5G Standardization Status in 3GPP

As the radio interface of mobile phones has evolved, it has typically been changed about every ten years, and the 5G (5th Generation) interface is expected to start being used in the 2020s.

Similar to 3G and 4G cases, ITU-R (International Telecommunication Union – Radio communication Study Groups) will request standard organizations to standardize a new interface based on their recommendations for performance and capabilities. After evaluation of each submission, the standards that succeed will be authorized and known as IMT-2020. For the 3G case, WCDMA submitted by 3GPP (the 3rd Generation Partnership Project) and CDMA-2000 by 3GPP2 were authorized as IMT-2000, and for the 4G case, LTE-A (Long Term Evolution-Advanced) by 3GPP and WiMAX-Advanced by WiMAX Alliance were authorized as IMT-Advanced.

In subsequent sections of this article, section 1 explains the vision of 5G proposed by ITU-R. Section 2 covers the activity of 3GPP in the past, and the way forward in the future. Section 3 explains aspects of 5G technologies, and finally section 4 provides an overall summary.

1 - ITU-R's Vision of 5G

1.1 New Usage Scenarios in 5G

ITU-R has investigated networked society in the 2020s with new usage scenarios envisaged, and published a report explaining the detail[1)]. There, the following three usage scenarios are picked as the most important ones:

- Enhanced Mobile Broadband
- Ultra-reliable and Low Latency Communications
- Massive Machine Type Communications

These three usage scenarios can be used alone or combined as variable new services, as shown in Figure 1.

Enhanced Mobile Broadband increases the transmission speed over 3G, and support 1 Gbps for both DL (Downlink) and UL (Uplink). This will enable high definition video transmission, such as 4K and 8K display.

Ultra-reliable and Low Latency Communications aim to eliminate transmission error, and decrease the RTT (Round-Trip-Time). This will enable technologies such as self-driving cars and remote-controlled surgery.

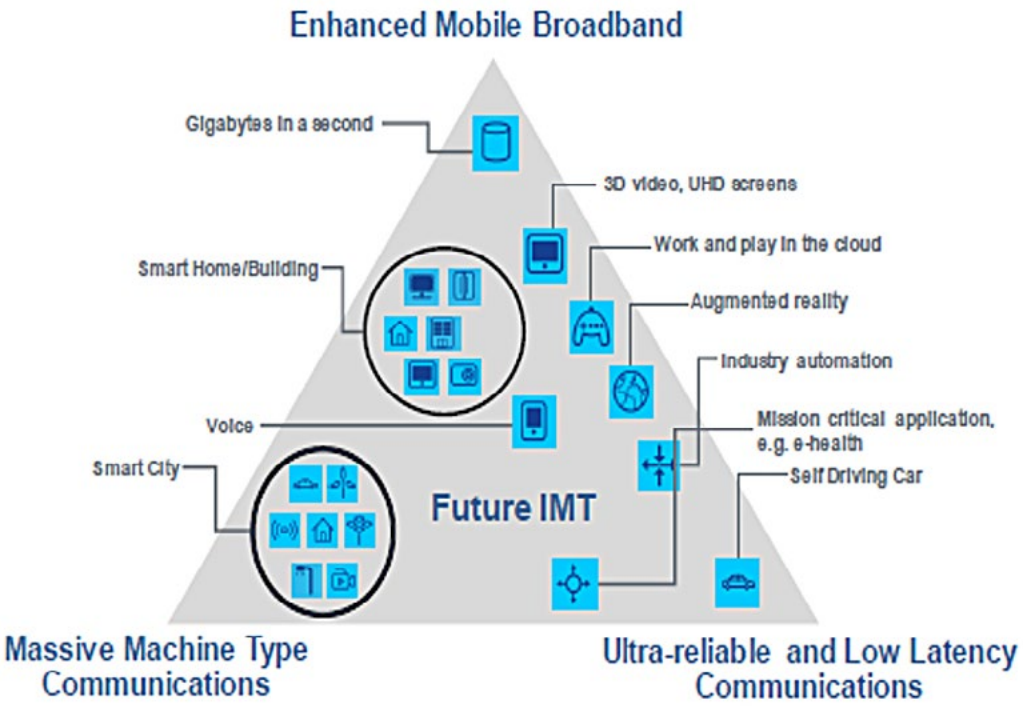


Figure 1: New Usage Scenarios and Services in 5G (Reproduced with the kind permission of ITU)

Massive Machine Type Communications will provide infrastructure when almost every device is connected to the Internet.

