International Journal of Advanced Research in Science, Engineering and Technology

Vol. 12, Issue 7, July 2025

ISSN: 2350-0328

# Enhanced 5G New Radio Evaluation Against IMT-2020 Key Performance Indicators

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**ABSTRACT:** A new delivery model as the fifth generation (5G) of mobile radio technologies has been defined where services are tailored to specific vertical industries. 5G supports three types of services are supported with different and heterogeneous requirements, i.e. enhanced Mobile Broadband (eMBB), Ultra-Reliable Low Latency Communications (URLLC) and massive Machine-Type Communications (mMTC). These services are directly related to exemplary verticals such as media, vehicular communications or the industry 4.0. This work provides a detailed analysis and performance evaluation of 5G New Radio (NR) against a set of Key Performance Indicators (KPI), as defined in the International Mobile Telecommunications 2020 (IMT-2020) guidelines, and provides an overview about the fulfilment of their associated requirements. The objective of this work is to provide an independent evaluation, complementing the Third Generation Partnership Project (3GPP) contribution. From the original group of sixteen KPIs, eleven of them have been carefully selected, paying special attention to eMBB services. Results shows that 5G NR achieves all considered requirements, therefore fulfilling the specific markets needs for years to come.

**Index Terms:** 5G, new radio, IMT-2020, KPI, requirements, data rate, spectral efficiency, latency, mobility, energy efficiency.

## I. INTRODUCTION

The fifth generation (5G) of mobile communications represents a change of paradigm in the way that wireless transmissions are conceived. 5G New Radio (NR) not only brings a large number of technical improvements compared to the fourth generation (4G) Long Term Evolution (LTE), but also expands the mobile communications concept to new industry sectors. 5G aims at supporting three major service types with different and heterogeneous requirements, i.e. enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communications (URLLC) and massive Machine-Type Communications (mMTC). 5G is expected to cover an extensive number of use cases for the digitalization of new verticals [1], [2] such as media, the industry 4.0 or vehicular communications, among others. 5G NR is expected to fulfil a wide set of high-demanding and stringent requirements to cover multiple use cases of targeted verticals [3]. 5G requirements are linked to specific Key Performance Indicators (KPIs), which were defined by the International Telecommunication Union- Radio communication (ITU-R) sector towards the International Mobile Telecommunications for 2020 (IMT-2020) landmark [4]. 5G was specified for the first time in the Third Generation Partnership Project (3GPP) Release (Rel ) 15, structured in three phases [5]. An early drop non-stand-alone (NSA) version.

### A.USAGE SCENARIOS OF IMT-2020

Three main usage scenarios for IMT-2020 have been identified in Recommendation ITU-R M.2083, “IMT Vision–Framework and overall objectives of the future development of IMT for 2020 and beyond”, which are enhanced mobile broadband, ultra-reliable and low latency communications, and massive machine-type communications. Additional use cases are expected to emerge, which are currently not foreseen. For future IMT, flexibility will be necessary to adapt to new use cases that come with a widely varying range of requirements. IMT-2020 will encompass a large number of different features. Depend on the circumstances and the different needs in different countries, future IMT 74, IMT for 2020 and Beyond Figure 1.1 Usage scenarios of IMT-2020. systems should be designed in a highly modular manner so that not all features have to be implemented in all networks. Figure 1.1 illustrates some examples of envisioned usage scenarios for IMT-2020.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 12, Issue 7, July 2025

