EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: MISSION CRITICAL PUBLIC-SAFETY COMMUNICATIONS: ARCHITECTURES, ENABLING TECHNOLOGIES, AND FUTURE APPLICATIONS

Disaster management organizations such as fire brigades, rescue teams, and emergency medical service providers have a high priority demand to communicate with each other and with the victims by using mission-critical voice and data communications [item 1) in the Appendix]. In recent years, public safety agencies and organizations have started planning to evolve their existing land mobile radio system (LMRS) with long-term evolution (LTE)-based public safety solutions which provides broadband, ubiquitous, and mission-critical voice and data services. LTE provides high bandwidth and low latency services to the customers using internet protocol-based LTE network. Since mission critical communication services have different demands and priorities for dynamically varying situations for disaster-hit areas, the architecture and the communication technologies of the existing LTE networks need to be upgraded with a system that has the capability to respond efficiently and in a timely manner during critical situations.

The third generation partnership project (3GPP) objective is to preserve the considerable strengths of LTE while also adding features needed for public safety. Moreover, 3GPP Release 13 has recently included the Mission-critical push-to-talk (MCPTT) functionality into LTE standard. In this standard, MCPTT enables the feature of direct mode communication, an added device discovery feature which will help the users to find other users in the vicinity either by using network-assisted mode or direct-mode discovery without the assistance of network. In addition, relay capability has been added to provide services for an out-of-coverage user who needs to connect to a fixed existing network via device [item 2) in the Appendix]. The existing network may be updated by adding unmanned air vehicles (UAV) that can increase the chance of providing a link to the users in the event of no network coverage in disaster areas [item 3) in the Appendix]. Moreover, 3GPP has identified the device-to-device (D2D) communications as the key driver in the emergency situation. The main motivation of considering D2D communications for public protection, disaster relief and mission-critical situations is its capability of providing

emergency services by using network-assisted scenario or by acting as a relay to transmit information from one end to another end, similar to the ad-hoc network [item 4) in the Appendix], [item 5) in the Appendix].

This Special Section in IEEE ACCESS is intended to provide a platform for researchers and practitioners from both academia and industry in the area of mission critical public safety networks. We published 2 invited articles from highly reputed researchers working in public safety communications.

The first invited article, authored by A. El-Keyi, O. Üreten, H. Yanikomeroglu and T. Yensen, is "LTE for Public Safety Networks: Synchronization in the Presence of Jamming" which introduces an algorithm for timing synchronization, cell identity detection, and carrier frequency offset estimation for long-term evolution systems that proves robust against partial-band interference and/or jamming. The second invited article, Base Station Ordering for Emergency Call Localization in Ultra-Dense Cellular Networks, authored by H. Elsawy, W. Dai, M. Alouini and M. Z. Win, proposes the base station ordering localization technique for emergency call localization in cellular networks. Results show that reporting the order of six neighboring base stations is sufficient to localize the agent within 10% of the cell area.

In this Special Section, we also include an additional 19 high-quality articles from leading research groups around the world working on different research aspects of public safety networks.

The first contribution, co-authored by Ahmad, *et al.*, is "LTE-Railway User Priority-Based Cooperative Resource Allocation Schemes for Coexisting Public Safety and Railway Networks," addresses the issues of resource allocation and co-channel interference management for coexistence of and cooperation between the LTE-based public safety network (PS-LTE) and LTE-based high-speed railway (LTE-R) network. The next article, entitled "Multi-Cell Cooperative Outage Compensation in Cloud-RANs based 5G Public Safety Network," co-authored by Mengjun Yin *et al.*, propose an efficient multi-cell

cooperative outage compensation convergence for the scene where more than one radio remote units are destructed in C-RAN-based PS-LTE network. This scheme compensates the network using both cooperative transmission and power adjustment.

Ali Malik *et al.*, in their article entitled "Optimisation Methods for Fast Restoration of Software-Defined Networks" represent a step toward tackling these two issues in the context of single link failures. The main contribution lies in the definition of new algorithms that aim to enhance the problem of finding alternative paths in large-scale networks with minimal cost and time-to-update factors. Thearticle entitled "M3-Cast: A Novel Multicast Scheme in Multi-channel and Multi-rate WiFi Direct Networks for Public Safety," co-authored by Khan *et al.*, investigates the problem of selecting the most favorable channel and rate for a multicast communication system in the context of public safety using a WiFi direct 802.11 network. M3-Cast protocol proposed to not only choose the most favorable communication channel and transmission rate, but also considers the implementation details of the underlying WiFi direct technology, thereby optimizing the overall system performance.

