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Vision, requirements and evaluation guidelines for satellite radio interface(s) of IMT-2020

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

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Note*: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R M.2514-0

Vision, requirements and evaluation guidelines for satellite radio interface(s) of IMT-2020[1]

(2022)

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[1] This vision, requirements and evaluation guidelines document may not apply to TDD systems operating in the 1 616 to 1 626.5 MHz frequency band.

1 Introduction

As defined in Resolution ITU-R 56, 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. Based on Recommendation ITU-R M.2083, the capabilities of IMT-2020, include three service categories i.e. enhanced Mobile Broadband (eMBB), massive Machine Type Communications (mMTC) and ultra-Reliable and Low Latency Communications (URLLC) which are defined to support the multitude of applications and services for IMT-2020. The specific minimum technical requirements for these service categories (eMBB, mMTC, URLLC) are defined in Report ITU-R M.2410. In Recommendation ITU-R M.2083 – IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond, it is presented that various access technologies including a combination of different fixed, terrestrial and satellite networks should interwork in IMT-2020. Each component should fulfil its own role, but also be integrated[2] with other components to provide service continuity as well as reinforced availability to achieve ubiquitous seamless coverage.

Regarding the development of terrestrial radio interface(s) of IMT-2020, the ITU-R has already developed Recommendations ITU-R M.2083, ITU-R M.2150 and Reports ITU-R M.2320, ITU-R M.2376, ITU-R M.2410, ITU-R M.2411 and ITU-R M.2412 in order to define service and minimum technical requirements and present evaluation guidelines and criteria for the terrestrial radio interface(s) of IMT-2020. This sequence of Reports and Recommendations could serve as a model for work on the satellite radio interfaces of satellite IMT-2020.

It is envisioned that the satellite use cases and technical requirements for the satellite radio interface for IMT-2020 will differ from that of the terrestrial interface of IMT-2020 developed in 2017. The use and objective of satellite radio interfaces is expected to be complementary to terrestrial IMT-2020 operations, given satellites’ unique ability to address coverage challenges and use-cases. Certain aspects of IMT-2020 are not expected to be served by the satellite radio interface for IMT-2020, for example very high data throughputs of eMBB, very high connection density of mMTC and low latency for URLLC, given the inherent distance of satellites to associated terminals or earth stations and the challenge of resulting greater latency compared to terrestrial operations. Therefore, the requirements and evaluation guidelines developed previously for the terrestrial component of IMT-2020 may be considered for the development of satellite radio interface(s) of IMT-2020 and modified considering specific satellite characteristics, such as modified throughput and user data rates, as necessary.

The new satellite-based service categories are reflected in the enhanced Mobile Broadband (eMBB-s), massive Machine Type Communications (mMTC-s) and High Reliability Communications (HRC-s) usage scenarios for the satellite component of IMT-2020. It is to be noted that these usage scenarios have been and are being provided by mobile satellite networks and systems, without these satellite services being part of the satellite component of IMT.

The vision presented in this Report for the satellite radio interface for IMT-2020 identifies new capabilities beyond that of the requirements defined for the satellite radio interface of IMT-Advanced in Report ITU-R M.2176.

2 Purpose and scope

The purpose of this Report is to build a vision, the requirements and evaluation guidelines for the satellite component of IMT-2020 including use cases, application scenarios, capabilities, system,

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[2] Integration means that the satellite and terrestrial components of the network are able to work together seamlessly to provide coverage continuity to end users.

radio interface, and the considered specific features, particularly with respect to service and technical requirements.

3 Structure of the Report

– Section 4 provides a list of the documents that are related to this Report.
– Section 5 provides a list of acronyms and abbreviations.
– Section 6 describes visions on the satellite component of IMT-2020.
– Section 7 defines requirements for the satellite radio interface(s) of IMT-2020.
– Section 8 provides guidelines for evaluation of candidate satellite radio interface(s) of IMT-2020.

4 Related ITU-R and ITU-T documents

Recommendation ITU-R M.1182

Recommendation ITU-R M.1822

Recommendation ITU-R M.1850

Recommendation ITU-R M.2083

Recommendation ITU-R M.2047

Recommendation ITU-R M.2150

Report ITU-R M.2410

Report ITU-R M.2412

Report ITU-R M.2460

Report ITU-R SM.2423

Report ITU-R M.2176

Report ITU-R M.2411

Resolution ITU-R 56

Resolution ITU-R 65

Resolution 225 (Rev.WRC-12)

Recommendation ITU-T G.1010

5 Acronyms and abbreviations

CDF	Cumulative distribution function
DL	Downlink
eMBB	Enhanced mobile broadband
eMBB-s	Enhanced mobile broadband via satellite
GSO	Geostationary satellite orbit
HRC-s	High reliability communications via satellite
ICT	Information and communication technology
IMT	International mobile telecommunications

IoT	Internet of things
ISL	Inter-satellite link
LEO	Low earth orbit
MEO	Medium earth orbit
MIMO	Multiple input multiple output
mMTC	Massive machine type communications
mMTC-s	Massive machine type communications via satellite
MTD	Machine type device
PDU	Protocol data unit
QoE	Quality of experience
QoS	Quality of service
RIT	Radio interface technology
SDU	Service data unit
SRIT	Set of radio interface technologies
TDD	Time division duplex
TRxP	Transmission reception point
UE	User equipment
UL	Uplink
URLLC	Ultra-reliable and low-latency communications

6 Vision on the satellite component of IMT-2020

The ability to ensure global service continuity, high service reliability and availability is an important challenge for the whole ICT sector.

Meeting this challenge requires combining a variety of access technologies. Adding satellite component in the picture will contribute to extend the coverage of the IMT-2020 service in under and unserved areas where complementing the terrestrial component is most relevant. Moreover, the two types of network components will contribute to increase the overall reliability of the IMT-2020 systems.

Different levels of integration, as described in Recommendation ITU-R M.1182 may be used, which may benefit from adopting a common architecture framework to improve support of mobility management, multiconnectivity[3], service continuity and enhance the reliability/quality of the service.

Given that the terrestrial component of IMT-2020 is already defined, the satellite component of IMT-2020 should take into account the capabilities, the system architecture and the radio interface(s) of the terrestrial component. Moreover, it should be clear that due to inherent physical constraints, the satellite component will feature different technical and performance characteristics (e.g. latency, data rate) compared to the terrestrial component.

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3 Multiconnectivity in this instance refers to user equipment that may be connected to two or more network nodes.

The aim of this section is to define visions of the satellite component of IMT-2020 with respect to use cases, capabilities, system, radio and network interface aspects, taking into account the task of maintaining network coverage seamlessly based on the use of terrestrial and satellite communication links.

Various radio interfaces may be considered, as different satellite systems could communicate only with terminals having compatible radio interfaces.

The QoE (Quality of Experience) by end-users should always be maximized to the extent possible with respect to the service requirement, regardless of what physical principles the communication and data transmission channels are based on.