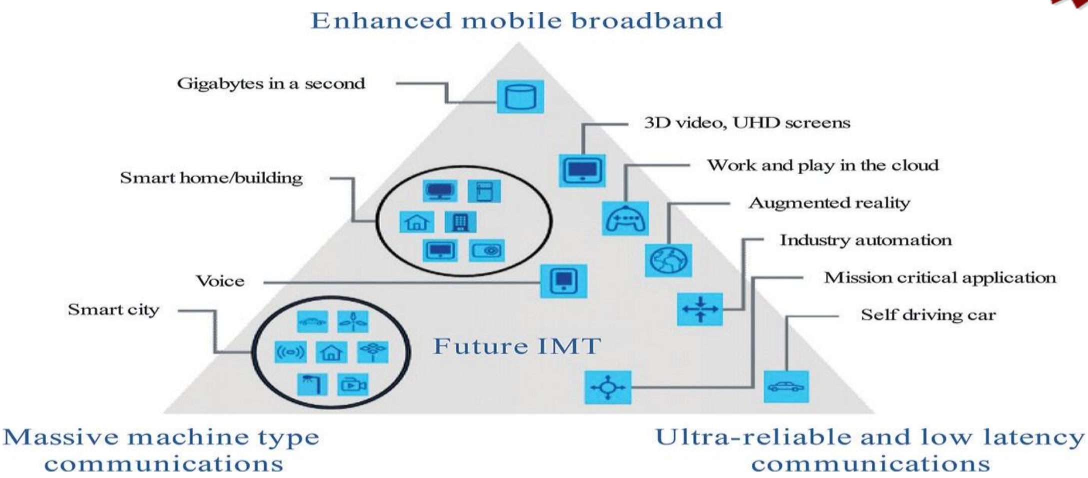


**Figure 1.1:** Usage scenarios of IMT-2020.

A. **Capabilities of IMT-2020**

IMT-2020 systems are mobile systems that include the new capabilities of IMT that go beyond those of IMT-Advanced. IMT-2020 systems will need to support low to high mobility applications and a wide range of data rates in accordance with user and service demands inmultiple usage scenarios. IMT-2020 also needs to have capabilities for high quality multimedia applications within a wide range of services and platforms, providing a significant improvement in performance and quality of service. The key design principles of capabilities of IMT-2020 are flexibility and diversity to serve many different use cases and scenarios. The following eight parameters are considered to be key capabilities of IMT-2020:

**Peak data rate**

Maximum achievable data rate under ideal conditions per user/device (in Gbit/s).

**User experienced data rate**

Achievable data rate that is available ubiquitously across the coverage area to a mobile user/device (in Mbit/s or Gbit/s).

**Latency**

The contribution by the radio network to the time from when the source sends a packet to when the destination receives it (in ms).

**Mobility**

Maximum speed at which a defined QoS and seamless transfer between radio nodes which may belong to different layers and/or radio access technologies (multi-layer/-RAT) can be achieved (in km/h).

**Connection density**

Total number of connected and/or accessible devices per unit area (per km2).

**Energy efficiency**

Energy efficiency has two aspects:

• on the network side, energy efficiency refers to the quantity of information bits transmitted to/received from users, per unit of energy consumption of the radio access network (RAN) (in bit/Joule);

• on the device side, energy efficiency refers to quantity of information bits per unit of energy consumption of the communication module (in bit/Joule).

**Spectrum efficiency**

Average data throughput per unit of spectrum resource and per cell (bit/s/Hz).

**Area traffic capacity**

Total traffic throughput served per geographic area (in Mbit/s/m2).

The key capabilities of IMT-2020 are shown in Figure 1.2, compared with those of IMT Advanced.

**Key Technology Enablers**:

Report ITU-R M.2320 [7] provides a broad view of future technical aspects of terrestrial IMT systems considering the time frame 2015 –2020 and beyond. It includes information on technical and operational characteristics of IMT systems, including the evolution of IMT through advances in technology and spectrally-efficient techniques, and

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 12, Issue 7, July 2025

their deployment. Key technologies that are expected to influence the development of IMT-2020 are briefly described below.

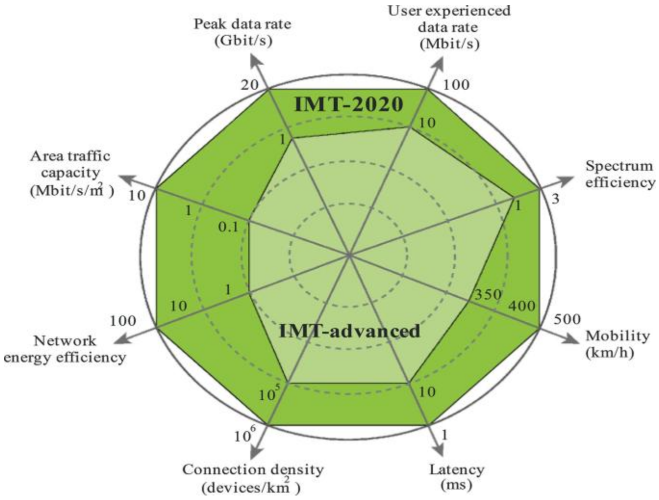


Figure 1.2: Enhancement of key capabilities from IMT-Advanced to IMT-2020.

