Radiocommunication Study Groups

Source: Doc. 5D/TEMP/43 (edited)

Annex 5.4 to
Document 5D/77-E
12 February 2024
English only

Annex 5.4 to Working Party 5D Chairman's Report

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R M.[IMT-2030.TECH PERF REQ]

Minimum requirements related to technical performance for IMT-2030 radio interface(s)

Table of Contents

1 Introduction 3

2 Scope and purpose 3

3 Related ITU-R documents 3

4 Minimum Technical Performance Requirements 4

4.1 Peak data rate 4

4.2 User experienced data rate 5

4.3 Spectrum Efficiency 6

4.3.1 Peak Spectrum Efficiency 6

4.3.2 Average spectrum efficiency 7

4.3.3 5th percentile user spectrum efficiency 8

4.4 Area traffic capacity 9

4.5 Connection Density 10

4.6 Mobility 10

4.6.1 Mobility interruption time 11

4.7 Latency 11

4.7.1 User plane latency 11

4.7.2 Control plane latency 12

4.8 Reliability 12
4.9 Coverage 13
4.10 Positioning.. 13
4.11 Bandwidth 14
4.12 Sensing-related capabilities... 14
4.13 AI-related capabilities... 14
4.14 Sustainability 14
4.15 Security and resilience 16
4.16 Interoperability 16

5 List of acronyms and abbreviations 16

Editor's notes:

A. *The annexes at the end of this main document are for further discussion, and may or may not be included as general text to the main document*

B. *This is a working document. As such, the entire text is considered to be in [square brackets]*

C. *Numbers in square brackets before text (e.g., [66]) refer to the input contribution source document number (e.g., 5D/66)*

D. *Where "M.2410" appears before text it refers to text that is from ITU-R M.2410-0, "Minimum requirements related to technical performance for IMT-2020 radio interface(s)*

E. *Where "M.2160" appears before text it refers to Recommendation ITU-R M.2160-0, "Framework and overall objectives of the future development of IMT for 2030 and beyond"*

1 Introduction

[33][44]

As defined in Resolution ITU-R 56-3, International Mobile Telecommunications-2030 (IMT-2030) systems are mobile systems that include new radio interface(s) which support enhanced capabilities and new capabilities beyond IMT-2020, IMT-Advanced and IMT-2000. In Recommendation ITU-R M.2160 – Framework and overall objectives of the future development of IMT for 2030 and beyond, the capabilities of IMT-2030 are identified, which aims to make IMT-2030 more capable, flexible, reliable and secure than previous IMT systems when providing diverse and novel services in the intended six usage scenarios, including immersive communication, hyper reliable and low-latency communication (HRLLC), massive communication, ubiquitous connectivity, artificial intelligence and communication, and integrated sensing and communication (ISAC).

2 Scope and purpose

[19][22][33][44][48]

This Report describes key requirements related to the minimum technical performance of IMT-2030 candidate radio interface technologies. It also provides the necessary background information about the individual requirements and the justification for the items and values [TBD] to be chosen. Provision of such background information is needed for a broader understanding of the requirements.

[22][33][44]

These key technical performance requirements are used in the development of Report ITU-R M.[EVAL GUIDELINES].

This Report is based on the ongoing development activities of external research and technology organizations.

3 Related ITU-R documents

Resolution ITU-R 56-3

Resolution ITU-R 65-1

Report ITU-R M.2410-0

Recommendation ITU-R M.2160

Report ITU-R M.2516-0

Report ITU-R M.2376-0

Report ITU-R M.2516-0

Report ITU-R M.[IMT.ABOVE 100 GHz]

Report ITU-R M.[IMT-2030.EVAL]

Report ITU-R M.[IMT-2030.SUBMISSION]

Document IMT-2030/1

Document IMT-2030/2

Circular Letter X/LCCE/xxx

4 Minimum Technical Performance Requirements

[33]

As noted in Recommendation ITU-R M.2160, IMT-2030 is expected to provide enhanced capabilities as well as new capabilities compared with those described in Recommendation ITU-R M.2083. In addition, IMT-2030 can be considered from multiple perspectives, including users, manufacturers, application developers, network operators, verticals, and service and content providers. Therefore, it is recognized that technologies for IMT-2030 can be applied in a variety of deployment scenarios and can support a range of environments, service capabilities, and technology options.

The key minimum technical performance requirements defined in this document are for the purpose of consistent definition, specification, and evaluation of the candidate IMT-2030 radio interface technologies (RITs)/Set of radio interface technologies (SRIT) in conjunction with the development of ITU-R Recommendations and Reports, such as the detailed specifications of IMT-2030. The intent of these requirements is to ensure that IMT-2030 technologies are able to fulfil the objectives of IMT-2030 and to set a specific level of performance that each proposed RIT/SRIT needs to achieve in order to be considered by ITU-R for IMT-2030.

These requirements are not intended to restrict the full range of capabilities or performance that candidate RITs/SRITs for IMT-2030 might achieve, nor are they intended to describe how the RITs/SRITs might perform in actual deployments under operating conditions that could be different from those presented in other ITU-R Recommendations and Reports on IMT-2030. Further information on specific industry needs using the terrestrial component of IMT-2030 may be found in other ITU-R Reports on IMT-2030.

Requirements are to be evaluated according to the criteria defined in Report ITU-R M.[IMT-2030.EVAL] and Report ITU-R M.[IMT-2030.SUBMISSION] for the development of IMT-2030.

Recommendation ITU-R M.2160 defines fifteen key "Capabilities of IMT-2030", which form a basis for the [x] technical performance requirements presented here.

4.1 Peak data rate

M.2410

Peak data rate is the maximum achievable data rate under ideal conditions (in bit/s), which is the received data bits assuming error-free conditions assignable to a single mobile station, when all assignable radio resources for the corresponding link direction are utilized (i.e. excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times).