6.1 Use cases

Recommendation ITU-R M.2083 on the IMT-2020 vision, identifies three usage scenarios for IMT-2020 and beyond: Enhanced Mobile Broadband (eMBB), Massive machine type communications (mMTC) and Ultra-reliable and low latency communications (URLLC). Satellite networks providing the satellite component of IMT-2020[4] are envisioned to provide eMBB-s and mMTC-s usage scenarios that are satellite variants of eMBB and mMTC defined in Recommendation ITU-R M.2083. The suffix –s of the naming captures the satellite specificity in terms of expected performance. The satellite component of IMT-2020 will not address the URLLC, but will cover the satellite specific High Reliability Communications (HRC-s) usage scenario. Use cases specific to the three categories are described hereunder.

The satellite component can be used to provide many different applications, for example:

– Global connectivity to end user devices
– Network resilience through high availability combined with high reliability for HRC-s
– Connectivity for transportation purposes
– Content delivery in broadcast or multicast mode to end user devices
– Machine type communications

The Enhanced Mobile Broadband (eMBB-s) usage scenario, in the context of the satellite component of IMT-2020, should support high data rate applications in rural and remote areas, air and maritime environments, and, in some cases, suburban areas. Terminal devices on the move, capable of supporting communications at high velocity, should be supported to meet transportation needs and their associated users. Specifically, the following cases are identified:

– Coverage continuity: moving pedestrian (consumer smart phones) should be able to maintain access to a large range of communication services and applications while moving out to remote areas for e.g. remote working, leisure, etc.
– Connecting populations in unserved or underserved areas
– Connectivity to transport: buses, trains, vessels (leisure or cruise) or airplanes
– Public safety: to provide communication services (e.g. messaging, voice, video) to emergency responders (e.g. fire brigade, medical personnel).

The massive machine type communications (mMTC-s) provided through the satellite component of IMT-2020 should be able to address large number of scattered connected fixed or mobile devices

[4] This Report describes RITs/SRITs key requirements related to the minimum technical performance of satellite component of IMT-2020. However, mobile broadband, machine type and high reliability communications can and have been provided by a variety of satellite technologies outside of the IMT-2020 ecosystem. Such technologies are outside the scope of this report.

over wide areas. Such devices may be low cost and have long battery life. Several use cases typical of the mMTC-s usage scenario in a satellite context are identified below:

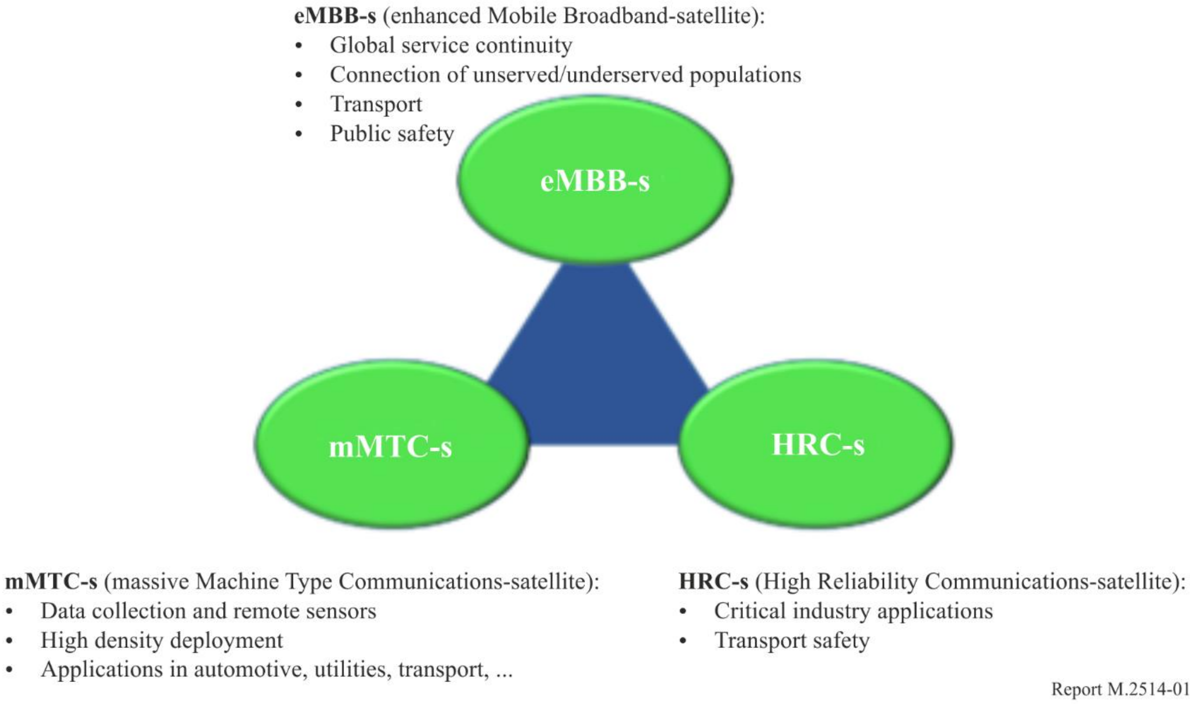
– Automotive: this may include traffic flow optimisation, automotive diagnostic, safety status reporting
– Utilities: e.g. surveillance of oil/gas, energy/water supply infrastructures, wind farms
– Transport (road, railway, maritime, aeronautic): Fleet management, asset tracking, digital signage, remote roads alerts.

The high reliability communications (HRC-s) scenario has specific requirements for availability and reliability.

Figure 1 below illustrates the use cases specific to the satellite component of IMT-2020.

FIGURE 1

Satellite component of IMT-2020 use cases



Annex 1 provides a summary of the minimum requirements for the satellite component of IMT-2020 radio interface supporting channel bandwidth up to 30 MHz.

6.2 Capabilities

Recommendation ITU-R M.2083 considered the following eight parameters as key capabilities for IMT-2020 system:

– Peak data rate
– User experienced data rate
– Latency
– Mobility
– Connection density
– Energy efficiency

– Spectrum efficiency
– Area traffic capacity.

These parameters are also considered relevant for the satellite component of IMT-2020.

Due to inherent constraints resulting from the distance between satellite user equipment and the space station, the satellite component will feature different technical and performance capabilities compared to the terrestrial component. Also, it should be noted that different satellite networks and systems have unique characteristics and architectures in delivering their services.

6.3 System

Recommendation ITU-R M.2083 states that: "Users should be able to access services anywhere, anytime. To achieve this goal, interworking will be necessary among various access technologies, which might include a combination of different fixed, terrestrial and satellite networks. Each component should fulfil its own role, but also should be integrated or interoperable with other components to provide ubiquitous seamless coverage." These systems will rely on technologies to switch between the satellite and terrestrial components of IMT to enable a user to receive connectivity. In addition, terrestrial and satellite networks can complement one another to meet specific requirements for additional capacity and coverage in any areas, including in those areas underserved by terrestrial IMT, as well address other performance requirements.