## II. METHODS

**Technologies to Enhance the Radio Interface**

Advanced waveforms, modulation, coding, and multiple access schemes, e.g., filtered OFDM (FOFDM), filter bank multi-carrier modulation (FBMC), pattern division multiple access (PDMA), sparse code multiple access (SCMA), interleave division multiple access (IDMA) and low density spreading (LDS) may improve the spectral efficiency of the future IMT systems. Advanced antenna technologies such as 3D-beamforming(3D-BF), active antenna system (AAS), massive MIMO and network MIMO will achieve better spectrum efficiency.

In addition, TDD-FDD joint operation, dual connectivity and dynamic TDD can enhance the spectrum flexibility. Simultaneous transmission and reception on the same frequency with self-interference cancellation could also increase spectrum efficiency. Other techniques such as flexible backhaul and dynamic radio access configurations can also enable enhancements to the radio interface. Reduced overhead may provide performance enhancement due to lower mobility In small cells, higher-order modulation and modifications to the reference signal structure with in small cell deployments and potentially higher signal-to interference ratios compared to the wide-area case. Flexible spectrum usage, joint management of multiple radio access technologies (RATs) and flexible uplink/downlink resource allocation, can provide technical solutions to address the growing traffic demand in the future and may allow more efficient use of radio resources.

### A. NETWORK TECHNOLOGIES

Future IMT will require more flexible network nodes which are configurable based on the Software-Defined Networking (SDN) architecture and network function virtualization (NFV) for optimal processing the node functions and improving the operational efficiency of network. Featuring centralized and collaborative system operation, the cloud RAN (C-RAN) encompasses the baseband and higher layer processing resources to form a pool so that these resources can be managed and allocated dynamically on demand, while the radio units and antenna are deployed in a distributed manner. The radio access network (RAN) architecture should support a wide range of options for inter-cell coordination schemes. The advanced self organizing network (SON) technology is one example solution to enable operators to improve the OPEX efficiency of the multi-RAT and multi-layer network, while satisfying the increasing throughput requirement of subscribers.

### B. TECHNOLOGIES TO ENHANCE MOBILE BROADBAND SCENARIOS

A relay based multi-hop network can greatly enhance the Quality of Service (QoS) of cell edge users. Small-cell deployment can improve the QoS of users by decreasing the number of users in a cell and user quality of experience can be enhanced. Dynamic adaptive streaming over HTTP (DASH) enhancement is expected to improve user experience and accommodate more video streaming content in existing infrastructure. IMT for 2020 and Beyond Bandwidth saving and transmission efficiency improvement is an evolving trend for Evolved Multimedia Broadcast and Multicast Service (eMBMS). Dynamic switching between unicast and multicast transmission can be beneficial. IMT systems currently provide support for RLAN interworking, at the core network level, including seamless as

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 12, Issue 7, July 2025

well as non-seamless mobility, and can offload traffic from cellular networks into license-exempt spectrum-bands. Context aware applications may provide more personalized services that ensure high QoE for the end user and proactive adaptation to the changing context. Proximity-based techniques can provide applications with information whether two devices are in close proximity of each other, as well as enabling direct device-to-device (D2D) communication. Group communication, including push-to-talk type of communication, is highly desirable for public safety applications.

### C. TECHNOLOGIES TO ENHANCE MASSIVE MACHINE TYPE COMMUNICATIONS

Future IMT systems are expected to connect a large number of M2M devices with a range of performance and operational requirements, with further improvement of low-cost and low complexity device types as well as extension of coverage.

### D. TECHNOLOGIES TO ENHANCE ULTRA-RELIABLE AND LOW LATENCY COMMUNICATIONS

To achieve ultra-low latency, the data and control planes may both require significant enhancements and new technical solutions addressing both the radio interface and network architecture aspects. It is envisioned that future wireless systems will, to a larger extent, also be used in the context of machine - to - machine communications, for instance in the field of traffic safety, traffic efficiency, smart grid, e-health, wireless industry automation, augmented reality, remote tactile control and tele-protection, requiring high reliability techniques.

### E. TECHNOLOGIES TO IMPROVE NETWORK ENERGY EFFICIENCY

In order to enhance energy efficiency, energy consumption should be considered in the protocol design. The energy efficiency of a network can be improved by both reducing RF transmit power and saving circuit power. To enhance energy efficiency, the traffic variation characteristic of different users should be well exploited for adaptive resource management. Examples include discontinuous trans mission (DTX), base station and antenna muting, and traffic balancing among multiple RATs.