1.2 Requirements for 5G

The requirements for 5G can be derived from those of the usage scenarios. The capabilities for each usage scenarios are selected, and their importance is shown in Figure 2.

The important capability for Enhanced Mobile Broad-band is mainly transmission speed.

Those for Ultra-reliable and Low Latency Communications are Mobility and Latency.

For Massive Machine Type Communications, Connection Density is most important. Network Energy Efficiency is of middle importance, but energy efficiency of the UE is of high importance and battery life over ten years is required.

As the importance of capabilities is different for each usage scenario, a suitable configuration for each usage scenario may be economically feasible.

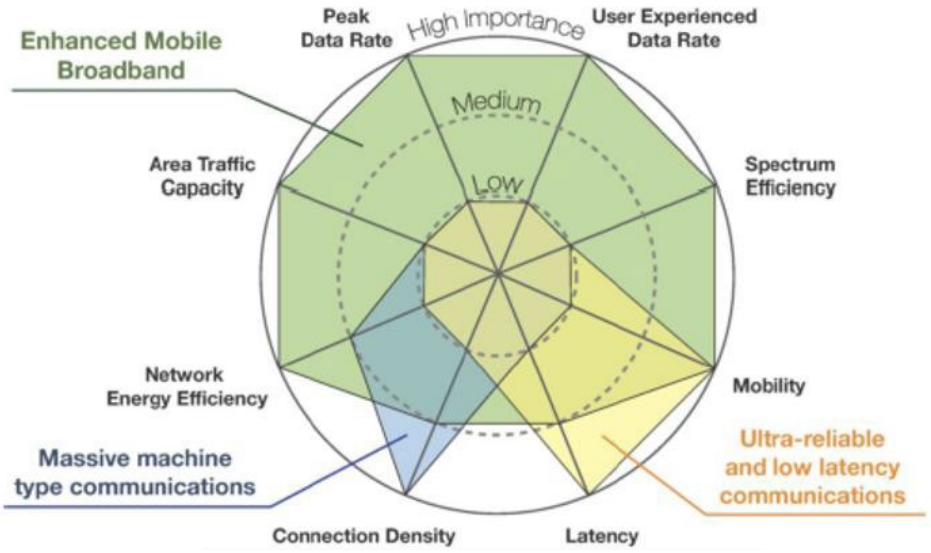


Figure 2: Importance of capabilities for each usage scenario (Reproduced with the kind permission of ITU)

The requirements for each capability are shown in Figure 3, taking the most stringent values across all the usage scenarios. Here, the requirements for IMT-Advanced are shown as a reference.

- Spectrum Efficiency is required to be a modest three times better than IMT-Advanced, but Peak Data Rate is required to be better by a rather more aggressive factor of 20.
- Area Traffic Capacity is required to be a 100 times better than IMT-Advanced, driven by infotainment applications in shopping malls and stadiums.
- Mobility is required to be 500 km/h to be applicable for magnetic levitation trains.
- Network Energy Efficiency is required to be 100 times better, aiming to achieve a green network with reduced CO_2 emissions.
- Latency is required to be 1ms, with the requirement coming from traffic safety e.g. collision avoidance of self-driving cars.
- Connection Density is required to be 1 million connections per square kilometer.

1.3 Future Schedule and Updates

The past and future schedule of ITU-R activities is shown in Figure 4. As shown, Working Party (WP) 5D of ITU-R published a technical report[2)] and a recommendation[1)] in November 2014. Also, WRC-15 (World Radio Conference 2015) was held in Geneva. There, seven bands above 6 GHz are selected for study in WRC-19.

During 2016 and 2017 ITU-R will complete technical performance specifications, determine a evaluation method and criteria, and design a format of submission. The liaison statement for IMT-2020 application will then be sent to standardization organizations. A workshop will be held in late 2017, enabling the standardization to proceed smoothly. After a deadline for submission in the middle of 2019, IMT-2020 will be evaluated and decided , finally authorizing IMT-2020 in 2020.