Advances in satellite technology which could also benefit IMT-2020 satellite component services include:

– Flexible payloads enabling
  • Beam forming of up to thousand beams
  • Moving or earth-fixed cells, through continuous beam steering
  • In-orbit reconfigurability (e.g. beam pattern, frequency plan)
  • Support of part or all of radio access network functions
– Large antennas: large aperture onboard antennas to provide high directivity towards users
– Large constellation thanks to optimized manufacturing, deployment and operation processes
– Inter-satellite links (ISL) where relevant through RF or optical bands.

FIGURE 2

Example of typical system scenarios whereby the satellite implements respectively a transparent and a regenerative payload

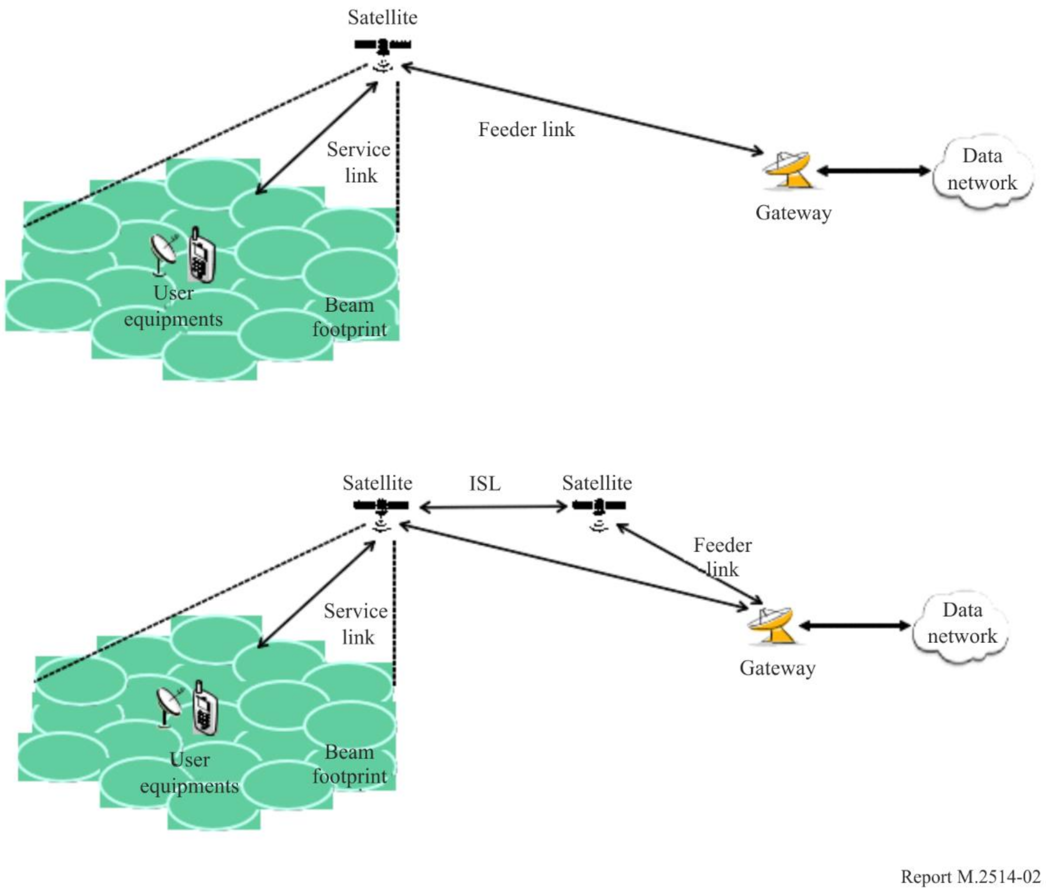


Figure 2 illustrates two typical system scenarios whereby the satellite implements respectively a transparent and a regenerative payload. In both cases, the Satellite Radio Interface (SRI) is implemented on the service link between the satellite and the User Equipment (UE). The UE is the termination point at the user side of the IMT-2020 satellite radio interface link.

In the satellite context, the base station is the network termination point of the satellite radio interface link serving the UE. In the case of a transparent satellite, the base station is located on the ground, e.g. at the gateway earth station. In the case of a regenerative satellite, the base station may be located (all or in part) on board the satellite.

The other links (feeder links, ISL) and functional units are represented only for information to show the overall operational context of the Satellite Radio Interface.

In Fig. 2 above:

– The first image illustrates a transparent payload: the satellite payload forwards the SRI protocol between the service link and the feeder link. For example, such payload may implement radio frequency filtering, frequency conversion, signal processing and amplification. Protocol-related base station functions are handled at the gateway earth stations. The use of inter-satellite links is not foreseen in this case.

– The second image illustrates a regenerative payload: the payload processes the SRI protocol between the service link and the feeder link, with potential use of inter-satellite links depending on the chosen architecture. For example, such payload may implement radio frequency filtering, frequency conversion, signal processing, routing/switching, protocol handling and RF amplification. This is effectively equivalent to having protocol-related base station functions on board the satellite.

6.4 Radio interface

The satellite radio interface of IMT-2020 and associated systems should be designed to accommodate the specific features of the satellite environment. The following table identifies specific effects which may affect the radio interfaces and protocol of the satellite component of IMT-2020:

Effects inherent in satellite networks/systems affecting the radio interfaces and protocols of Satellite Component of IMT-2020	
Satellite network/systems specifics	**Example**
Motion in the space (satellite and user terminal)	Moving or fixed cell pattern on ground Delay variation Doppler shift
Orbit altitude of satellite	Long latency
Propagation channel	High pathloss
Beam footprint (cell size) of satellite	Differential delay in footprint
Duplex mode of channel	Typically restricted to frequency division duplex (FDD) due to excessive round-trip time
Satellite payload performance	Gain and power limitations due to physical constraints associated with the satellite orbit
Satellite network architecture	The architecture needs to support a built-in flexibility to cater for the mobility of the satellites relative to end users and gateways

Doppler-induced frequency variations may be important in particular for Low Earth Orbit satellite systems. Typical values for maximum Doppler shift and Doppler shift variations are provided below for information.

	GSO	**LEO**
Max Doppler shift (earth fixed user equipment)	0.93 ppm	24 ppm for 600 km satellite altitude at 10 degrees elevation angle
Max Doppler shift variation (earth fixed user equipment)	0.000 045 ppm/s	0.27 ppm/s for 600 km satellite altitude at 10 degrees elevation angle

The satellite radio interface technology should leverage from similar capabilities of the IMT-2020 terrestrial radio interface technology to the extent feasible, in order to reduce complexity of satellite user terminal and network equipment.

Multi-vendor interoperability should be fostered, and environmental impact be minimized with energy efficiency enablers.

For the satellite radio interfaces of IMT-2020, re-using part of the IMT-2020 terrestrial radio interfaces should be considered. Recommendation ITU-R M.2150 provides detailed specifications of the terrestrial radio interfaces of IMT-2020.

