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GUEST EDITORIAL

5G System Design Solutions for Wireless Personal Applications

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5G wireless standards will play a vital role in ensuring security, enabling automation on many fronts such as connected vehicles, and facilitating data rates that are orders of magnitude greater than 4G LTE and thereby enabling rapid access to information. With the evolution in wireless technology, starting from 1G to the present 5G wireless networks, the data rates have grown exponentially to tens and hundreds of Gbps, paving the foundation for future networks with Tbps data rates. It is a major challenge to share huge volumes of data (videos, pictures) at the 5G rates in a multi-user environment. Even though NOMA and OFDMA address the problem of interference in a multi-user environment, the network infrastructure and backhaul communication still lack the capabilities required to meet the challenges posed by 5G data rates. There exists an urgent need to develop a suitable model and protocols at all levels of the protocol stack for personal data access and networking. Consequently, this special issue seeks to address the need to develop a portable standard model in the areas of wireless personal access, 5G Mobile IOT, wireless personal home automation solutions, and network security.

Various authors around the globe submitted thirty four papers for consideration in this special issue, among which the guest editors have selected the best articles based on peer review. We have grouped the papers under several 5G solution themes and provide a summary of the papers below.

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1 5G Personal Access Solutions

The field of Intelligent Reflecting Surfaces (IRS) forms an exciting new research area. The paper by Nagarajan and Balakrishnan discusses the use of IRS to modify the phase of the carrier signal generated at the source and reflect the signal to the destination. The authors analyze the performance of the system over k-mu fading channels using the moment generating function approach and validate the theoretical results using simulation. The results reveal that significant performance gains can be achieved.

In order to capture the potential gains of Non-Orthogonal Multiple Access(NOMA)-aided Mobile Edge Computing systems, the paper by Nguyen et al. proposes a design of multiple antennas and full-duplex for an edge computing aware NOMA architecture.

In the study by Le et al., the authors propose a scheme that combines NOMA with cognitive radio (CR) for vehicle-to-everything (V2X) as a promising application with high spectrum efficiency. Simulation results are provided to validate the derived expressions and exhibit the advantages of the proposed CR-NOMA assisted V2X system with respect to outage probability and bit error rate.

Millimeter wave (mmWave) communication requires large antenna arrays to increase the capability of cellular networks of the fifth generation with good beam-forming gains and a substantial reduction in path losses for both transmitting and receiving terminals. As large antenna arrays require one radio frequency chain per antenna element, the fully digital beamforming technique results in high cost and high-power consumption, and it is therefore not feasible. Hybrid schemes are possible with exciting solutions that overcome the deficiencies of pure digital or analog beam forming, which are explored in the paper by Jeyakumar et al.

2 5G Massive MIMO Design Solutions

The paper by Sohal et al. investigates the effect of massive MIMO antenna in both linear array and planar array configurations on the propagation environment of cellular systems with line of sight (LoS) channels using minimum mean squared error detection technique for uplink and derive some interesting conclusions regarding the suitability for different scenarios.

The paper by Kumar and Babu presents a six-port multi-band MIMO antenna prototype for 5G mobile phone applications that operates in the frequency band 3.33–3.63 GHz. The paper studies MIMO parameters like *envelope correlation coefficient* (ECC), *peak channel capacity*, and *specific absorption rate* (SAR) through measurements.

The paper by Priya et al. proposes a rectangular array antenna-based hybrid beamforming in a massive MIMO model to improve the spectral efficiency of the system. Thus, channel capacity with small RF chains is used. To achieve the high signal strength in the main lobe, the work applies Chebyshev tapering to suppress the side lobe signals. The hybrid beamforming system offers bothreduced complexity and increasedspectral efficiency.

In the paper by Dwivedi et al., a compact size wideband circularly polarized 2-port MIMO antenna is designed for 5G with (≤ -10 dB) impedance bandwidth of 900 MHz in the frequency band 3.3–4.2 GHz and 100% 3-dB axial ratio bandwidth. The antenna covers the potential 5G band ranging from 3.3 to 3.8 GHz having left-handed circular polarization characteristics.

The paper by Khwandah et al. presents the MIMO technology evolution and challenges in a simple introductory way and investigates potential system enhancements.