2 - 3GPP Activities for 5G

2.1 Standardization Steps of 3GPP

In 3GPP new standards are made in one-and-half or two-year cycles, and frozen as a distinctive release with ascending number. This process enables fast service roll out based on the new standards. Currently Rel-13 (Release-13) is proceeding, and scheduled to be frozen in March 2016. Past releases are characterized by main functionality such inter- and intra-band contiguous CA (Carrier Aggregation) for Rel-10, intra-band non-contiguous CA for Rel-11, and CA using both FDD and TDD band for Rel-12. A new CA method using 5 GHz WiFi bands is being standardized in Rel-13, called Licensed Assisted Access (LAA).

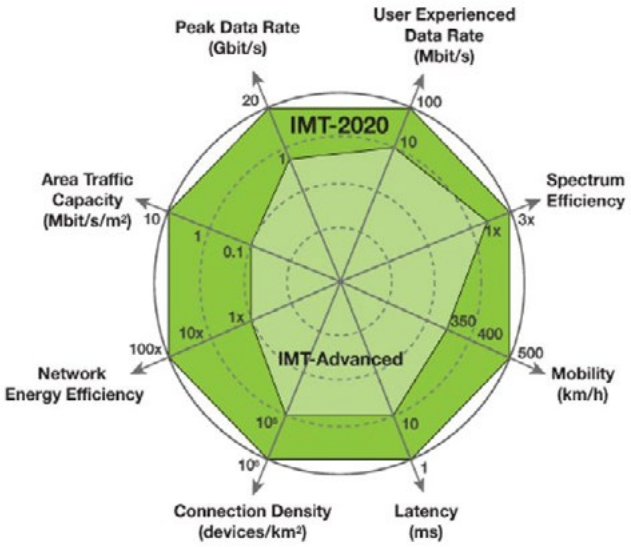


Figure 3: Requirements for 5G capabilities (Reproduced with the kind permission of ITU)

3GPP is scheduled to start 5G standardization after the end of Rel-13. From Rel-14, new fundamentals will be studied to select the best methods for 5G. Then, the selected methods will be formalized into standards in Rel-15 (Phase 1) and Rel-16 (Phase 2). In Figure 4 a probable schedule for future releases are shown. The cycle of each release is shortened to one-and-quarter-years, aiming to make Rel-15 standards operational at least in 2020. However, others support a normal one-and-half-year cycle for each release. The cycle will be decided in the future Radio Access Network (RAN) Plenary meetings.

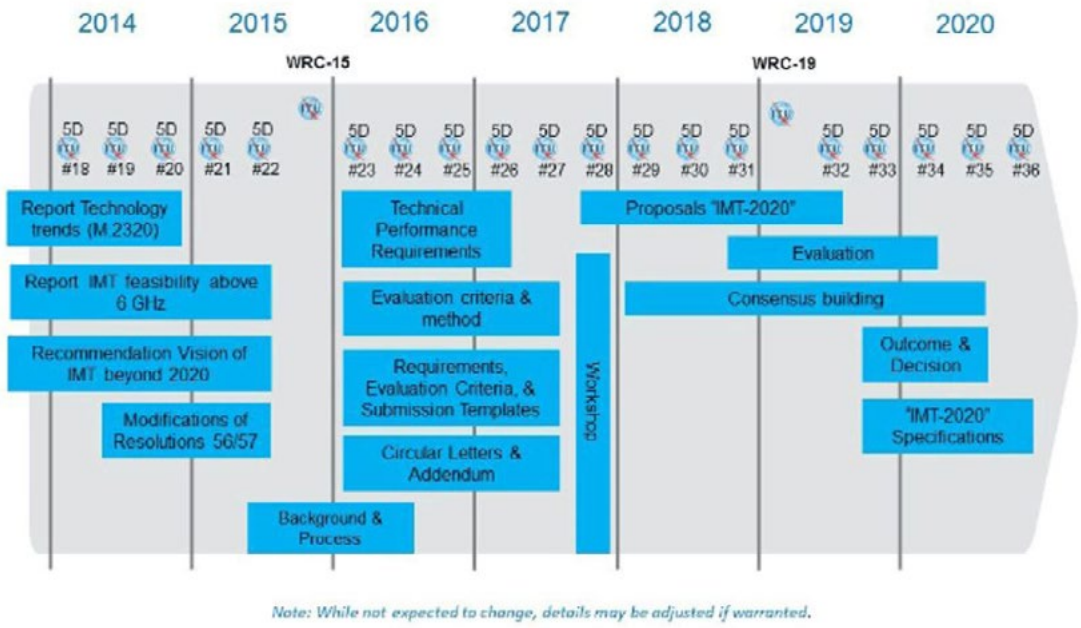


Figure 4: ITU-R Schedule for 5G and 3GPP Releases (Reproduced with the kind permission of ITU)