7 Requirements for the satellite radio interface(s) of IMT-2020

7.1 Service aspects

Due to their wide coverage, resiliency, multicast and broadcast capabilities, satellite systems will provide scalable and efficient network solutions. The satellite IMT component will expand the benefits of satellite IMT-2020 use cases and their associated service requirements. Both geostationary and non-geostationary mobile satellite systems have a role to play in this context.

The IMT-2020 satellite radio interface is mainly expected to support eMBB-s and mMTC-s, a satellite variant of enhanced Mobile Broadband (eMBB) and massive Machine Type Communications (mMTC) services. The satellite component is also expected to support High Reliability Communications (HRC-s) service in particular to reinforce the reliability.

7.2 Technical performance requirements

Requirements related to technical performance criteria for candidate satellite radio interfaces of IMT-2020 are described in this section.

As mentioned above, the satellite component of IMT-2020 systems could be complementary to the terrestrial component in order to provide a ubiquitous and reinforced availability of the services. In particular, the satellite component can effectively offer services in certain regions beyond terrestrial coverage.

Therefore, a main target service area for the satellite component would be the rural, maritime and aeronautical environments, etc.

Given the link budget and spacecraft constraints experienced in satellite network components compared to terrestrial ones, it is obvious that the satellite component cannot support the same level of technical requirements as the terrestrial component, thus different performance requirements are provided. Nevertheless, similar technical performance parameters are adopted, to the extent possible, to allow consistency and alignment with requirements defined for the terrestrial component.

Therefore, specific performance targets should be defined for each technical parameter compared to the minimum performance requirements of the terrestrial component of IMT-2020.

There are currently three types of mobile satellite terminals in use:

Terminal types	**Handheld**	**Directional terminal**	**Machine type device (MTD)**
Example	Handhelds/handsets available to the general public, or adapted to the specific needs of a group of users e.g. first responders, security organisations, etc.	Terminals deployed temporarily (nomadic) or mounted on moving platforms such as vehicle, aircrafts, vessels and trains to provide connectivity to users on-board these platforms	Sensors capable of sending and receiving short packets.
Antenna type and configuration	Omni-directional	Directional	Omni-directional

Further details can be found for information in § 8.2.1.5.

Some of the requirements listed in the following sections can apply to different terminal types, unless a specific mention restricts or differentiates the requirement applicability to a specific terminal type.

In order to evaluate whether a proposed satellite radio interface technology meets the technical performance requirements for the Satellite Component of IMT-2020, demonstration of compliance assuming handheld terminals is necessary and sufficient. Other evaluations, e.g. for directional and MTD devices, may be provided by the proponent, though are not required.

Some additional information on potential performance requirements for the satellite component of IMT-2020 radio interface supporting channel bandwidth up to 400 MHz can be found in Annex 2.

7.2.1 Peak data rate

Peak data rate is the maximum achievable data rate under ideal conditions, which is the received data bits assignable to a single mobile station, when up to 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_a denote the assigned bandwidth and SE_p denote the peak spectral efficiency in that band achieved at the assigned bandwidth. Then the user peak data rate R_p is given by:

$$R_p = W_a \times SE_p$$

The following Table indicates the required peak data rate and, in notes, the maximum bandwidth that may be used to achieve the required rate. Radio interfaces may use any bandwidth up to the maximum specified in order to achieve the required peak data rate.

Peak data rate (DL)	70 Mbit/s (1)
Peak data rate (UL)	2 Mbit/s (1)

(1) Requirements were derived using an assignable bandwidth of up to 30 MHz over one satellite beam.

These requirements are defined for the eMBB-s usage scenario and apply to handheld devices.

The above data rates may also be supported by other type of satellite terminals.

The proponent should report the peak data rate values achievable by the candidate RITs/SRITs and identify the assumed frequency band(s) of operation and the assigned DL and UL bandwidths in that(those) band(s).

Proponents should demonstrate that the peak data rate requirement can be met for, at least, one declared carrier frequency.

Suitable evaluation parameters should be used and reported by the proponent, using examples provided in § 8.2 (associated to the Rural-eMBB-s test environment) as needed.

7.2.2 Peak spectral efficiency

Peak spectral efficiency is the maximum data rate under ideal conditions normalized by the assigned bandwidth (in bit/s/Hz), where the maximum data rate is the received data bits assignable to a single mobile station, when up to 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 and guard bands).

The minimum requirements for peak spectral efficiencies are as follows:

Peak spectral efficiency (DL)	3 bit/s/Hz [(1)]
Peak spectral efficiency (UL)	1.5 bit/s/Hz [(1)]

[(1)] Requirements were derived using an assignable bandwidth of up to 30 MHz over one satellite beam.

These requirements are defined for the eMBB-s usage scenario and apply to handheld devices.

The above values may also be supported by other type of satellite terminals.

The proponent should report the peak spectral efficiencies achievable by the candidate RITs/SRITs and identify the assumed frequency band(s) of operation and the assigned DL and UL bandwidths in that(those) band(s).

Proponents should demonstrate that the peak spectral efficiency requirement can be met for, at least, one declared carrier frequency.

Suitable evaluation parameters should be used and reported by the proponent, using examples provided in § 8.2 (associated to the Rural-eMBB-s test environment) as needed.

7.2.3 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.

Assuming one frequency band and one layer of transmission reception points (TRxP), the user experienced data rate should be derived from the 5th percentile user spectral efficiency through equation (1). 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:

$$R_{user} = W \times SE_{user} \tag{1}$$

The requirements below are defined for the purpose of evaluation in the Rural-eMBB-s test environment (see § 8.2) applicable to handheld devices.

User experienced data rate (DL)	1 Mbit/s
User experienced data rate (UL)	100 kbit/s

The proponent should report the user experienced data rate achievable by the candidate RITs/SRITs and identify the assumed frequency band(s) of operation and the channel bandwidths in that(those) band(s).

Suitable evaluation configuration parameters according to § 8.2 should be used and reported by the proponent of the evaluation. The evaluation follows the methods outlined for the 5th percentile user spectral efficiency.

7.2.4 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 requirements below are defined for the purpose of the evaluation in the Rural-eMBB-s test environment (see § 8.2), applicable to handheld devices:

5^{th} percentile user spectral efficiency (DL)	0.03 bit/s/Hz
5^{th} percentile user spectral efficiency (UL)	0.003 bit/s/Hz

The proponent should report the 5^{th} percentile user spectral efficiency achievable by the candidate RITs/SRITs, and identify the assumed frequency band(s) of operation and the channel bandwidths in that(those) band(s).

The evaluation methodology for the systems simulations should follow the principles outlined in § 7.1.2 of Report ITU-R M.2412 with needed adaptations.

7.2.5 Average spectral efficiency

Average spectral efficiency 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.

In the context of a satellite component radio interface, a TRxP (transmission and reception point) refers to a beam generated by the satellite.

The channel bandwidth for this purpose is defined as the effective bandwidth times the frequency reuse factor.