Peak data rate is defined for a single mobile station. In a single band, it is related to the peak spectral efficiency in that band. Let W denote the channel bandwidth and SE_p denote the peak spectral efficiency in that band. Then the user peak data rate R_p is given by:

$$R_p = W \times SE_p \quad (1)$$

Peak spectral efficiency and available bandwidth may have different values in different frequency ranges. In case bandwidth is aggregated across multiple bands, the peak data rate will be summed over the bands. Therefore, if bandwidth is aggregated across Q bands then the total peak data rate is

$$R = \sum_{i=1}^{Q} W_i \times SEp_i \quad (2)$$

where W_i and SEp_i (i = 1,…Q) are the component bandwidths and spectral efficiencies respectively.

This requirement is defined for the purpose of evaluation in the TBD usage scenario.

The minimum requirements for peak data rate are as follows:

– Downlink peak data rate is TBD Gbit/s.

– Uplink peak data rate is TBD Gbit/s.

M.2160

Maximum achievable data rate under ideal conditions per device.

The research target of peak data rate would be greater than that of IMT-2020[1]. Values of 50, 100, 200 Gbit/s are given as possible examples applicable for specific scenarios, while other values may also be considered.

[66]

Editor's Note: It is noted that peak data rate is a popular "marker" for performance, but the value is a theoretical maximum under ideal conditions and is never widely reached in real deployments. The minimum requirement should be chosen with this in mind, not to create exaggerated expectations. The number depends directly on peak spectral efficiency (below) and available bandwidth, making it strongly frequency band dependent. Further discussion will take place on this text.

4.2 User experienced data rate

M.2410

User experienced data rate is the 5% point of the cumulative distribution function (CDF) of the user throughput. User throughput (during active time) is defined as the number of correctly received bits, i.e. the number of bits contained in the service data units (SDUs) delivered to Layer 3, over a certain period of time.

[19] This must be achievable while using full rate encryption of the data channel.

M.2140

In case of one frequency band and one layer of transmission reception points (TRxP), the user experienced data rate could be derived from the 5th percentile user spectral efficiency through equation (3). Let W denote the channel bandwidth and SE_{user} denote the 5th percentile user spectral efficiency. Then the user experienced data rate, R_{user} is given by:

$$R_{user} = W \times SE_{user} \quad (3)$$

In case bandwidth is aggregated across multiple bands (one or more TRxP layers), the user experienced data rate will be summed over the bands.

This requirement is defined for the purpose of evaluation in the related TBD test environment(s).

[1] 20 Gbit/s in Recommendation ITU-R M.2083.

The target values for the user experienced data rate are as follows in the TBD test environment(s):

– Downlink user experienced data rate is TBD Mbit/s.

– Uplink user experienced data rate is TBD Mbit/s.

These values are defined assuming supportable bandwidth as described in Report ITU-R M.[IMT-2030.EVAL] for each test environment. However, the bandwidth assumption does not form part of the requirement. The conditions for evaluation are described in Report ITU-R M.[IMT-2030.EVAL].

M.[2160]

Achievable data rate that is available ubiquitously[2] across the coverage area to a mobile device.

The research target of user experienced data rate would be greater than that of IMT-2020[3]. Values of 300 Mbit/s and 500 Mbit/s are given as possible examples, while other values greater than these examples may also be explored and considered accordingly.

[66]

Editor's note: The user experienced data rate is a metric heavily dependent on the deployment and would be associated with a sufficiently dense base station deployment. It is derived from the 5th percentile user spectral efficiency and depends directly on available bandwidth. Different requirements could be considered for different deployment scenarios.

4.3 Spectrum Efficiency

Editor's note: More discussion is needed as to whether this text below refers to only average spectrum efficiency or other sections in 4.3.

M.2160

Spectrum efficiency refers to average data throughput per unit of spectrum resource and per cell[4].

The research target of spectrum efficiency would be greater than that of IMT-2020. Values of 1.5 and 3 times greater than that of IMT-2020 could be a possible example, while other values greater than these examples may also be explored and considered accordingly.

[19]

4.3.1 Peak Spectrum Efficiency

M.2410

Peak spectral efficiency is the maximum data rate under ideal conditions normalised by channel bandwidth (in bit/s/Hz), where the maximum data rate is the received data bits assuming error-free conditions assignable to a single mobile station, when all assignable radio resources for the corresponding link direction are utilized (i.e. excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times).

---

[2] The term "ubiquitous" is related to the considered target coverage area and is not intended to relate to an entire region or country.

[3] 100 Mbit/s in Recommendation ITU-R M.2083.

[4] The coverage area over which a mobile terminal can maintain a connection with one or more units of radio equipment located within that area. For an individual base station, this is the coverage area of the base station or of a subsystem (e.g. sector antenna).

This requirement is defined for the purpose of evaluation in the TBD usage scenario.

The minimum requirements for peak spectral efficiencies are as follows:

– Downlink peak spectral efficiency is TBD bit/s/Hz.

– Uplink peak spectral efficiency is TBD bit/s/Hz.

These values were defined assuming an antenna configuration to enable TBD spatial layers (streams) in the downlink and TBD spatial layers (streams) in the uplink. However, this does not form part of the requirement and the conditions for evaluation are described in Report ITU-R M.[IMT-2030.EVAL].

[66]

Editors Note: Substantial increase in peak spectral efficiency is not expected based on new modulation and coding schemes, except for possible larger signal constellations (beyond 256-QAM) and increased number of MIMO layers.

Editor's note: This capability was not defined in M.2160.

4.3.2 Average spectrum efficiency

M.[2160]

Spectrum efficiency refers to average data throughput per unit of spectrum resource and per cell[5].

