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(11/2017)

Minimum requirements related to technical performance for IMT-2020 radio interface(s)

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

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REPORT ITU-R M.2410-0

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(2017)

1 Introduction

As defined in Resolution ITU-R 56-2, International Mobile Telecommunications-2020 (IMT-2020) systems are mobile systems that include new radio interface(s) which support the new capabilities of systems beyond IMT-2000 and IMT-Advanced. In Recommendation ITU-R M.2083 – IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond, the capabilities of IMT-2020 are identified, which aim to make IMT-2020 more flexible, reliable and secure than previous IMT when providing diverse services in the intended three usage scenarios, including enhanced mobile broadband (eMBB), ultra-reliable and low-latency communications (URLLC), and massive machine type communications (mMTC).

2 Scope and purpose

This Report describes key requirements related to the minimum technical performance of IMT-2020 candidate radio interface technologies. It also provides the necessary background information about the individual requirements and the justification for the items and values chosen. Provision of such background information is needed for a broader understanding of the requirements.

These key technical performance requirements are used in the development of Report ITU-R M.2412-0.

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

3 Related ITU-R documents

Resolution ITU-R 56-2

Resolution ITU-R 65

Recommendation ITU-R M.2083-0

Report ITU-R M.2320-0

Report ITU-R M.2376-0

Report ITU-R M.2411-0

Report ITU-R M.2412-0

4 Minimum Technical Performance Requirements

As noted in Recommendation ITU-R M.2083, IMT-2020 is expected to provide far more enhanced capabilities than those described in Recommendation ITU-R M.1645, and these enhanced capabilities could be regarded as new capabilities of future IMT. In addition, IMT-2020 can be considered from multiple perspectives, including the users, manufacturers, application developers, network operators, and service and content providers. Therefore, it is recognized that technologies for IMT-2020 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-2020 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-2020. The intent of these requirements is to ensure that IMT-2020 technologies are able to fulfil the objectives of IMT-2020 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-2020.

These requirements are not intended to restrict the full range of capabilities or performance that candidate RITs/SRITs for IMT-2020 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-2020.

Further information on specific industry needs using the terrestrial component of IMT-2020 may be found in other ITU-R Reports on IMT-2020.

Requirements are to be evaluated according to the criteria defined in Report ITU-R M.2412-0 and Report ITU-R M.2411-0 for the development of IMT-2020.

Recommendation ITU-R M.2083 defines eight key "Capabilities for IMT-2020", which form a basis for the 13 technical performance requirements presented here. Recommendation ITU-R M.2083 also recognizes that the key capabilities will have different relevance and applicability for the different usage scenarios addressed by IMT-2020.

4.1 Peak data rate

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 eMBB usage scenario.

The minimum requirements for peak data rate are as follows:

– Downlink peak data rate is 20 Gbit/s.

– Uplink peak data rate is 10 Gbit/s.

4.2 Peak spectral efficiency

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).

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

The minimum requirements for peak spectral efficiencies are as follows:

– Downlink peak spectral efficiency is 30 bit/s/Hz.

– Uplink peak spectral efficiency is 15 bit/s/Hz.

These values were defined assuming an antenna configuration to enable eight spatial layers (streams) in the downlink and four 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.2412-0.

4.3 User experienced data rate

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.

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:

$$R_{user} = W \times SE_{user} \tag{3}$$

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 eMBB test environment.

The target values for the user experienced data rate are as follows in the Dense Urban – eMBB test environment:

– Downlink user experienced data rate is 100 Mbit/s.

– Uplink user experienced data rate is 50 Mbit/s.

These values are defined assuming supportable bandwidth as described in Report ITU-R M.2412-0 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.2412-0.

4.4 5th percentile user spectral efficiency

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 $R_i(T_i)$ 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).

$$r_i = \frac{R_i(T_i)}{T_i \cdot W} \tag{4}$$

This requirement is defined for the purpose of evaluation in the eMBB 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

Test environment	**Downlink (bit/s/Hz)**	**Uplink (bit/s/Hz)**
Indoor Hotspot – eMBB	0.3	0.21
Dense Urban – eMBB (NOTE 1)	0.225	0.15
Rural – eMBB	0.12	0.045

NOTE 1 – This requirement will be evaluated under Macro TRxP layer of Dense Urban – eMBB test environment as described in Report ITU-R M.2412-0.

The performance requirement for Rural-eMBB is not applicable to Rural-eMBB LMLC (low mobility large cell) which is one of the evaluation configurations under the Rural- eMBB test environment.

The conditions for evaluation including carrier frequency and antenna configuration are described in Report ITU-R M.2412-0 for each test environment.