### F. TERMINAL TECHNOLOGIES

The mobile terminal will become a more human friendly companion as a multipurpose Information and Communication Technology (ICT) device for personal office and entertainment, and will also evolve from being predominantly a hand-held smart phone to also include wearable smart devices. Technologies for chip, battery, and display should therefore be further improved.

### G. TECHNOLOGIES TO ENHANCE PRIVACY AND SECURITY

Future IMT systems need to provide robust and secure solutions to counter the threats to security and privacy brought by new radio technologies, new services and new deployment cases.

### H. SPECTRUM FOR IMT OPERATION

This Section discusses about needs for IMT operation spectrum as well as harmonization, identification and technical issues on spectrum for IMT.

### I. SPECTRUM REQUIREMENTS REPORT

ITU-R M.2290 [8] provides the results of studies on estimated global spectrum requirements for terrestrial IMT in the year 2020. The estimated total requirements include spectrum already identified for IMT plus additional spectrum requirements. It is noted that no single frequency range satisfies all the criteria required to deploy IMT systems, particularly in countries with diverse geographic and population density; therefore, to meet the capacity and coverage requirements of IMT systems multiple frequency ranges would be needed. It should be noted that there are differences in the markets and deployments and timings of the mobile data growth in different countries. For future IMT systems in the year 2020 and beyond, contiguous and broader channel bandwidths than available to current IMT systems would be 80 IMT for 2020 and Beyond desirable to support continued growth. Therefore, availability of spectrum resources that could support broader, contiguous channel bandwidths in this time frame should be explored.

### J. STUDIES ON TECHNICAL FEASIBILITY OF IMT BETWEEN 6 AND 100 GHZ

Report ITU-R M.2376 [9] provides information on the technical feasibility of IMT in the frequencies between 6 and 100 GHz. It includes information on potential new IMT radio technologies and system approaches, which could be appropriate for operation in this frequency range. The potential advantages of using the same spectrum for both access and fronthaul/backhaul, as compared with using two different frequencies for access and fronthaul/backhaul, are also described in the Report. The theoretical assessment, simulations, measurements, technology development and prototyping described in the Report indicate that utilizing the bands between 6 and 100 GHz is feasible for studied IMT deployment scenarios, and could be considered for the development of IMT for 2020 and beyond.

**K. SPECTRUM HARMONIZATION**

Where radio systems are to be used globally, it is highly desirable for existing and newly allocated spectrum to be harmonized. The benefits of spectrum harmonization include: facilitating economies of scale, enabling global roaming, reducing equipment design complexity, preserving battery life, improving spectrum efficiency and potentially reducing cross border interference. Mobile devices typically contain multiple antennas and associated radio frequency front-ends to enable operation in multiple bands to facilitate roaming. While mobile devices can benefit from common chipsets, variances in frequency arrangements necessitate different components to accommodate these differences, which leads to higher equipment design complexity. Consequently, harmonization of spectrum for IMT will lead to simplification and commonality of equipment, which is desirable for achieving economies of scale and affordability of equipment.

**L. SPECTRUM IDENTIFICATION**

As mentioned previously, it was by a decision by the 1992 World Administrative Radiocommunication Conference that the first specific frequency bands for the operation of FPLMTS (now IMT) were identified in the ITU Radio 6.6 Spectrum for IMT Operation 81 Regulations, the international treaty governing the use of the radio frequency spectrum and satellite orbits. Identification of a frequency band in the Radio Regulations does not afford any priority for such use with respect to other radio services allocated to that spectrum, but it does provide a clear signal to the national regulators for their spectrum planning, and also provides a degree of confidence for equipment manufacturers and network operators to make the long term investments necessary to develop IMT in these bands.

Since then, successive World Radiocommunication Conferences have periodically identified additional frequency bands for IMT within the range of 450 MHz to 6 GHz to cater for the rapidly growing demand for mobile communications, particularly mobile broadband data.

While the 2015 World Radiocommunication Conference made good progress in identifying additional frequency bands and globally harmonized arrangements below 6 GHz for the operation of IMT, it also recognized a potential future requirement for large contiguous blocks of spectrum at higher frequencies for these systems.

Consequently, it called for 11 frequency bands above24GHz to be studied by ITU-R as bands that may be identified for use by IMT at the World Radiocommunication Conference in 2019 (WRC-19). The frequency bands to be studied are shown in Table 2.1 below.