Editors note: More discussion is needed as to whether this text below refers to only average spectrum efficiency or other sections in 4.3.

The research target of spectrum efficiency would be greater than that of IMT-2020. Values of 1.5 and 3 times greater than that of IMT-2020 could be a possible example, while other values greater than these examples may also be explored and considered accordingly.

M.2410

Average spectral efficiency[6] is the aggregate throughput of all users (the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time) divided by the channel bandwidth of a specific band divided by the number of TRxPs and is measured in bit/s/Hz/TRxP.

The channel bandwidth for this purpose is defined as the effective bandwidth times the frequency reuse factor, where the effective bandwidth is the operating bandwidth normalized appropriately considering the uplink/downlink ratio.

Let $R_i(T)$ denote the number of correctly received bits by user i (downlink) or from user i (uplink) in a system comprising a user population of N users and M TRxPs. Furthermore, let W denote the channel bandwidth and T the time over which the data bits are received. The average spectral efficiency, SE_{avg} is then defined according to equation (5).

$$\mathrm{SE}_{\mathrm{avg}} = \frac{\sum_{i=1}^{N} \mathrm{R}_i(T)}{T \cdot \mathrm{W} \cdot M} \tag{5}$$

[5] The coverage area over which a mobile terminal can maintain a connection with one or more units of radio equipment located within that area. For an individual base station, this is the coverage area of the base station or of a subsystem (e.g. sector antenna).

[6] Average spectral efficiency corresponds to “spectrum efficiency” in Recommendation ITU-R M.2160.

This requirement is defined for the purpose of evaluation in the TBD usage scenario.

The minimum requirements for average spectral efficiency for various test environments are summarized in Table 2.

TABLE Y

Average spectral efficiency

The conditions for evaluation including carrier frequency and antenna configuration are described in Report ITU-R M.[IMT-2030.EVAL] for each test environment.

[66]

Editors Note: This is an essential metric that has direct impact on the area traffic capacity achievable. While IMT-2020 spectral efficiency numbers are already high, it is noted that higher numbers could be achievable with an assumption on having more antenna elements.

4.3.3 5th percentile user spectrum efficiency

M.2410

The 5th percentile user spectral efficiency is the 5% point of the CDF of the normalized user throughput. The normalized user throughput is defined as the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time, divided by the channel bandwidth and is measured in bit/s/Hz.

The channel bandwidth for this purpose is defined as the effective bandwidth times the frequency reuse factor, where the effective bandwidth is the operating bandwidth normalized appropriately considering the uplink/downlink ratio.

With $\mathrm{R}_i\,(T_i)$ denoting the number of correctly received bits of user i, T_i the active session time for user i and W the channel bandwidth, the (normalized) user throughput of user i, r_i, is defined according to equation (4).

$$r_i = \frac{\mathrm{R}_i(T_i)}{T_i \cdot \mathrm{W}} \tag{4}$$

This requirement is defined for the purpose of evaluation in the TBD usage scenario.

The minimum requirements for 5th percentile user spectral efficiency for various test environments are summarized in Table 1.

TABLE 1

5th percentile user spectral efficiency

TABLE Y

5th percentile spectrum efficiency

Test Environment	Downlink (bit/s/Hz/)	Uplink (bit/s/Hz/)
A		
B		
…		

The conditions for evaluation including carrier frequency and antenna configuration are described in Report ITU-R M.[IMT-2030.EVAL] for each test environment.

[25]

TABLE Y

5th percentile spectrum efficiency

Test Environment	Downlink (bit/s/Hz/cell)	Uplink (bit/s/Hz/cell)
A		
B		
…		

[66]

Editor’s note: A higher requirement is essential for managing increased traffic and higher user data rates, as it is used as a basis for the user experienced data rate number.

Editor's note: This capability was not defined in M.2160.

4.4 Area traffic capacity

M.2410

Area traffic capacity is the total traffic throughput served per geographic area (in Mbit/s/m^2). The throughput is the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time.

This can be derived for a particular use case (or deployment scenario) of one frequency band and one TRxP layer, based on the achievable average spectral efficiency, network deployment (e.g. TRxP (site) density) and bandwidth.

Let W denote the channel bandwidth and ρ the TRxP density (TRxP/m^2). The area traffic capacity C_{area} is related to average spectral efficiency SE_{avg} through equation (6).

$$C_{area} = \rho \times W \times SE_{avg} \quad (6)$$

In case bandwidth is aggregated across multiple bands, the area traffic capacity will be summed over the bands.

This requirement is defined for the purpose of evaluation in the related TBD test environment.

The target value for Area traffic capacity in downlink is TBD in the– TBD test environment.

The conditions for evaluation including supportable bandwidth are described in Report ITU-R M.[IMT-2030.EVAL] for the test environment.

M.2160

Total traffic throughput served per geographic area.

The research target of area traffic capacity would be greater than that of IMT-2020[7]. Values of 30 Mbit/s/m^2 and 50 Mbit/s/m^2 are given as possible examples, while other values greater than these examples may also be explored and considered accordingly.

[7] 10 Mbit/s/m^2 in Recommendation ITU-R M.2083.

[66]

Editor's note: This is an essential metric that has direct impact on the area traffic capacity achievable. While IMT-2020 spectral efficiency numbers are already high, it is noted that higher numbers could be achievable with an assumption on having more antenna elements.

4.5 Connection Density

M.2410

Connection density is the total number of devices fulfilling a specific quality of service (QoS) per unit area (per km^2).

Connection density should be achieved for a limited bandwidth and number of TRxPs. The target QoS is to support delivery of a message of a certain size within a certain time and with a certain success probability, as specified in Report ITU-R M.[IMT-2030.EVAL].