2.2 RAN 5G Workshop

3GPP held a RAN 5G workshop in September 2015. There, members of 3GPP and 5G related forums presented their vision and schedule for 5G, with the vision based on that of ITU-R. But for the schedule, there are three groups with differing interests:

- Japanese, Korean, and US operators, main infra-structure vendors, main chip-set vendors
- Chinese operators and infrastructure vendors
- European operators

Group A prioritizes the usage scenario of Enhanced Mo-bile Broadband for Phase 1, and other usage scenarios for Phase 2. Group B doesn't prioritize within the usage scenarios, and proposes to standardize all three usage scenarios in Phase 1. Group C prioritizes the usage scenario of Massive Machine Type Communications, based on the immediate profit potential. This issue will be discussed in future RAN Plenary meetings, and a compromise agreement will be reached.

2.3 Future Schedule

One possible future schedule for 5G is shown in Figure 5. Here, the schedule proposed by Group A is followed, with some of the authors' predictions included. The 3GPP standardization process is composed of an analysis phase, followed by a documentation of the new functionality. In the analysis phase an SI

(Study Item) is proposed for approval by the RAN Plenary meeting, and the analysis starts after approval. In the standard documentation phase a WI (Work Item) is proposed for approval, and the documentation starts after approval. The SIs for Channel Model and Enhanced Mobile Broadband have already been approved in RAN#69 (the 69th RAN Plenary) meeting.

In the Channel Model SI, a simulation model will be built to analyze each usage scenario. For an efficient start of the analysis, this SI will begin during Rel-13.

In the Enhanced Mobile Broadband SI, new methods will be analyzed, applicable for general frequency bands. The Rel-15 WI will deal with legacy bands, and the Rel-16 WI will deal with millimeter bands. The analysis will be about new waveform, new numerology, and Massive MIMO processing, etc.

The eMTC and NB-IoT (Narrow-Band Internet of Things) Work Items already in Rel-13 are related to the usage scenario of Massive Machine Type Communications, and may be extended into Rel-14 SI or WI. Also the Latency SI in Rel-13 is extended into a WI, which treats part of the usage scenario of Ultra-reliable and Low Latency Communications.