4.5 Average spectral efficiency

Average spectral efficiency[1] 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).

$$SE_{avg} = \frac{\sum_{i=1}^{N} R_i(T)}{T \cdot W \cdot M} \qquad (5)$$

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

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

[1] Average spectral efficiency corresponds to “spectrum efficiency” in Recommendation ITU-R M.2083.

TABLE 2

Average spectral efficiency

Test environment	Downlink (bit/s/Hz/TRxP)	Uplink (bit/s/Hz/TRxP)
Indoor Hotspot – eMBB	9	6.75
Dense Urban – eMBB (Note 1)	7.8	5.4
Rural – eMBB	3.3	1.6

NOTE 1 – This requirement applies to Macro TRxP layer of the Dense Urban – eMBB test environment as described in Report ITU-R M.2412-0.

The performance requirement for Rural-eMBB is also applicable to Rural-eMBB LMLC which is one of the evaluation configurations under the Rural- eMBB test environment. The details (e.g. 8 km inter-site distance) can be found in Report ITU-R M.2412-0.

The conditions for evaluation including carrier frequency and antenna configuration are described in Report ITU-R M.2412-0 for each test environment.

4.6 Area traffic capacity

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).

$$C_{area} = \rho \times W \times SE_{avg} \tag{6}$$

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 eMBB test environment.

The target value for Area traffic capacity in downlink is 10 Mbit/s/m^2 in the Indoor Hotspot – eMBB test environment.

The conditions for evaluation including supportable bandwidth are described in Report ITU-R M.2412-0 for the test environment.

4.7 Latency

4.7.1 User plane latency

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 eMBB and URLLC usage scenarios.

The minimum requirements for user plane latency are:

– 4 ms for eMBB

– 1 ms for URLLC

assuming unloaded conditions (i.e. a single user) for small IP packets (e.g. 0 byte payload + IP header), for both downlink and uplink.

4.7.2 Control plane latency

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 eMBB and URLLC usage scenarios.

The minimum requirement for control plane latency is 20 ms. Proponents are encouraged to consider lower control plane latency, e.g. 10 ms.

4.8 Connection density

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.2412-0.

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

The minimum requirement for connection density is 1 000 000 devices per km^2.

4.9 Energy efficiency

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 eMBB 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.

4.10 Reliability

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 small 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 URLLC usage scenario.

The minimum requirement for the reliability is $1\text{-}10^{-5}$ success probability of transmitting a layer 2 PDU (protocol data unit) of 32 bytes within 1 ms in channel quality of coverage edge for the Urban Macro-URLLC test environment, assuming small application data (e.g. 20 bytes application data + protocol overhead).

Proponents are encouraged to consider larger packet sizes, e.g. layer 2 PDU size of up to 100 bytes.

4.11 Mobility

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:

– Stationary: 0 km/h

– Pedestrian: 0 km/h to 10 km/h

– Vehicular: 10 km/h to 120 km/h

– High speed vehicular: 120 km/h to 500 km/h.

High speed vehicular up to 500 km/h is mainly envisioned for high speed trains. Table 3 defines the mobility classes that shall be supported in the respective test environments.

TABLE 3

Mobility classes

	Test environments for eMBB		
	Indoor Hotspot – eMBB	**Dense Urban – eMBB**	**Rural – eMBB**
Mobility classes supported	Stationary, Pedestrian	Stationary, Pedestrian, Vehicular (up to 30 km/h)	Pedestrian, Vehicular, High speed vehicular

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 eMBB 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)
Indoor Hotspot – eMBB	1.5	10
Dense Urban – eMBB	1.12	30
Rural – eMBB	0.8	120
	0.45	500

These values were defined assuming an antenna configuration as described in Report ITU-R M.2412-0.

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.

4.12 Mobility interruption time

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 signalling 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 eMBB and URLLC usage scenarios.

The minimum requirement for mobility interruption time is 0 ms.

4.13 Bandwidth

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-2020 evaluation.

The requirement for bandwidth is at least 100 MHz.

The RIT/SRIT shall support bandwidths up to 1 GHz for operation in higher frequency bands (e.g. above 6 GHz).

Proponents are encouraged to consider extensions to support operation in wider bandwidths considering the research targets expressed in Recommendation ITU-R M.2083.

The RIT/SRIT shall support scalable bandwidth. Scalable bandwidth is the ability of the candidate RIT/SRIT to operate with different bandwidths.

5 List of acronyms and abbreviations

CDF Cumulative distribution function

eMBB Enhanced mobile broadband

LMLC Low mobility large cell

mMTC Massive machine type communications

PDU Protocol data unit

QoS Quality of service

RIT	Radio interface technology
SDU	Service data unit
SRIT	Set of radio interface technologies
TRxP	Transmission reception point
URLLC	Ultra-reliable and low-latency communications

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