This requirement is defined for the purpose of evaluation in the TBD usage scenario.

The minimum requirement for connection density is TBD devices per km^2.

M.2160

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

The research target of connection density could be $10^6 – 10^8$ devices/km^2.

Editor's note: The connection density, i.e. devices per area unit, should be complemented with the size of the area that the density applies over. Since device density is use case dependent, multiple areas sizes and related device distributions could be defined.

4.6 Mobility

M.2410

Mobility is the maximum mobile station speed at which a defined QoS can be achieved (in km/h).

The following classes of mobility are defined:

[TBD]

Table 3 defines the mobility classes that shall be supported in the respective test environments.

TABLE 3

Mobility classes

	Test environments for TBD		
Mobility classes supported			

A mobility class is supported if the traffic channel link data rate on the uplink, normalized by bandwidth, is as shown in Table 4. This assumes the user is moving at the maximum speed in that mobility class in each of the test environments.

This requirement is defined for the purpose of evaluation in the TBD usage scenario.

TABLE 4

Traffic channel link data rates normalized by bandwidth

Test environment	Normalized traffic channel link data rate (bit/s/Hz)	Mobility (km/h)

These values were defined assuming an antenna configuration as described in Report ITU-R M.[IMT-2030.EVAL].

Proponents are encouraged to consider higher normalized channel link data rates in the uplink. In addition, proponents are encouraged to consider the downlink mobility performance.

M.2160

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/multi-RAT) can be achieved.

The research target of mobility could be 500 – 1 000 km/h.

4.6.1 Mobility interruption time

M.2410

Mobility interruption time is the shortest time duration supported by the system during which a user terminal cannot exchange user plane packets with any base station during transitions.

The mobility interruption time includes the time required to execute any radio access network procedure, radio resource control signaling protocol, or other message exchanges between the mobile station and the radio access network, as applicable to the candidate RIT/SRIT.

This requirement is defined for the purpose of evaluation in the TBD usage scenarios.

The minimum requirement for mobility interruption time is TBD ms.

Editor’s note: This capability was not defined in M.2160.

4.7 Latency

[66]

Editors note: While low latency is important for several usage scenarios, the contribution from the radio network may not be the bottleneck. Stricter requirement on latency needs to be motivated by convincing use cases, noting that requirements on latency in wired scenarios do not directly translate to wireless.

4.7.1 User plane latency

M.2160

Latency over the air interface refers to the contribution by the radio network to the time from when the source sends a packet of a certain size to when the destination receives it.

The research target of latency (over the air interface) could be 0.1 – 1 ms.

M.2410

User plane latency is the contribution of the radio network to the time from when the source sends a packet to when the destination receives it (in ms). It is defined as the one-way time it takes to successfully deliver an application layer packet/message from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface in either uplink or downlink in the network for a given service in unloaded conditions, assuming the mobile station is in the active state.

This requirement is defined for the purpose of evaluation in the TBD usage scenarios.

The minimum requirements for user plane latency are:

– TBD ms for TBD

assuming unloaded conditions (i.e. a single user) for TBD IP packets), for both downlink and uplink.

4.7.2 Control plane latency

M.2410

Control plane latency refers to the transition time from a most “battery efficient” state (e.g. Idle state) to the start of continuous data transfer (e.g. Active state).

This requirement is defined for the purpose of evaluation in the TBD usage scenarios.

The minimum requirement for control plane latency is TBD ms. Proponents are encouraged to consider lower control plane latency, e.g. TBD ms

[19]

More specific transition times can be considered, for example related to trigger-response reconnection time, referring to the time from which a device receives a trigger (ping, page, etc.), to when the UE reconnects to the network and receives Mobile Terminating (MT) traffic. This can be relevant for LPWA use cases.

Editor's note: This capability was not defined in M.2160.

[22]

4.8 Reliability

M.2410

Reliability relates to the capability of transmitting a given amount of traffic within a predetermined time duration with high success probability.

Reliability is the success probability of transmitting a layer 2/3 packet within a required maximum time, which is the time it takes to deliver a TBD data packet from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface at a certain channel quality.

This requirement is defined for the purpose of evaluation in the TBD usage scenario.

The minimum requirement for the reliability is TBD success probability of transmitting a layer 2 PDU (protocol data unit) of TBD bytes within TBD ms in channel quality of coverage edge for the TBD test environment, assuming TBD application data .

M.2160

Reliability over the air interface relates to the capability of transmitting successfully a predefined amount of data within a predetermined time duration with a given probability.

The research target of reliability (over the air interface) could range from $1\text{-}10^{-5}$ to $1\text{-}10^{-7}$.

[66]

Editor's note: While the minimum requirements for IMT-2020 was set for small packets, including higher data rates would reflect more relevant scenarios. Such scenarios could be defined by a combined requirement on latency, reliability and data rate.

4.9 Coverage

M.2160

Coverage refers to the ability to provide access to communication services for users in a desired service area. In the context of this capability, coverage is defined as the cell edge distance of a single cell through link budget analysis.

[25]

Editor's note: The minimum requirements for coverage for test environment(s) are summarized in Table TBD.

[66]

Editor's note: While the IMT-2020 link budget analysis was for information and without a requirement, coverage is now defined as an IMT-2030 capability. A TPR could be defined for a RIT to support a certain communication quality, which could be a combination of bitrate, delay, and reliability, at a given radio link quality. How to deploy networks and what radio link and communication quality to support would be up to the network operator and not defined by the requirement.

4.10 Positioning

M.2160

Positioning is the ability to calculate the approximate position of connected devices. Positioning accuracy is defined as the difference between the calculated horizontal/vertical position and the actual horizontal/vertical position of a device.