As can be seen, the different bands span from around 24GHz upto 86GHz. While some of those bands are already allocated for the operation of mobile services in the Radio Regulations, others would require a mobile service allocation in addition to an identification for operation of IMT systems.

The focus of these studies should be to identify a limited subset of these bands that are recommended to be identified globally for use by IMT. The studies on these bands will be conducted in a Task Group of ITU-R Study Group 5, and the results of the studies will be included in the Conference Preparatory Meeting report to the World Radiocommunication Conference 2019.

**Table 2.1** Bands under study for IMT identification by WRC-19

| Existing Mobile Allocation. | No Global Mobile Allocation |
|---|---|
| 24.25 GHz–27.5 GHz | 31.8–33.4 GHz |
| 37–40.5 GHz | 42.5–43.5 GHz |
| 45.5–47 GHz | 47.2–50.2 GHz |
| 50.4–52.6 GHz | 66–76 GHz |
| 81–86 GHz | 40.5–42.5 GHz |
| 47–47.2 GHz | 82 IMTfor2020 and Beyond |

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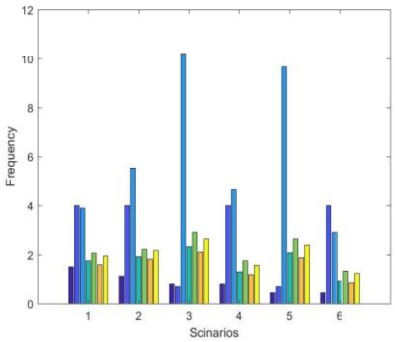
ISSN: 2350-0328

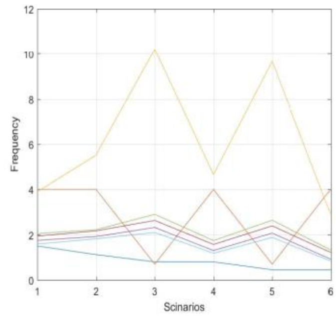
Vol. 12, Issue 7, July 2025

## III.RESULTS AND DISCUSSION

**TABLE 3.1: Mobility evaluation results for different test environments.**

| Scenario | ITURequirement (bit/s/Hz) | Frequency (GHz) | 50%-ileSINR CDF(dB) | Uplink SE(bit/s/Hz) | | | |
|---|---|---|---|---|---|---|---|
| | | | | FDD | | TDD | |
| | | | | NLoS | LoS | NLoS | LoS |
| InH(12TRxP) | 1.5 | 4 | 3.90 | 1.75 | 2.05 | 1-59 | 1.94 |
| UMa | 1.12 | 4 | 5.52 | 1.92 | 2.22 | 1.82 | 2.17 |
| RMa(120km/h) | 0.8 | 0.7<br>4 | 10.21<br>4.66 | 2.32<br>1.30 | 2.90<br>1.74 | 2.10<br>1.18 | 2.63<br>1.57 |
| RMa(500km/h) | 0.45 | 0.7<br>4 | 9.67<br>2.90 | 2.07<br>0.92 | 2.64<br>1.33 | 1.88<br>0.84 | 2.39<br>1.22 |

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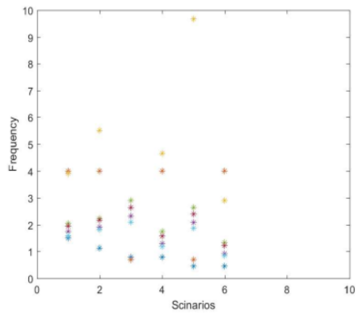


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## IV. CONCLUSIONS

The scope of IMT-2020 is much broader than the previous generations of mobile broadband communication systems. We are talking here about not just an enhancement to the traditional mobile broadband scenarios, but extending the application of this technology to use cases involving ultra-reliable and low latency communications, and massive machine-type communications. The ITU's work in developing the specifications for IMT-2020, in close collaboration with the whole gamut of 5G stake holders, is now well underway, along with the associated spectrum management and spectrum identification aspects. IMT is the enabler of new trends in communication devices– from the connected car and intelligent transport systems to augmented reality, holography, and wearable devices, and a key enabler to meet social needs in the areas of mobile education, connected health and emergency telecommunications. E-applications are transforming the way we do business and govern our countries, and smart cities are pointing the way to cleaner, safer, more comfortable lives in our urban conglomerates. Certainly, IMT-2020 will be a cornerstone for all of the activities related to attaining the goals in the 2030 Agenda for Sustainable Development.

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