and security tradeoff are examined to facilitate the design of the transmitting parameters. Then, the paper also presents the closed-form expression for the effective secrecy throughput and characterizes the overall efficiency of these transmission strategies. Furthermore, the paper conducts the asymptotic analysis for the

secrecy throughput, which enables to determine the optimal transmission strategy under different environments. Analytical and numerical results in the paper demonstrate that compared with the noncooperative and AF strategies, CJ strategy shows the best performances in terms of the reliability and security tradeoff. Moreover, it has also been found that the effective secrecy throughputs of AF strategy is nearly invariable when the quality of the second hop changes.

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