[66]

Editor's note: For positioning of active/connected objects, minimum requirements should be defined for a limited number of use cases. It is noted that the positioning performance depends on the geometry and density of transmitters and receivers. Furthermore, the positioning signals typically need to be heard from/at multiple sites, which will impact the minimum required signal strength/quality at the receiver. Thus, deployment with advantageous (serving cell) connectivity does not in itself guarantee good positioning performance. Additionally, both horizontal and vertical positioning accuracy are important, at least for some use cases.

It is further noted that positioning accuracy on cm-level may only be reached in some specific environments and deployments.

4.11 Bandwidth

M.2410

Bandwidth is the maximum aggregated system bandwidth. The bandwidth may be supported by single or multiple radio frequency (RF) carriers. The bandwidth capability of the RIT/SRIT is defined for the purpose of IMT-2030 evaluation.

The requirement for bandwidth is TBD.

Editor's note: This capability was not defined in M.2160. The RIT/SRIT may support scalable bandwidth. Scalable bandwidth is the ability of the candidate RIT/SRIT to operate with different bandwidths.

4.12 Sensing-related capabilities

M.2160

Sensing-related capabilities refer to the ability to provide functionalities in the radio interface including range/velocity/angle estimation, object detection, localization, imaging, mapping, etc. These capabilities could be measured in terms of accuracy, resolution, detection rate, false alarm rate, etc.

[66]

Editor's note: In a first step, the objective of sensing and the related sensing tasks need to be defined, applicable for a limited number of use cases (e.g., Smart home, Transport, Industry, UAV). Some examples of sensing tasks are presence/absence detection, localisation of passive/non-connected objects, velocity/direction estimation, distance estimation, condition detection (e.g., weather), etc.

For the supported sensing tasks, a limited set of performance metrics should to be determined for characterizing overall sensing performance. In the next step test environments would be defined, where the performance is constrained by the deployment geometry and density.

4.13 AI-related capabilities

M.2160

Applicable AI-related capabilities refer to the ability to provide certain functionalities throughout IMT-2030 to support AI enabled applications. These functionalities include distributed data processing, distributed learning, AI computing, AI model execution and AI model inference, etc.

[66]

Editors note: The TPR should relate to the functionalities needed to support AI-enabled applications, as stated in Recommendation ITU-R M.2160 and would thus consist of functional requirements on the RIT for providing those functionalities. Such requirements could be evaluated by analysis or inspection of the RIT as part of the submission template and would most likely be qualitative in nature.

4.14 Sustainability

M.2410

Network energy efficiency is the capability of a RIT/SRIT to minimize the radio access network energy consumption in relation to the traffic capacity provided. Device energy efficiency is the capability of the RIT/SRIT to minimize the power consumed by the device modem in relation to the traffic characteristics.

Energy efficiency of the network and the device can relate to the support for the following two aspects:

a) Efficient data transmission in a loaded case;

b) Low energy consumption when there is no data.

Efficient data transmission in a loaded case is demonstrated by the average spectral efficiency (see § 4.5).

Low energy consumption when there is no data can be estimated by the sleep ratio. The sleep ratio is the fraction of unoccupied time resources (for the network) or sleeping time (for the device) in a period of time corresponding to the cycle of the control signaling (for the network) or the cycle of discontinuous reception (for the device) when no user data transfer takes place. Furthermore, the sleep duration, i.e. the continuous period of time with no transmission (for network and device) and reception (for the device), should be sufficiently long.

This requirement is defined for the purpose of evaluation in the TBD usage scenario.

The RIT/SRIT shall have the capability to support a high sleep ratio and long sleep duration. Proponents are encouraged to describe other mechanisms of the RIT/SRIT that improve the support of energy efficient operation for both network and device.

M.2160

Sustainability, or more specifically environmental sustainability, refers to the ability of both the network and devices to minimize greenhouse gas emissions and other environmental impacts throughout their life cycle. Important factors include improving energy efficiency, minimizing energy consumption and the use of resources, for example by optimizing for equipment longevity, repair, reuse and recycling.

Energy efficiency is a quantifiable metric of sustainability. It refers to the quantity of information bits transmitted or received, per unit of energy consumption (in bit/Joule). Energy efficiency is expected to be improved appropriately with the capacity increase in order to minimize overall power consumption.

[25]

Some Quantifiable metrics for sustainability may be:

– Energy efficiency: It refers to the quantity of information bits transmitted or received, per unit of energy consumption (in bit/Joule)

– Network energy efficiency: [TBD]

– Device energy efficiency: [TBD]

– Waveform efficiency: [TBD].

[66]

Editors Note: Sustainability in its broader definition covering economic, social and environmental aspects may be difficult to define as a TPR that can be evaluated by inspection, analysis or simulation of the RIT. Description of impact from the RIT on sustainability could however be a mandatory part of the submission template.

The IMT-2020 requirement for "low energy consumption when there is no data" from Report ITU-R M.2410 is a good reference, but the IMT-2030 requirement should be quantified in nature.

It is also essential that energy efficiency is not severely hampered by the capabilities of the RIT to operate in different usage scenarios such as Integrated Sensing, hRLLC or Ubiquitous connectivity.

4.15 Security and resilience

M.2160

In the context of IMT-2030:

– Security refers to preservation of confidentiality, integrity, and availability of information, such as user data and signaling, and protection of networks, devices and systems against cyberattacks such as hacking, distributed denial of service, man in the middle attacks, etc.
– Resilience refers to capabilities of the networks and systems to continue operating correctly during and after a natural or man-made disturbance, such as the loss of primary source of power, etc.

4.16 Interoperability

M.2160

Interoperability refers to the radio interface being based on member-inclusivity and transparency, so as to enable functionality(ies) between different entities of the system.