The following requirements are defined for the purpose of the evaluation in the Rural-eMBB-s test environment (see § 8.2), applicable to handheld devices:

Average spectral efficiency (DL)	0.5 bit/s/Hz
Average spectral efficiency (UL)	0.1 bit/s/Hz

The proponent should report the average spectral efficiency achievable by the candidate RITs/SRITs, and identify the assumed frequency band(s) of operation and the channel bandwidths in that(those) band(s).

The evaluation methodology for the systems simulations for determining the average spectral efficiency should follow the principles outlined in § 7.1.1 of Report ITU-R M.2412 with adaptations as needed.

Suitable evaluation configuration parameters according to § 8.2 should be used and declared by the proponent of the evaluation.

7.2.6 Area traffic capacity

Area traffic capacity is the total traffic throughput served per geographic area (in Mbit/s/km^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 assuming 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} as follows:

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

The requirements below are defined for the purpose of the evaluation in the Rural-eMBB-s test environment (see § 8.2), applicable to handheld devices:

Area traffic capacity (DL)	8 kbit/s/km^2
Area traffic capacity (UL)	1.5 kbit/s/km^2

The area capacity is averaged over a satellite beam.

7.2.7 Latency

7.2.7.1 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.

User plane latency should be equal to or less than 10 ms, for both downlink and uplink, assuming unloaded conditions (i.e. a single user) and small IP packets (e.g. 0 byte payload + IP header).

This requirement is defined for the eMBB-s usage scenario and the above target applies to handheld devices. The proponent should provide the elements and their values in the calculation of the user plane latency, for both UL and DL. Table 3 in § 7.2.6 of Report ITU-R M.2412 provides an example of the elements in the calculation of the user plane latency that should be followed with needed adaptions to e.g. include the assumed time-of-flight between the terminal and the base station.

In addition to compliance with the above requirement, the proponent may provide indication that the Satellite Radio Interface is able to support larger latencies, e.g. up to 650 ms, and may operate with a range of relevant satellite orbits.

7.2.7.2 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).

Control plane latency should be equal to or less than 40 ms.

This requirement is defined for the eMBB-s usage scenario and the above target applies to handheld devices. The proponent should provide the elements and their values in the calculation of the control plane latency. Table 2 in § 7.2.5 of Report ITU-R M.2412 provides an example of the elements in the calculation of the control plane latency that should be followed with needed adaptions to e.g. include the assumed time-of-flight between the terminal and the base station.

In addition to compliance with the above requirement, the proponent may provide indication that the Satellite Radio Interface is able to support larger latencies, e.g. up to 1.15 s, and may operate with a range of relevant satellite orbits.

7.2.8 Connection density

Connection density is the total number of devices fulfilling a specific quality of service (QoS) per unit area (per km^2). A connection density of at least 500 devices per km^2 should be supported. The requirement was derived assuming up to and including a 30 MHz bandwidth.

The proponent should report the connection density achievable by the candidate RITs/SRITs, and identify the assumed frequency band(s) of operation and the channel bandwidths in that(those) band(s).

The evaluation methodology for the systems simulations for determining the connection density should follow the principles outlined in § 7.1.3 of Report ITU-R M.2412 with needed adaptations.

The evaluation is conducted in the Rural-mMTC-s test environment (see § 8.2), applicable to handheld devices or, optionally, MTD. Suitable evaluation configuration parameters according to § 8.2 for this test environment should be used and declared by the proponent of the evaluation.

7.2.9 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 § 7.2.5).

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 signalling (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 applies to the eMBB-s usage scenario and can be assessed qualitatively (no quantitative target).

The RIT/SRIT shall have the capability to support a high sleep ratio and long sleep duration.

The energy efficiency for both network and device is verified by inspection by demonstrating that the candidate RITs/SRITs can support high sleep ratio and long sleep duration as defined above when there is no data.

Inspection can also be used to describe other mechanisms of the candidate RITs/SRITs that improve energy efficient operation for both network and device.

7.2.10 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.

The satellite component of IMT-2020 shall be able to support reliability as high as $1\text{-}10^{-3}$. The connection time duration required to meet the reliability target should be provided by the proponent of the submitted RIT/SRIT.

The proponent should report the reliability achievable by the candidate RIT/SRIT, and identify the assumed frequency band(s) of operation and the channel bandwidths in that(those) band(s).

The evaluation methodology for determining the reliability should follow the principles outlined in § 7.1.5 of Report ITU-R M.2412 with needed adaptations.

The evaluation is conducted in the Rural-HRC-s test environment (see § 8.2), applicable to handheld devices.

7.2.11 Mobility

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

The satellite component of IMT-2020 shall be capable of communicating with terminals in motion at speeds up to those indicated in the Table below.

The requirements below are defined for the purpose of evaluation of the Rural-eMBB-s test environment (see § 8.2), applicable to handheld devices:

Max speed	**250 km/h (on-board high-speed car)**
Normalized traffic channel link data rate (bit/s/Hz)	0.005

In addition, proponents are encouraged to support a higher speed of up to 1 200 km/h.

Although the mobility requirement target is not applicable to the mMTC-s scenario, the satellite component of IMT-2020 may also operate with MTDs moving at speeds (e.g. up to 500 km/h).

The proponent should report the mobility achievable by the candidate RITs/SRITs, and identify the assumed frequency band(s) of operation and the channel bandwidths in that(those) band(s).

The evaluation methodology for determining the mobility should follow the principles outlined in § 7.1.4 of Report ITU-R M.2412 with needed adaptations.

Suitable evaluation configuration parameters according to § 8.2 for this test environment should be used and declared by the proponent of the evaluation.

7.2.12 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 satellite and/or gateway node 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.

The requirement for mobility interruption time is 50 ms.

The procedure of exchanging user plane packets with base stations during transitions shall be described based on the proposed technology including the functions and the timing involved.

The requirement value above pertains to the eMBB-s usage scenario and applies to handheld devices.

7.2.13 Bandwidth

Bandwidth is the maximum aggregated system bandwidth. Scalable bandwidth is the ability of the candidate RIT/SRIT to operate with different bandwidth. The bandwidth capability of the RIT/SRIT is defined for the purpose of IMT-2020 evaluation.

The RIT/SRIT should support a scalable bandwidth up to 30 MHz. The support of maximum bandwidth is verified by inspection of the proposal.

The scalability requirement is verified by demonstrating that the candidate RITs/SRITs can support different bandwidth values. These values shall include the minimum and maximum supported bandwidth of the candidate RIT/SRIT.

8 Guidelines for evaluation of the satellite radio interface(s) of IMT-2020

This section provides guidelines to be used in evaluating the proposed IMT-2020 satellite radio interface(s) for a number of test environments considered for evaluation.

8.1 Evaluation criteria

The requirements established in § 7 are related to service and technical performance aspects. Regarding service aspects, a wide range of telecommunication services to mobile users should be provided by the satellite component of IMT-2020. In relation to technical aspects, it should be determined if candidate satellite radio interface(s) meets the technical requirements for the test environments defined in § 8.2.1.2.