An algorithm to predict user location in 5G networks by using received signal strength measurements is presented in the article co-authored by Alee Khan *et al.*, "Location Awareness in 5G Networks Using RSS Measurements for Public Safety Applications." The relative coordinates of users are computed using Isomap, then the relative coordinates of users are transformed by Procrustes analysis. Guillén-Gámez *et al.*, in their article entitled "A Proposal to Improve the Authentication Process in m-Health Environments," presented a way of authenticating the identity of each patient, doctor or any stakeholder involved in the process by using a software application that analyzes their faces through the cams integrated in their devices. The selection of an appropriate facial authentication software application requires a fair comparison between alternatives through a common database of face images.

In the article entitled "Modeling Unreliable Operation of mmWave-Based Data Sessions in Mission-Critical PPDR Services" by A. Ometov *et al.*, authors first presented the important use cases, challenges, and requirements in the context of next-generation mobile networking for PPDR applications. They also argue that many emerging services may be supported by the novel communication technology operating in millimeter-wave spectrum. The next article "QoS-Aware Frequency-Based 4G + Relative Authentication Model for Next Generation LTE and Its Dependent Public Safety Networks" co-authored by Baskaran *et al.*, proposes the 4G plus relative authentication model (4G + RAM), which is composed of Privacy-protected evolved packet system authentication and key agreement protocol for the initial authentication (PEPS-AKA) and 4G plus frequency-based re-authentication protocol for the re-authentication of known and frequent users (4G + FRP). The 4G + RAM supports seamless communication with a minimum signaling load on core elements

and conceals users' permanent identifiers to ensure user privacy.

In the article entitled "Public Safety Communications above 6 GHz: Challenges and Opportunities" by Mezzavilla *et al.*, authors briefly introduced the public safety communications services and requirements. Moreover, the potential of the frequencies above 6 GHz for public safety communications and the open problems that need to be solved in order to pave this way has been discussed. Fadi Al-Turjman *et al.*, in their article entitled "Seamless Key Agreement Framework for Mobile-Sink in IoT Based Cloud-Centric Secured Public Safety Sensor Networks" presented a strategy of mobile-sink for the extension of user authentication over cloud-based environments. A seamless secure authentication and key agreement (S-SAKA) approach using bilinear pairing and elliptic-curve cryptosystems is presented. The proposed S-SAKA approach satisfies the security properties, and as well as being resilient to node capture attacks, it also resists significant numbers of other well-known potential attacks related with data confidentiality, mutual authentication, session-key agreement, user anonymity, password guessing, and key impersonation.

The next article "A Stackelberg-Game Approach for Disaster-Recovery Communications Utilizing Cooperative D2D," co-authored by Chu *et al.*, investigates disaster-recovery communications utilizing two-cell cooperative D2D communications where they partitioned into healthy and disaster areas. User equipment in the healthy area aims to assist a user in the disaster area to recover wireless information transfer via an energy harvesting relay. The results provided a sustainable framework for disaster recovery. In the article entitled "Heterogeneous Public Safety Network Architecture Based on RAN Slicing" by Marabissi et al., authors propose a heterogeneous network communication architecture where both infrastructures and spectrum are shared between public safety and commercial operators thus reducing deployment costs and times, and addressing the main challenges of public safety communications. The shared radio access network is managed by means of network slicing and resources virtualization. Moreover, the proposed architecture is based on a three-tier scheduler that allows it to manage different network layers and different RAN slices.

Kumbhar *et al.*, in their article entitled "Exploiting LTE-Advanced HetNets and FeICIC for UAV-Assisted Public Safety Communications," design a public safety communications LTE-Advanced HetNet for various path loss models and deployment mechanism for unmanned air base stations (UABSs). This improves the system-wide spectral efficiency by applying cell range expansion to UABSs and mitigating the inter-cell interference. The next article, "Using Firefighter Mobility Traces to Understand Ad-Hoc Networks in Wildfires," co-authored by Cabrero-Barros *et al.*, investigate analyzes, and simulates the mobility traces of a fire department during 30 wildfires. The analysis shows interesting insights into the communication range and the type of network in these scenarios.