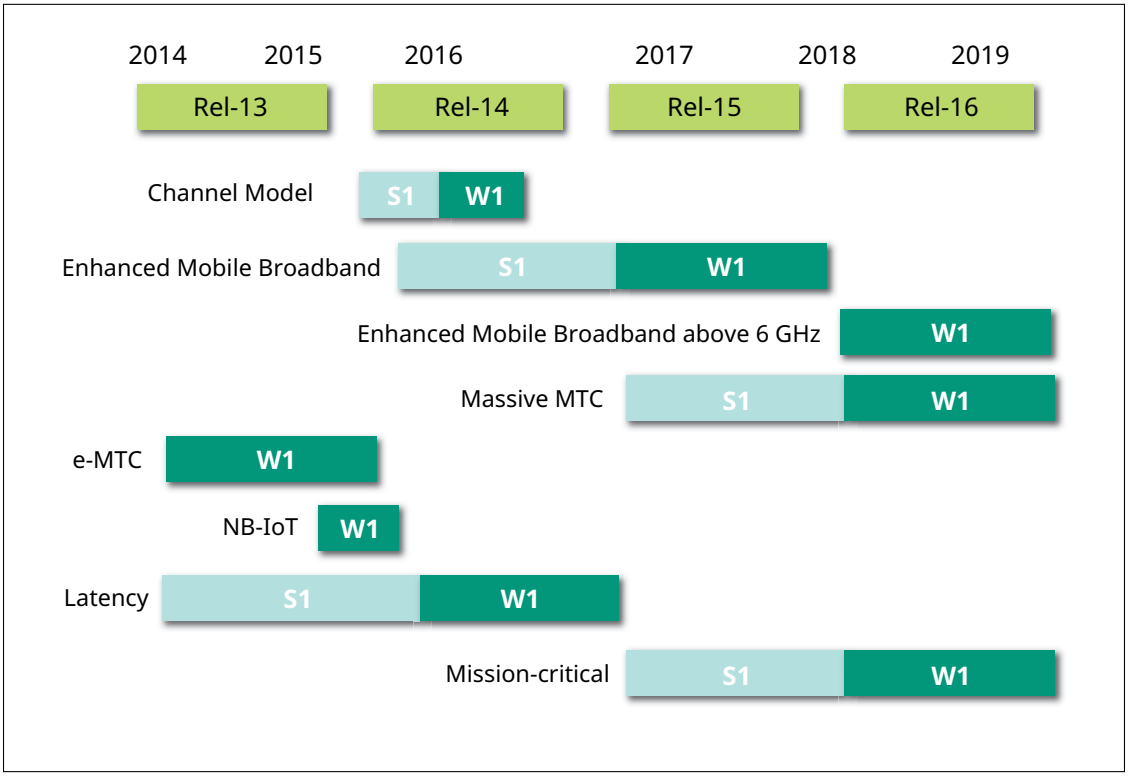


Figure 5: Future Schedule of 3GPP RAN

3 - New Functionalities in 5G

In this section some of new functionalities such as new waveform and new numerology are introduced.

3.1 New Waveform

OFDM (Orthogonal Frequency Division Multiplex) is used in LTE, but has some shortcomings such as out-of-band emission and side lobes. To reduce the effects of emission, a large guard band is assigned, which decreases the spectrum efficiency.

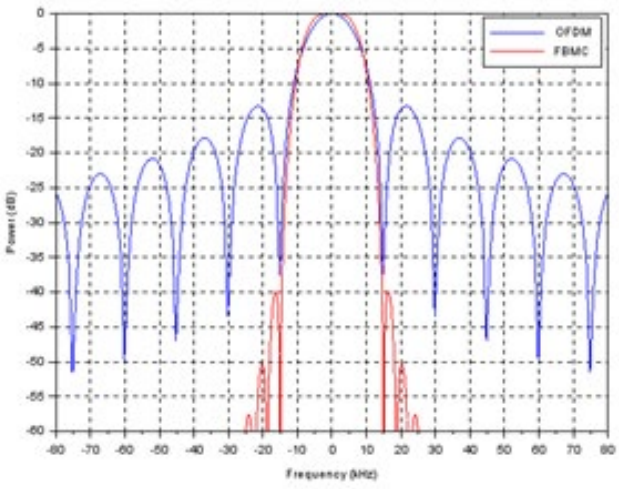


Figure 6: Spectrum of Shaping Pulses for OFDM and FBMC

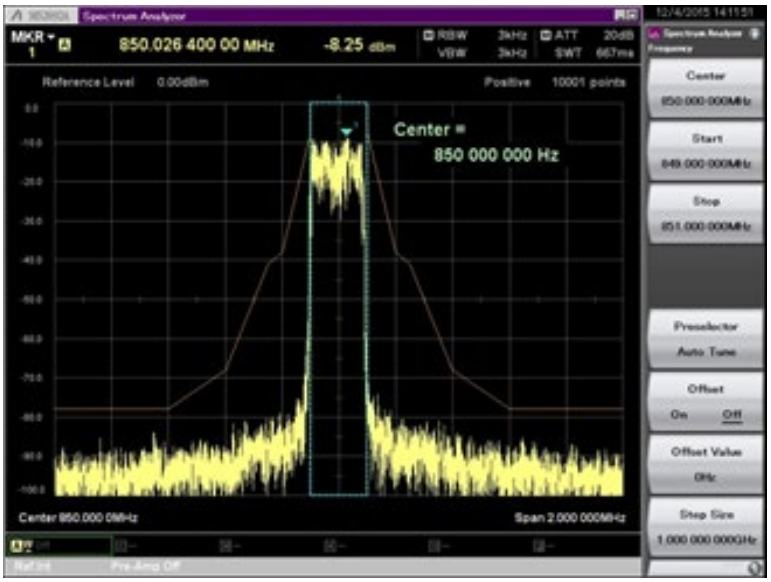
Equation (1) is a general time-domain waveform of a linear modulation, which includes OFDM as an instance[3].

$$x(t) = \sqrt{PT_S} \sum_l s_l (t - lT_S) \quad (1)$$

where P, T_s and $s_l(t)$ are power, symbol period and lth symbol waveform respectively. $s_l(t)$ is expressed as equation (2).

$$s_l(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} d_{k,l} p(t) e^{j2\pi k \frac{\delta_f \delta_t}{T_s} (t+T_s)} \quad (2)$$

where N, $d_{(k,l)}$, p(t) are the number of sub-carriers, lth demodulation symbol, pulse shaping waveform respectively, and δ_f, δ_t are frequency separation between sub-carriers and the percentage of CP (Cyclic Prefix) in a symbol length. The side-lobes of OFDM are shown in Figure 6, where 15 kHz sub-carrier width is assumed as for LTE, and using a rectangular wave as a pulse shaping waveform. The power of side-lobes decreases rather slowly with respect to frequency.