8.2 Evaluation methodology

The parameters and assumptions described in this section are solely for the purpose of consistent evaluation of the candidate satellite radio interface(s) and relate only to specific test environments used in evaluations. They should not be considered as the values that must be used in any deployment of any IMT-2020 system nor should they be taken as the default values for any other or subsequent study in ITU or elsewhere. They do not necessarily themselves constitute any requirements on the implementation of the system.

8.2.1 Test environments and evaluation configurations

This section describes the test environments and evaluation configurations necessary to evaluate the performance capabilities of the candidate RIT/SRIT.

The predefined test environments are not intended to limit or preclude any real deployment scenarios or capabilities, i.e. the satellite component of IMT-2020 should be able to support a wide range of performance requirements in a wide range of deployment environments.

8.2.1.1 Usage scenarios

There are three usage scenarios for the satellite component of IMT-2020:

– Enhanced Mobile Broadband (eMBB-s)

– Massive machine type communications (mMTC-s)

– High reliability communications (HRC-s)

These usage scenarios are described in detail in § 6.1.

8.2.1.2 Test environments

A test environment reflects a combination of geographic environment and usage scenario. For the satellite component of IMT-2020, all usage scenarios are combined into a Rural test environment.

Evaluation of the candidate RIT/SRIT should be performed in selected test environments.

The following test environments are defined:

– Rural-eMBB-s: An environment with large and continuous area coverage, supporting pedestrian and vehicular users with high data rates.
– Rural-mMTC-s: An environment targeting large and continuous coverage focusing on a high number of connected machine type devices.
– Rural-HRC-s: An environment targeting large and continuous coverage for highly reliable communications.

The mapping of the deployment and usage scenarios to test environments is given in the below Table.

Usage scenarios	**eMBB-s**	**mMTC-s**	**HRC-s**
Test environments	Rural-eMBB-s	Rural-mMTC-s	Rural-HRC-s

8.2.1.3 Satellite system configuration

Overall capacity and coverage of the satellite component are largely dependent on deployment models and targeted system configuration assumed for the proposed RIT/SRIT, such as the configuration of the constellation including the type and altitude of the orbit, number of satellites, configuration of the spot beams, etc. Proponents should provide the targeted satellite system configuration intended for the proposed RIT/SRIT in the test environments to be evaluated, and then they should submit the self-evaluation results based on the selected system configuration.

8.2.1.3.1 Antenna patterns

Proponents should identify the antenna configuration which can be appropriately used in the targeted system evaluation. For example, antenna characteristics such as antenna pattern, gain, side-lobe level for antennas at the satellite and user terminal should be specified. These characteristics do not form any kind of requirements and should be used only for evaluation.

8.2.1.4 Satellite configuration

Proponents should provide the satellite configuration information required for evaluation such as the operating frequency, polarization, e.i.r.p., beam-configuration, the number of satellites and their altitude, antenna gain, etc.

8.2.1.5 Terminal configuration

The following are examples of parameters for different types of user terminals that may be considered in the evaluations, and are provided for information only.

Terminal types	**Handheld**	**Directional terminal**	**MTD**
Examples	Handset, smartphone	Transportation applications	Smart meters, sensors, etc. (stationary and mobile applications)
Antenna type and configuration	Omni-directional	Directional	Omni-directional
Polarisation	Linear: ±45°X-pol	circular	Linear: ±45°X-pol or circular
Antenna gain (dBi)	0	> 12	0
Antenna temperature (K)	290	150	290
Noise figure (dB)	7	1.2	≤ 9
Tx transmit power	200 mW (23 dBm)	2 W (33 dBm)	≤ 200 mW (23 dBm)

8.2.2 Channel model

The channel modelling should take advantage of the IMT-2020 advances in channel modelling and follow the principles of the methodologies outlined in Report ITU-R M.2412 Annex 1 with needed adaptations identified by the proponents to capture aspects relevant for satellite access.

Alternatively, the model described in Report ITU-R M.2176 can be followed.

General aspects such as path loss, LOS probability, shadow fading, outdoor-to-indoor building penetration loss and fast fading should be modelled and capture the specifics of the simulated test environment. Satellite access specific aspects such as atmospheric absorption, ionospheric scintillation, and faraday rotation should be considered when required by the evaluation methodology.

Regarding high-speed airborne mobility cases, Recommendations ITU-R P.682-3 and ITU-R P.2041 provide relevant information.

8.2.3 Evaluation configuration

This section contains baseline configuration parameters that should be applied in analytical and simulation assessment of candidate satellite radio interface(s).

The parameters are solely for the purpose of consistent evaluation of the candidate satellite radio interface(s) and relate only to specific test environments used in these evaluations. They should not be considered as the values that must be used in any deployment of any IMT-2020 system nor should they be taken as the default values for any other or subsequent study in ITU or elsewhere. They do not necessarily themselves constitute any requirements on the implementation of the system.

Evaluation configuration parameters in each test environment depend on the identified satellite system configuration. Therefore, proponents should provide the evaluation configuration parameters for the test environments where the proposed RIT/SRITs are intended to be used and then, they should submit the self-evaluation results based on the specific configuration parameters. This information would also help the evaluation process of other evaluation groups. Some reference examples of system parameters pertaining to the evaluation of Rural-eMBB-s, Rural-HRC-s and Rural-mMTC-s test environments are shown in Table 1 below.

The specific configuration parameters used for the RIT/SRIT evaluation should be provided by proponents and considered by the evaluation groups that intend to assess the characteristics of the RIT/SRIT.

TABLE 1

Example parameters used in evaluations for handheld and MTD terminals

Parameters	**Values/Types/Configurations**			
	Rural-eMBB-s	**Rural-mMTC-s**		**Rural-HRC-s**
Terminal type (see § 8.2.1.5)	Handheld	Handheld	MTD	Handheld
Satellite orbit configuration	LEO, 600 km altitude			
Spot beam pattern	Hexagonal pattern, at least 19 spot beams Influence of adjacent beam interference on the results should be accounted for, e.g. by collecting statistics only from the inner spot beams			
Service link frequency (1)	2 GHz			
Channel bandwidth	30 MHz	30 MHz	180 kHz – 3 MHz	30 MHz

TABLE 1 (*end*)

Parameters	**Values/Types/Configurations**			
	Rural-eMBB-s	**Rural-mMTC-s**		**Rural-HRC-s**
3 dB beam width	4.41 degrees			
Satellite EIRP density	34 dBW/MHz			
Satellite antenna gain	30 dBi			
Satellite G/T	1.1 dB/K			
Device deployment	100% outdoor, randomly and uniformly distributed over the area			
UE density	10 UEs per spot beam	At least 500 per km^2	At least 500 per km^2	10 UEs per spot beam
UE mobility model	For mobility evaluations: Fixed and identical speed of 250 km/h of all UEs, randomly and uniformly distributed direction. For all other evaluations: Stationary	Stationary	Stationary	Fixed and identical speed of 30 km/h of all UEs, randomly and uniformly distributed direction
Traffic model	Full buffer	With layer 2 PDU (Protocol Data Unit) message size of 32 bytes: 1 message/day/device or 1 message/2 hours/device Packet arrival follows Poisson arrival process for non-full buffer system-level simulation	With layer 2 PDU (Protocol Data Unit) message size of 32 bytes: 1 message/day/device or 1 message/2 hours/device Packet arrival follows Poisson arrival process for non-full buffer system-level simulation	Full buffer
UE antenna height	1.5 m			

(1) See Resolution **225 (Rev.WRC-12)**. The carrier frequency of 2 GHz is an indicative value.