In the article entitled, ''To Smart City: Public Network Design For Emergency'' by Wan *et al.*, authors propose a system structure composed of a central agent and three layers: unmanned aerial vehicle (UAV) layer, multi-robot layer and sensor network layer. The UAVs act as moving sensors and conveyors in the air. They provide the overall rough monitoring data from the air and transport robots to the emergency occurring places. Viamonte*et al.*, in their article entitled ''A Distributed Man-Machine Dispatching Architecture for Emergency Operations Based on 3GPP Mission Critical Services,'' design the mission critical ''bot'' concept as an entity capable of gathering environmental/situational information and triggering certain automated actions without the need of human intervention. They proved that in certain circumstances these bots can help quickly resolve emergency situations and complement traditional centralized coordination from dispatch control rooms.

In the article entitled ''Autonomous Self-Backhauled LTE Mesh Network With QoS Guarantee'' co-authored by Favraud et al., the authors present a novel radio access network infrastructure architecture that enables multi-hop LTE mesh networking for nomadic and autonomous base stations via in-band self-backhauling. Furthermore, the authors investigate the coordination and orchestration functionality within the proposed architecture and propose a hierarchical resource scheduling algorithm in order to efficiently meet quality of service requirements for real-time traffic while maximizing the throughput for elastic flows. In the article entitled ''Accurate 3D Localization Method for Public Safety Applications in Vehicular Ad-hoc Networks'' co-authored by Ansari *et al.*, the authors present improved subspace algorithm proposed for time of arrival measurements in VANETs localization. The proposed method gives a closed-form solution, and it is robust for large measurement noise, as it is based on the Eigen form of a scalar product and dimensionality. Furthermore, they developed the Cramer–Rao Lower Bound (CRLB) to evaluate the performance of the proposed 3-D VANETs localization method. Simulation results show that the proposed 3-D VANETs localization method is better than the literature methods, especially for fewer anchors at road side units and large noise variance.

In the last article entitled ''CHESS-PC: Cluster-HEad Selection Scheme with Power Control for Public Safety Networks,'' co-authored by Ansari *et al.*, the proposed scheme utilizes Fuzzy C-Means (FCM) as a clustering tool. The results show that the proposed scheme significantly reduces the power consumption of the network. The proposed scheme achieved an efficiency improvement of 30.24% and 20.46% compared with non-clustering based and FCM clustering-based conventional schemes.

To conclude, we would like to sincerely thank all the authors for submitting their articles to our Special Section, and the large number of reviewers who kindly volunteered their time and expertise to help us curate a high-quality Special Section on this important and timely topic. We would

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APPENDIX
RELATED WORKS

1) Z. Kaleem and K. Chang, "Public safety priority-based user association for load balancing and interference reduction in PS-LTE systems," IEEE Access, vol. 4, pp. 9775–9785, 2016.
2) Z. Kaleem, Y. Li, and K. Chang, "Public safety users' priority-based energy and time-efficient device discovery scheme with contention resolution for ProSe in third generation partnership project long-term evolution-advanced systems," IET Commun., vol. 10, no. 15, pp. 1873–1883, Oct. 2016.
3) Z. Kaleem and M. H. Rehmani, "Amateur drone monitoring: State-of-the-art architectures, key enabling technologies, and future research directions," IEEE Wireless Commun., vol. 25, no. 2, pp. 150–159, Apr. 2018.
4) M. H. Rehmani, A. C. Viana, H. Khalife, and S. Fdida, "A cognitive radio based Internet access framework for disaster response network deployment," in Proc. 3rd Int. Symp. Appl. Sci. Biomed. Commun. Technol., Rome, Italy, Nov. 2010, pp. 1–5.
5) Y. Saleem, M. H. Rehmani, and S. Zeadally, "Integration of cognitive radio technology with unmanned aerial vehicles: Issues, opportunities, and future research challenges," J. Netw. Comput. Appl., vol. 50, pp. 15–31, Apr. 2015.

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