In the Rel-13 NB-IoT WI, a new waveform is proposed using the Hanning window as a pulse shaping waveform, to reduce the side-lobe and keep it within the spectrum emission mask for GSM[4].

Figure 7: FBMC Spectrum and GSM Mask

A more general but more complex method is FBMC (Filter Bank Multiple Carrier), which diminishes side-lobes as shown in Figure 6. A FBMC waveform for NB-IoT cases is shown in Figure 7, showing there is enough margin against the GSM mask.

3.2 New Numerology

In LTE the TTI (Transmission Time Interval) is fixed as 1 ms, and is not suitable for usage scenarios requiring quick response time such as Low Latency Communications. Also, the TTI of 1 ms is too short for MTC. Therefore, a method allowing variable TTI is being investigated, called new numerology. If new numerology and FBMC are combined, a band can be composed of sub-bands with different TTIs as shown in Figure 8. Here, three group of sub-bands with TTI of 0.5 ms (red), 2 ms (green), 1 ms (cyan) are combined into a band where the first, second and third group consists of 2, 4 and 4 sub-bands.

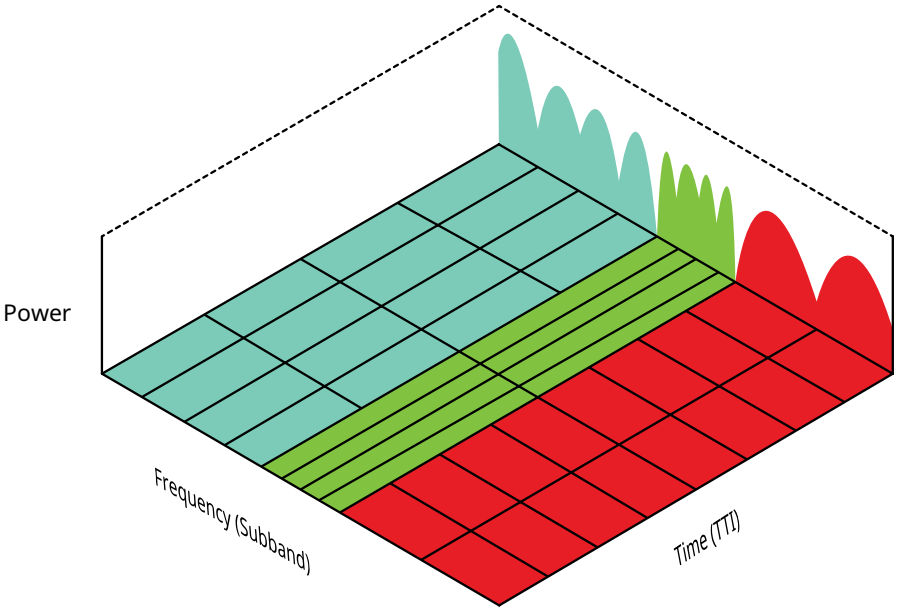


Figure 8: Combination of Sub-bands with Different TTIs

4 - Summary

3GPP is scheduled to standardize the 5G specification. Similar to 3G and 4G cases, it will submit IMT-2020 specifications based on ITU-R recommendations. Part of the 5G specification is to be operational within 2020. In this article, the probable schedule of 3GPP and some of the new technology has been described.

5 - Reference

1. ITU-R, “IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond”, Sep. 2015.
2. ITU-R, “Technical feasibility of IMT in bands above 6 GHz”, Jul. 2015.
3. Banelli, P. et. al., “Modulation Formats and Waveforms for 5G Networks: Who Will Be the Heir of OFDM?: An overview of alternative modulation schemes for improved spectral efficiency”, Vol 31, No. 6, Signal Processing Magazine, Nov. 2014
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