For the purpose of connection density evaluation in the Rural-mMTC-s test environment, demonstration of compliance for handheld terminals is sufficient. Evaluation for MTD may be provided by the proponent, though is not required.

8.2.4 Assessment methods

The requirements are evaluated using different high-level assessment methods:

– Simulation (including system-level and link-level simulations, according to the principles of the simulation procedure given in Report ITU-R M.2412).

– Analytical (via calculation or mathematical analysis).

– Inspection (by reviewing the functionality and parameterization of the proposal).

The mapping of requirements to assessment methods is summarized in the Table below.

Characteristic for evaluation	**High-level assessment method**	**Requirement description in this Report**	**Related section of Report ITU-R M.2412**
Peak data rate	Analytical	§ 7.2.1	M.2412, § 7.2.2
Peak spectral efficiency	Analytical	§ 7.2.2	M.2412, § 7.2.1
User experienced data rate	Simulation and Analytical	§ 7.2.3	M.2412, § 7.2.3
5th percentile spectral efficiency	Simulation	§ 7.2.4	M.2412, § 7.1.2
Average spectral efficiency	Simulation	§ 7.2.5	M.2412, § 7.1.1
Area traffic capacity	Simulation and Analytical	§ 7.2.6	M.2412, § 7.2.4
User plane latency	Analytical and Inspection	§ 7.2.7.1	M.2412, § 7.2.6
Control plane latency	Analytical and Inspection	§ 7.2.7.2	M.2412, § 7.2.5
Connection density	Simulation	§ 7.2.8	M.2412, § 7.1.3
Energy efficiency	Inspection	§ 7.2.9	M.2412, § 7.3.2
Reliability	Simulation	§ 7.2.10	M.2412, § 7.1.5
Mobility	Simulation	§ 7.2.11	M.2412, § 7.1.4
Mobility interruption time	Analytical	§ 7.2.12	M.2412, § 7.2.7
Bandwidth	Inspection	§ 7.2.13	M.2412, § 7.3.1

8.2.5 Description template

The description template is a template for the description of the characteristics of a candidate satellite radio interface(s) (see Table 2). It should be used by the proponents to describe their proposal for a satellite radio interface for IMT-2020 to a level of detail that will facilitate sufficient understanding of the proposed technology to enable an independent technical assessment of compliance with the IMT-2020 requirements as specified in this Report.

8.2.5.1 Description template – characteristics template

TABLE 2

Characteristics template

Item	Item to be described
8.2.5.1.1	**Test environment(s)**
8.2.5.1.1.1	What test environments does this technology description template address?
8.2.5.1.2	**Radio interface functional aspects**
8.2.5.1.2.1	*Multiple access schemes* Which access scheme(s) does the proposal use: TDMA, FDMA, CDMA, OFDMA, IDMA, SDMA, hybrid, or another? Describe in detail the multiple access schemes employed with their main parameters.
8.2.5.1.2.2	*Modulation scheme*
8.2.5.1.2.2.1	What is the baseband modulation scheme? If both data modulation and spreading modulation are required, describe in detail. Describe the modulation scheme employed for data and control information. What is the symbol rate after modulation?
8.2.5.1.2.2.2	*PAPR* What is the RF peak to average power ratio after baseband filtering (dB)? Describe the PAPR (peak-to-average power ratio) reduction algorithms if they are used in the proposed RIT.
8.2.5.1.2.3	*Error control coding scheme and interleaving*
8.2.5.1.2.3.1	Provide details of error control coding scheme for both downlink and uplink? For example: – FEC or other schemes? – Unequal error protection? Explain the decoding mechanism employed.
8.2.5.1.2.3.2	Describe the bit interleaving scheme for both uplink and downlink.
8.2.5.1.3	**Describe channel tracking capabilities (e.g. channel tracking algorithm, pilot symbol configuration, etc.) to accommodate rapidly changing delay spread profile**
8.2.5.1.4	**Physical channel structure and multiplexing**
8.2.5.1.4.1	What is the physical channel bit rate (Mbit/s) for supported bandwidths? i.e. the product of the modulation symbol rate (in symbols per second), bits per modulation symbol, and the number of streams supported by the antenna system.
8.2.5.1.4.2	*Layer 1 and Layer 2 overhead estimation* Describe how the RIT accounts for all Layer 1 (PHY) and Layer 2 (MAC) overhead and provide an accurate estimate that includes static and dynamic overheads.
8.2.5.1.4.3	*Variable bit rate capabilities* Describe how the proposal supports different applications and services with various bit rate requirements.
8.2.5.1.4.4	*Variable payload capabilities* Describe how the RIT supports IP-based application layer protocols/services (e.g. VoIP, video-streaming, interactive gaming, etc.) with variable-size payloads.

TABLE 2 (*continued*)

Item	Item to be described
8.2.5.1.4.5	*Signalling transmission scheme* Describe how transmission schemes are different for signalling/control from that of user data.
8.2.5.1.5	**Mobility management (Handover)**
8.2.5.1.5.1	Describe the handover mechanisms and procedures which are associated with – Inter-System handover; – Intra-System handover; – Intra-frequency and Inter-frequency; – Within the RIT or between RITs within one SRIT (if applicable). Characterize the type of handover strategy or strategies.
8.2.5.1.5.2	What are the handover interruption times for: – within the RIT (intra- and inter-frequency); – between various RITs within a SRIT; – between the RIT and another IMT system.
8.2.5.1.6	**Radio resource management**
8.2.5.1.6.1	Describe the radio resource management, support of: – centralized and/or distributed RRM; – dynamic and flexible radio resource management; – efficient load balancing.
8.2.5.1.6.2	*Inter-RIT interworking* Describe the functional blocks and mechanisms for interworking (such as a network architecture model) between heterogeneous RITs within a SRIT, if supported.
8.2.5.1.6.3	*Connection/session management* The mechanisms for connection/session management over the air-interface should be described. For example: – the support of multiple protocol states with fast and dynamic transitions; – the signalling schemes for allocating and releasing resources.
8.2.5.1.7	**Frame structure**
8.2.5.1.7.1	Describe the frame structure for downlink and uplink by providing sufficient information such as: – frame length; – the number of time slots per frame; – the number and position of switch points per frame for TDD; – guard time or the number of guard bits; – user payload information per time slot; – control channel structure and multiplexing; – power control bit rate.
8.2.5.1.8	**Spectrum capabilities and duplex technologies** NOTE 1 – Parameters for both downlink and uplink should be described separately, if necessary.
8.2.5.1.8.1	*Spectrum sharing and flexible spectrum use* Does the RIT/SRIT support flexible spectrum use and/or spectrum sharing for the bands for IMT? Provide details.

