Guest Editorial
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5G New Radio (NR): Standard and Technology

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Led by 3GPP, industry and research communities are now investing tremendous efforts to develop advanced technologies in order to meet all related requirements of ITU "IMT 2020 and Beyond" for 5G wireless communications in terms of enhanced mobile broadband (eMBB), massive machine-type communications (mMTC) and ultra-reliable and low latency communications (URLLC). 3GPP has defined a new name for its planned standard proposal of 5G as "New Radio" (NR), which will be submitted to ITU for the official international 5G standard. The related technologies for 5G NR can mainly be categorized into four areas, namely, 1) new modulation and coding algorithms including multi-user superposition and shared access, enhanced waveform generation and advanced error-correction coding; 2) new system and network architectures including network slicing, device to device (D2D) communications, cloud radio access network (C-RAN), and ultra-dense network (UDN); 3) new spatial-domain processing such as massive multiple-input multiple-output (massive-MIMO), adaptive 3D beamforming and multi-antenna diversity; 4) new spectrum opportunities including millimeter-wave band and license assisted access (LAA).

According to the 3GPP plan, the 5G NR standard has two phases. Phase 1 (Release 15) will be completed in 2018, mainly addressing a more urgent subset of the commercial needs, which could make it possible to deploy the first 5G network by around 2020. Phase 2 (Release 16) will be completed for the IMT-2020 submission in March of 2020 by addressing all identified use cases and requirements. More importantly, 5G NR design should be forward compatible at its core so that features can be added in later releases in an optimal way. It can be seen that the development of 5G NR standard in each stage will be very challenging tasks and require the huge efforts of the related industry, research, alliances and regulatory authorities so as to bring the success in a high quality and a timely manner.

From practice, technology and standard points of view, this special issue aims to provide a unique and timely forum to address all technology issues related to 5G NR standardization. The call-for-papers of this special issue has brought excellent submissions in both quality and quantity. After two-round reviews, seven excellent papers have been selected for publication in this special issue which is organized into the following two category groups.

Consisting of four papers, the first group of this special issue mainly addresses technology aspects of the physical layer for 5G NR by covering new modulation, channel coding, waveform generation, multi-user superposition and shared access, multiple antennas, frame structures, numerology, hybrid automatic repeat request (HARQ) and duplex. As its title "5G New Radio: Physical Layer Overview" exactly means, the first paper presents a comprehensive introduction to all the above key components of the physical layer of 5G NR by addressing basic principles, mathematical models, step-by-step algorithms, implementation complexities, schematic processing flow and the corresponding application scenarios. Moreover, a more detailed roadmap and timeline of the 3GPP 5G NR standard development is presented in this paper.

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Orthogonal frequency division multiplexing (OFDM) based waveform generation has become the dominant technology in many existing wireless and broadcasting standards and is actually also considered as one of key technologies in 5G radio access network (RAN). Titled as "Enhanced OFDM for 5G RAN", the second paper provides an overview on the various improved versions of OFDM for 5G NR in terms of waveform characteristics and parameters, out of band leakage, peak to average power, cyclic prefix, pilot signals, inter-carrier interference (ICI), inter-symbol interference (ISI), multipath distortion, the orthogonality and the related effect of frequency offset and phase noises, synchronization requirement in both the time domain and frequency domain, latency, mobility, signaling, compatibility, co-existence and integration with other processing such as massive MIMO.

The title of the third paper is "An Overview of Non-Orthogonal Multiple Access". Being considered as a novel and promising multiple access scheme, NOMA has been proposed and proved by NTT DOCOMO to be able to contribute to a significant improvement of the compromise among system capacity, spectrum efficiency and user fairness by introducing power-domain user multiplexing on the basis of channel difference among users. This paper provides an excellent overview on various technical aspects of NOMA by covering concept, design, performance, combination with MIMO and comparisons over orthogonal multiple access. More importantly, the status and open issue of 5G NR standardization related to NOMA in 3GPP are provided in this paper with emphasis on the multi-user superposition transmission (MUST).

As pointed out in the fourth paper titled as "Uplink Multiple Access Schemes for 5G: A Survey", signal transmitter and receiver are jointly optimized in a non-orthogonal multiple access (NMA) system, which suggests that multiple layers of data from more than one user can be simultaneously delivered in the same resource. As a matter of fact, uplink NMA is becoming a key candidate technology for 5G NR standard and a number of uplink NMA schemes from different companies have been proposed in recent 3GPP meetings. This paper reviews the key features, characteristics and standardization process status of these proposed NMA systems for 3GPP 5G NR by classifying them into three major categories in terms of their basic technique principles, namely: scrambling based NMA schemes, interleaving based NMA schemes and spreading based NMA schemes.

Organized into the second group, the fifth paper through the seventh paper included in this special issue deal with technical aspects related to massive MIMO in different frequency bands, D2D based cooperative relaying and a practical use of URLLC, respectively. "Massive MIMO 5G Cellular Networks: mm-Wave vs. μ-Wave Frequencies" is the fifth paper, which provides a comprehensive comparison between massive MIMO systems at mm-waves and at μ-waves (frequencies in the sub-6 GHz range) due to different propagation mechanisms in urban scenarios. All key differences between mm-waves and μ-waves are given in this paper in terms of channel modeling, antenna size, beam-steering , channel matrix rank, channel estimation, pre-coding design, pilot contamination and antenna diversity. It is believed that the comparisons and analyses given in this paper are very useful to the corresponding 3GPP working groups in addressing the massive MIMO part of the 5G NR standard.

"Novel MAC Layer Proposal for URLLC in Industrial Wireless Sensor Networks" is the title of the sixth paper. Taking industrial wireless sensor network (IWSN) as a representative case of the URLLC, this paper proposes a new hybrid multi-channel scheme so as to deliver a better performance in terms of enhanced throughput, increased reliability and reduced latencies. With the utilization of the multiple frequency channels, the proposed scheme defines a special purpose frequency channel that facilitates failed communications by retransmissions where the retransmission slots are allocated according to the priority level of failed communications of different nodes. The presented results show the accurateness of the theoretical analyses and the effectiveness of the proposed scheme.

Featured into the "Review" section of this special issue, the seventh paper is titled as "Device-to-Device Based Cooperative Relaying for 5G Network: A Comparative Review". As the author of this paper pointed out, the concept of cooperative communications opens a possibility of using multiple terminals to cooperatively achieve spatial diversity and hence the utilization of D2D-based cooperative relaying is promising in the era of 5G. By first proposing a new opportunistic space-time coding scheme, this paper then presents a comparative study on several cooperative multi-relay schemes in the presence of imperfect channel state information. The numerical results prove that the proposed scheme is the best up-to-date cooperative solution from the perspective of multiplexing-diversity trade-off.

As we conclude the introduction to this special issue and the contents of seven papers, we would like to thank all authors for their valuable contributions. We also express our sincere gratitude to all the reviewers for their timely and insightful comments on all submitted papers. It is hoped that the contents in this special issue are informative and useful from various aspects related to 5G NR standardization and technology development.