5 List of acronyms and abbreviations

HRLLC Hyper-reliable and low-latency communications

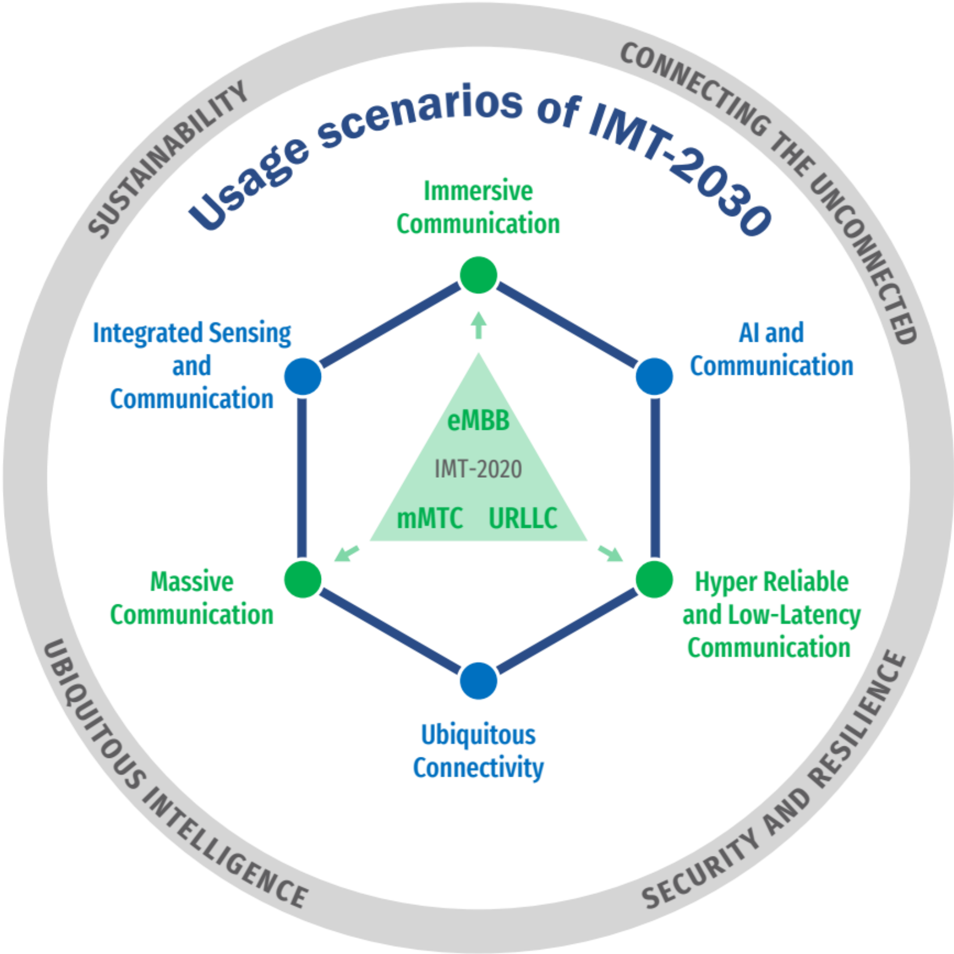
ISAC Integrated sensing and communication

RIT Radio interface technology

SRIT Set of radio interface technologies

ANNEX 1

Mapping between capabilities (TPRs) and usage scenarios



[25]

TABLE 1

Proposed Mapping between the Usage Scenarios and Capabilities

Capabilities \ Usage Scenario		Ubiquitous Communi-cations	Immersive Communi-cations	Massive Communi-cations	Hyper Reliability and Low Latency Communication	Artificial Intelligence and Communication	Integrated Sensing and Communication
Peak data rate		[No]	[Yes]	[No]	[No]	[TBD]	[TBD]
User experienced data rate		[TBD]	[Yes]	[No]	[No]	[TBD]	[TBD]
Spectrum efficiency	Average	[TBD]	[Yes]	[No]	[No]	[TBD]	[TBD]
	Peak	[No]	[Yes]	[No]	[No]	[TBD]	[TBD]
	5th percen-tile	[Yes]	[Yes]	[No]	[No]	[TBD]	[TBD]
Area traffic capacity		[TBD]	[Yes]	[No]	[No]	[TBD]	[TBD]
Connection Density		[TBD]	[No]	[Yes]	[No]	[TBD]	[TBD]
Mobility		[Yes]	[Yes]	[No]	[No]	[TBD]	[TBD]
Latency		[No]	[Yes]	[No]	[Yes]	[Yes]	[Yes]
Reliability		[No]	[No]	[Yes]	[Yes]	[Yes]	[Yes]
Coverage		[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]
Positioning		[TBD]	[No]	[No]	[No]	[TBD]	[Yes]
Sensing-related capabilities		[TBD]	[No]	[No]	[No]	[TBD]	[Yes]
Applicable AI-related capabilities		[TBD]	[No]	[No]	[No]	[Yes]	[TBD]
Security and resilience		[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]
Sustainability		[Yes]	[Yes]	[Yes]	[Yes]	[Yes]	[Yes]
Interoperability		[TBD]	[TBD]	[TBD]	[TBD]	[TBD]	[TBD]

NOTE: The above proposed mapping serves as a guidance towards further research requiring to determine the exact mapping.