The paper by Jeyakumar et al. proposes a design of 28 GHz microwave wireless backhaul link for small-cell base stations (SBSs) as well as the number of antennas required for the base station (BS) to achieve a target backhaul rate of 10 Gbit/s within a given transmit power of 40 dBm. The design minimizes the total transmit power over all BSs subjectto the constraints of the signal-to-interference-and-noise ratio (SINR) as beamformers are integrated in a distributed manner.

Satyanarayana Nimma Murthy et al. integrate two meta-heuristic algorithms, *beetle swarm optimization* (BSO) and *Grey Wolf optimization* (GWO), into a hybrid algorithm called the *alternative Grey Wolf with beetle swarm optimization* (AGW-BSO) for developing a hybrid beam selection scheme in MIMO-NOMA to support the multiple SBSs.

The paper by Neema and Gopi considers the problem of path power loss prediction in mmWave MIMO channels, line-of-sight as well as non-line-of-sight channels. The paper applies two deep learning models to address the problem. One of the two models, which the authors propose, is used to generate new data from a limited set of available channel data, and the other, a deep convolutional neural network, is applied to predict the channel path loss characteristics. Using simulations, the authors demonstrate that the two models, respectively, generate more useful data from the available limited set and predict the channel characteristics with minimum error.

The paper by Sujanth Narayanan KG, et al. presents a compact Co-Planar Waveguide (CPW) fed antenna for next-generation Vehicular Communications. The antenna is designed by employing two rectangular stacked patch structures and slots, making the antenna resonate at dual frequency bands. The analytical study of antenna design is carried out using the governing microstrip patch equations. On optimizing the patch's dimensions of CPW structures, the desired frequency range of operation is obtained from the single element antenna structure. The designed antenna resonates at 3.5 GHz (LTE-42 Band) and 5.9 GHz (DSRC Band), yielding this antenna to be a prime component for Vehicular to Everything (V2X) Communication. The overall efficiency of the antenna element is between 60% and 80% at both frequency bands.

3 5G Mobile IOT Solutions

The paper by Sachdeva and Tomar proposes a low power twelve transistor (12 T) SRAM cell that reduces multi-bit errors for IoT-based devices by facilitating bit interleaving, and improves read, and write ability. The SRAM cell also exhibits reduced power dissipation.

The field of Internet of Things (IoT) finds applicability in smart agriculture by facilitating efficient utilization of natural resources. In order to manage the data generated in the process of collecting information to administer smart agriculture, the paper by Al-Qurabat et al. proposes data traffic management based on compression and minimum description length techniques using differential encoding and Huffman encoding. Though the techniques are well known, the results for compressing temperature measurements seem to suggest that the scheme outperforms other available schemes.

The paper by Mishra et al. proposes an architecture for eHealthcare using the 5G NR. Simulation results reveal, not surprisingly, that 5G reduces the latency by an order of magnitude in comparison to LTE. The paper concludes that better eHealthcare facilities can be provided with 5GNR, thereby facilitating rapid data sharing and diagnosis.

In the paper by Héctor Poveda et al., a prototype is presented that measures a set of wireless metrics on raw wireless signals acquired with software defined radio technology. This prototype aims to provide mechanisms to sense and monitor spectrum usage that can mitigate one of the issues that IoT faces, i.e., the interference being produced by having different technologies using the same frequency channels.

Augmented, mixed and virtual reality are changing the way people interact and communicate. Five dimensional communications and services capable of integrating information from all human senses are expected to emerge, together with holographic communications (HC), providing a truly immersive experience. HC presents considerable challenges in terms of data gathering and transmission, demanding Artificial Intelligence empowered communication technologies such as 5G. The paper by Manolova et al. presents a model of a context-aware holographic architecture for real-time communication based on semantic knowledge extraction.

Chochliouros et al. introduce the architectural approach that has been proposed by the 5G ESSENCE project, addressing the paradigms of edge computing and small-cell as-a-service that has been realised via a cloud-enabled small-cell infrastructure leveraging multi-access technologies in 5G.They propose a dedicated public safety use case, able to offer a mission critical push-to-talk service as well as a chat and localization service.

Mahantesh et al. introduce a technique in which the optimum path is determined that satisfies the QoS constraints: Rule Caching (RC) cost, packet loss probability, and delay. A RC policy is designed that matches the requirements of SD-based IoT architecture such that the cost of RC is minimized.

The paper by Hasan et al. proposes an enhanced repetitions cooperative process of narrow band physical uplink shared channel (NPUSCH). The NPUSCH is transmitted using one or more resource units (RUs) and each of these RUs is repeated up to 128 times to enhance coverage as well as to meet the requirement of ultra-low end IoT. The optimum number of repetitions of identical slots for NPUSCH per RUs is calculated and then simulated. In addition, the paper describes analytical simulation to evaluate the proposed repetition of cooperative process performance for LTE-NPUSCH channel.

4 5G Network Security

The area of unmanned aerial vehicle (UAV) is gaining considerable attention recently due to the promises it offers as a background cooperative mobile relay network and as an augmented network to enhance the performance of mobile networks. The paper by Anandpushparaj et al. studies the system performance of UAV-assisted relay systems. Besides deriving a closed-form expression for outage probability and system throughput, simulation results provide some interesting insights on the impact of self-interference and the fading parameter.

Chochliouros et al. discuss several security requirements coming from an assessment of the use cases developed within the context of the original 5G-PPP "5G ESSENCE" project. They have separately assessed each one towards identifying security threats affecting the development of associated virtualised services within the broader 5G scope.

Jayapandian et al. propose tabu search concept to solve this encryption algorithm selection problem that reduces the average encoding and decoding time in multimedia data. The

local search scheduling concept is to schedule the encryption algorithm and store the data in local memory table.

Anil Kumar K et al. propose two reinforcement-learning techniques, namely the physical layer secured Q-learning algorithm for RS (PQL-RS) and the modified physical layer secured Q-learning algorithm for RS (MPQL-RS) for different scenarios. The proposed algorithms are compared to the different RS schemes. The simulation results show that the MPQL-RS can deliver better performance and save the convergence time. It is shown that the secrecy of the system improves by 7% on average for every doubling of modulation order.

Narasimha Vankudoth and Kiran Kumar Gurrala introduce a hybrid-decode-amplify-forward (HDAF) cooperative relaying into a control jamming aided NOMA network under Rayleigh-flat-fading channel conditions. The secrecy performance of the considered network in terms of secrecy rate at both NOMA users analytically under different jamming scenarios. Differential Evolution (DE) algorithm-based power allocation is adopted to optimize the powers of jammer, relay, and NOMA users for which maximization of secrecy rate is chosen as the cost function.

We have grouped the papers appearing in this special issue under four major 5G themes so as to direct the readers of this journal to the appropriate theme(s) and papers of interest. Though we selected papers targeting four key themes under 5G, we do think that many of the papers will find applicability to 6G systems and beyond and spur further research interests.

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Dr. Seshadri Mohan is currently a professor in Systems Engineering Department at University of Arkansas at Little Rock, where, from August 2004 to June 2013, he served as the Chair of the Department of Systems Engineering. Prior to the current position he served as the Chief Technology Officer (CTO) and Acting CEO of IP SerVoniX, where he consulted for several telecommunication firms and venture firms, and served as the CTO of Telsima (formerly known as Kinera). Besides these positions, his industry experience spans a decade at New Jersey-based Telcordia (formerly Bellcore) and Bell Laboratories. Prior to joining Telcordia, he was an associate professor at Clarkson and Wayne State Universities. Dr. Mohan has authored/coauthored over 150 publications in the form of books, patents, and papers in refereed journals and conference proceedings with citations to his publications in excess of 6330. He has co-authored the textbook Source and Channel Coding: An Algorithmic Approach. He has served as a Guest Editor for several Special issues of IEEE Network, IEEE Communications Magazine, and ACM MONET. In April 2011, he was awarded 2010 IEEE Region 5 Outstanding Engineering Educator Award. He received the best paper award for the paper "A Multi-Path Routing Scheme for GMPLS-Controlled WDM Networks," presented at the 4th IEEE Advanced Networks and Telecommunications Systems conference. Dr. Mohan holds a Ph.D. degree in electrical engineering from McMaster University, Canada, the Master's degree in electrical engineering from the Indian Institute of Technology, Kanpur, India, and the Bachelor's degree in Electronics and Telecommunications from the University of Madras, India.