[44]

TABLE 2

Example of relevance mapping table

Capabilities	Usage Scenarios					
	Immersive Communication	Hyper Reliable and Low Latency Communication	Massive Communication	Ubiquitous Connectivity	AI and Communication	Integrated Sensing and Communication
Peak data rate	V					
User experienced data rate	V				V	
Spectrum efficiency	V					
Area traffic capacity	V				V	
Connection density			V			
Mobility	V	V		V		
Latency	V	V				
Reliability		V				
Security and resilience	V	V	V		V	[V]
Coverage	V	[V]	V	V		
Positioning		V	V			V
Sensing-related capabilities		V	[V]			V
Applicable AI-related capabilities	V				V	V
Sustainability	V		V			
Interoperability				[V]		

The Republic of Korea is of the view that this table-based approach would be useful for productive discussion. Therefore, it might be incorporated into the Annex in the working document towards preliminary draft new Report ITU-R M.[IMT-2030.TECH PERF REQ], and detailed aspects such as criteria for determining the relevance, list of capabilities, and how to reflect the mapping table into the new Report could be discussed further. Lastly, taking into account the entire workplan for the development of the Report, we are of the view that it would be great to finalize the discussion for mapping no later than 46th meeting of WP 5D.

ANNEX 2

Additional Text from contributions to WP 5D #45

Editor's note: General introductory text has been excluded from this Annex.

[24]

Considering the above and to ensure efficient development of the new Report of TPR for IMT-2030, ETRI would like to propose several principles as follows:

– Both the structure (ToC) and the contents of the TPR, particularly the definitions of required capabilities, should reference and expand upon Report ITU-R M.2410, the analogous TPR for IMT-2020. Because this established document not only provides a valuable foundation for IMT-2030, but also ensures continuity and enables comparisons between IMT-2020 and IMT-2030. However, necessary modifications and new definitions can be made or introduced to address the unique characteristics of IMT-2030.

– While Recommendation ITU-R M.2160 outlines a comprehensive framework for IMT-2030, it leaves key capabilities without fully defined technical performance indicators and target values particularly sensing, AI, sustainability, and interoperability. To address this gap, Table 1 presents a starting point for discussion, listing possible performance indicators alongside relevant information for each capability. Further discussions are needed to address the following issues.

  • To effectively assess capabilities, while reducing burdens on evaluation efforts, selecting one or two performance indicators that play crucial representative roles could be considered.

  • Not all capabilities require corresponding technical performance indicators. Some capabilities in Recommendation ITU-R M.2160 may be inherently sufficient, even without explicit technical performance indicators to highlight their importance and significance.

TABLE 1

Potential performance indicators

Capability	Possible technical performance indicator	Evaluation type	Comments
Sensing-related	Accuracy of sensing (positioning, velocity, etc.) estimate	Quantifiable	Performance indicators could be assessed by quantifiable, analytical or inspected manner. Most of the RAN's power consumption is due to the active antenna units (AAUs) in gNBs, energy-saving should
	Confidence level	Quantifiable	
	Missed detection probability	Quantifiable	
	False alarm probability	Quantifiable	
	Max sensing service latency	Quantifiable	
	Refreshing rate	Quantifiable	
AI-related	Performance enhancement (in terms of throughput, accuracy, etc.)	Quantifiable	
	Inference latency	Quantifiable	
	Computational complexity	Analytical	

Capability	Possible technical performance indicator	Evaluation type	Comments
	Capability of providing inference as a service	Inspection (Y/N)	be assessed on the gNB side.
	Capability of automation (in terms of RAN configuration, OAM, performance enhancement, etc. with no or reducing human intervention)	Inspection (Y/N)	
Sustainability	Energy consumption per symbol or slot (in non-sleep mode)	Quantifiable	
	Controllability of power states (sleep, active DL, active UL, cell shutdown, etc.)	Quantifiable or Inspection (Y/N)	
Interoperability	Availability of open and standardized interfaces and protocols	Inspection (Y/N)	
	Availability of reference components for enhancing transparency and facilitating interoperability	Inspection (Y/N)	

– In the Report ITU-R M.2410, the target values of KPIs like spectral efficiency and mobility vary significantly with regard to the link type (downlink/uplink) and test environment. In Report ITU-R M.2410, the test environment is defined by a combination of geographic characteristics and usage scenario. The number of test environments for IMT-2020 is limited to five. With the IMT-2030 encompassing six usage scenarios (three usage scenarios in IMT-2020), more than five number of test environments are likely. To ensure more efficient and comprehensive development of TPR for IMT-2030, discussions on the test environments should begin early, even before the start of the development of new Report regarding "Evaluation criteria & Methodology".

[64]

The capabilities of IMT-2030 are defined in Recommendation ITU-R M.2160, where some are currently listed with a range of values. WP 5D is now expected to define Technical Performance Requirements (TPR) for the capabilities, which then need to be mapped to usage scenarios and test environments (refer to section 4 of Rec. ITU-R M.2160).

It should be recognized that some of these TPRs can be expressed and evaluated quantitatively, whereas others can only be expressed and evaluated qualitatively. Few capabilities that won't be evaluated may have to be left out of this Report (without having associated TPRs).

In furthering this work within WP 5D, we offer the below considerations:

1) One of the first steps for WP 5D is to establish the association of IMT-2030 capabilities with usage scenarios. Compared to IMT-2020, IMT-2030 introduces six new capabilities and altogether six usage scenarios, three of which are based on IMT-2020 usage scenarios.

2) The IMT-2030 usage scenarios of Immersive Communication, Hyper Reliable and Low-Latency Communication, as well as Massive Communication are extensions of IMT-2020 usage scenarios (eMBB, URLLC, and mMTC, respectively). Therefore, it is expected that the associated IMT-2020 TPRs are still largely relevant, after necessary review and modifications of values and their associated test environments.

3) As for the new IMT-2030 capabilities, it needs to be identified which usage scenario(s) they are associated with, if any, and then TPRs are to be defined. There could also be cases where new TPRs need to be added.

3) For the new usage scenarios (Ubiquitous Connectivity, AI and Communication, and Integrated Sensing and Communication), further study is needed to assess whether and how to associate them with IMT-2030 TPRs.

[66]

The Annex to this contribution gives a list of proposed Technical Performance Requirements (TPR) for the draft new Report ITU-R M.[IMT-2030.TECH PERF REQ]. The list is based on the IMT-2030 Capabilities listed in Recommendation ITU-R M.2160, while applying the experience from developing the IMT-2020 TPR documented in Report ITU-R M.2410. The following changes and additions were applied to the capabilities:

- *Peak spectral efficiency* is added as a standalone TPR, which is used to derive Peak data rate.
- Spectrum efficiency is expressed as two TPR: *5th percentile user spectral efficiency* and *Average spectral efficiency*.
- Latency is expressed as two TPR: *User plane latency* and *Control plane latency*.
- *Mobility interruption time* is added from Report ITU-R M.2410.
- *Bandwidth* is added from Report ITU-R M.2410.

For each TPR there is a proposal in brackets ("<…>") giving a first assumption for the TPR definition. For some TPR, considerations are given as input to the further work needed to set the TPR scope, detailed definition, and minimum requirements.

[67]

The next phase (2024-2027) will be the definition of relevant requirements and evaluation criteria for potential radio interface technologies (RIT) for IMT-2030. This phase is expected to provide precise technical specifications essential for realizing the envisioned capabilities of 6G technology.

When defining the evaluation criteria (KPIs) of certain capabilities qualitative metrics or analysis will have to be considered.

In general, quantitative analysis can provide the causal or correlational relationship between variables through testing hypotheses, whereas qualitative analysis provides an understanding of the phenomenon within a real-world context.

Qualitative analysis is the process of analysing and interpreting data which may be non-numeric, conceptual information, themes, and patterns. Qualitative measurement involves evaluating the efficacy of outcomes through non-numeric data through the use of experiences, perceptions, and behaviours. Qualitative data is defined as data that approximates and characterizes. Analysing qualitative data can be tricky as it largely remains the province of human analysts and is prone to the degree of contextual understanding and social intelligence.

There are different ways in which qualitative analysis can be achieved, a few are listed below:

1) Content analysis: Content analysis is a qualitative research method that examines and quantifies the presence of certain words, subjects, and concepts in text, image, video, or audio messages. The method transforms qualitative input into quantitative data to help you make reliable conclusions.

2) Thematic analysis: Thematic analysis helps you identify, categorize, analyse, and interpret patterns in qualitative study data,

3) Others such as Narrative analysis, Grounded theory analysis etc.

Importantly Qualitative data can also be mapped to Quantitative data subject to certain correctness that one might agree to. Qualitative data can also be mapped to certain static well understood outcomes and the nature of what approach to choose can be discussed in subsequent meetings / email discussions.

The agreed Capability items as per IMT-2030 framework are listed below.

Sr	**Capability items**	**Range of values**
1	Peak data rate	Greater than that of 5G (e.g., 50, 100, and 200 Gbit/s)
2	Spectrum efficiency	Greater than that of 5G (e.g., 1.5 and 3 times of 5G)
3	Connection density	106-108 devices/km²
4	Latency	0.1-1 ms
5	User experienced data rate	Greater than that of 5G (e.g., 300 and 500 Mbit/s)
6	Area traffic capacity	Greater than that of 5G (e.g., 30 and 50 Mbit/s/m²
7	Mobility	500-1,000 km/h
8	Reliability	(1-105) - (1-107)
9	Positioning	1-10 cm
10	Al-related capabilities	To be defined in TPR phase
11	Sustainability	To be defined in TPR phase
12	Coverage	To be defined in TPR phase
13	Sensing-related capabilities	To be defined in TPR phase
14	Security, privacy, and resilience	To be defined in TPR phase
15	Interoperability	To be defined in TPR phase

It can be easily understood that the below capabilities are best quantified via Qualitative Methods.

Proposal

Qualitative analysis / KPIs shall be explored / defined where necessary and specifically for the below capabilities.

10	Al-related capabilities	To be defined in TPR phase
11	Sustainability	To be defined in TPR phase
12	Coverage	To be defined in TPR phase
13	Sensing-related capabilities	To be defined in TPR phase
14	Security, privacy, and resilience	To be defined in TPR phase
15	Interoperability	To be defined in TPR phase

The below example provides an example of earlier work in ITU using Qualitative analysis for QoE analysis. Provided here just as an example.

Earlier ITU has earlier classified Quantification of QoE by the use of qualitative factors. Traditionally, QoE has been evaluated through subjective tests carried out on the users in order to assess their satisfaction degree with a mean opinion score (MOS) value. It defines the quality perceived subjectively by the end user, and it is defined by qualitative parameters, named Key Quality Indicators (KQI), such as "very good", "good", "poor", but these can also be deduced from the quantitative parameters. A QoE Influencing Factors (IF) has been defined as “any characteristic of a user, system, service, application, or context whose actual state or setting may have influence on the Quality of Experience for the user".

The QoE IFs had been put into the following three categories:

Human IFs	The characteristic can describe the demographic and socioeconomic background, the physical and mental constitution, or the user's emotional state (e.g., user's visual and auditory acuity, gender, age, motivation, education background, emotions).
System IFs	Refer to properties and characteristics that determine the technically produced quality of an application or service. They are related to media capture, coding, transmission, storage, rendering, and reproduction/display, as well as to the communication of information itself from content production to user (e.g., bandwidth, delay, jitter, loss, throughput, security, display size, resolution).
Context IFs	Defined as factors that embrace any situational property to describe the user's environment in terms of physical, temporal, social, economic, task, and technical characteristics" (e.g., location, movements, time of day, costs, subscription type, privacy).

Further the above IFs have been mapped to certain desired outcomes (QoE qualifiers) through mapping functions.