TABLE 2 (*continued*)

Item	Item to be described
8.2.5.1.8.2	*Channel bandwidth scalability* Describe how the proposal supports channel bandwidth scalability, including the supported bandwidths. Describe whether the proposed RIT supports extensions for scalable bandwidths wider than 30 MHz. Consider, for example: – the scalability of operating bandwidths; – the scalability using single and/or multiple RF carriers. Describe multiple contiguous (or non-contiguous) band aggregation capabilities, if any. Consider for example the aggregation of multiple channels to support higher user bit rates.
8.2.5.1.8.3	What are the frequency bands supported by the RIT? Please list.
8.2.5.1.8.4	What is the minimum amount of spectrum required to deploy a contiguous network, including guard bands (MHz)?
8.2.5.1.8.5	What are the minimum and maximum transmission bandwidth (MHz) measured at the 3 dB down points?
8.2.5.1.8.6	What duplexing scheme(s) is (are) described in this template? (e.g. TDD, FDD or half-duplex FDD). Describe details such as: – What is the minimum (up/down) frequency separation in case of full- and half-duplex FDD? – What is the requirement of transmit/receive isolation in case of full- a half-duplex FDD? Does the RIT require a duplexer in either the mobile station (MS) or space segment? – What is the minimum (up/down) time separation in case of TDD? – Whether the DL/UL Ratio variable for TDD? What is the DL/UL ratio supported? If the DL/UL ratio for TDD is variable, what would be the coexistence criteria for adjacent cells?
8.2.5.1.9	**Support of advanced antenna capabilities**
8.2.5.1.9.1	Fully describe the multi-antenna systems supported in the User segment, Space segment, or both that can be used and/or must be used; characterize their impacts on systems performance; e.g. does the RIT have the capability for the use of: – spatial multiplexing techniques; – space-time coding (STC) techniques; – beam-forming techniques (e.g. adaptive or switched).
8.2.5.1.9.2	How many antennas are supported by the Space segment and MS for transmission and reception? Specify if correlated or uncorrelated antennas in co-polar or cross-polar configurations are used. What is the antenna spacing (in wavelengths)?
8.2.5.1.9.3	Provide details on the antenna configuration that is used in the self-evaluation.
8.2.5.1.9.4	If spatial multiplexing (MIMO) is supported, does the proposal support (provide details if supported): – Single codeword (SCW) and/or multi-codeword (MCW). – Open and/or closed loop MIMO. – Cooperative MIMO. – Single-user MIMO and/or multi-user MIMO.

TABLE 2 (*continued*)

Item	Item to be described
8.2.5.1.9.5	*Other antenna technologies* Does the RIT/SRIT support other antenna technologies, for example Active Antenna System (AAS) If so, please describe.
8.2.5.1.10	**Link adaptation and power control**
8.2.5.1.10.1	Describe link adaptation techniques employed by RIT/SRIT, including: – the supported modulation and coding schemes; – the supporting channel quality measurements, the reporting of these measurements, their frequency and granularity; Provide details of any adaptive modulation and coding schemes, including: – hybrid ARQ or other retransmission mechanisms? – algorithms for adaptive modulation and coding, which are used in the self-evaluation; – other schemes?
8.2.5.1.10.2	Provide details of any power control scheme included in the proposal, for example: – power control step size (dB); – power control cycles per second; – power control dynamic range (dB); – minimum transmit power level with power control; – associated signalling and control messages.
8.2.5.1.11	**Power classes**
8.2.5.1.11.1	*Mobile station emitted power*
8.2.5.1.11.1.1	What is the radiated antenna power measured at the antenna (dBm)?
8.2.5.1.11.1.2	What is the maximum peak power transmitted while in active or busy state?
8.2.5.1.11.1.3	What is the time averaged power transmitted while in active or busy state? Provide a detailed explanation used to calculate this time average power.
8.2.5.1.11.2	*Space segment emitted power*
8.2.5.1.11.2.1	What is the base station transmit power per RF carrier?
8.2.5.1.11.2.2	What is the maximum peak transmitted power per RF carrier radiated from antenna?
8.2.5.1.11.2.3	What is the average transmitted power per RF carrier radiated from antenna?
8.2.5.1.12	**Scheduler, QoS support and management, data services**

8.2.5.1.12.1	*QoS support*
	– What QoS classes are supported?
	– How QoS classes associated with each service flow can be negotiated.
	– QoS attributes, for example:
	  – data rate (ranging from the lowest supported data rate to maximum data rate supported by the MAC/PHY);
	  – control plane and user plane latency (delivery delay);
	  – packet error rate (after all corrections provided by the MAC/PHY layers), and delay variation (jitter).
	– Is QoS supported when handing off between radio access networks? Please describe.
	– How users may utilize several applications with differing QoS requirements at the same time.

TABLE 2 (*continued*)

Item	Item to be described
8.2.5.1.12.2	*Scheduling mechanisms* – Exemplify scheduling algorithm(s) that may be used for full buffer in the technology proposal for evaluation purposes. Describe any measurements and/or reporting required for scheduling.
8.2.5.1.13	**Radio interface architecture and protocol stack**
8.2.5.1.13.1	Describe details of the radio interface architecture and protocol stack such as: Logical channels – Control channels. – Traffic channels. Transport channels and/or physical channels.
8.2.5.1.13.2	What is the bit rate required for transmitting feedback information?
8.2.5.1.13.3	*Channel access* Describe in detail how RIT/SRIT accomplishes initial channel access, (e.g. contention or non-contention based).
8.2.5.1.14	**Beam selection**
8.2.5.1.14.1	Describe in detail how the RIT/SRIT accomplishes cell selection to determine the serving cell for the users.
8.2.5.1.15	**Location determination mechanisms**
8.2.5.1.15.1	Describe any location determination mechanisms that may be used, e.g. to support location-based services.
8.2.5.1.16	**Priority access mechanisms**
8.2.5.1.16.1	Describe techniques employed to support prioritization of access to radio or network resources for specific services or specific users (e.g. to allow access by emergency services).
8.2.5.1.17	**Unicast, multicast and broadcast**
8.2.5.1.17.1	Describe how the RIT enables: – broadcast capabilities; – multicast capabilities; – unicast capabilities; using both dedicated carriers and/or shared carriers. Please describe how all three capabilities can exist simultaneously.
8.2.5.1.17.2	Describe whether the proposal is capable of providing multiple user services simultaneously to any user with appropriate channel capacity assignments?
8.2.5.1.17.3	Does the RIT support multiple voice and/or video codecs? Provide details.
8.2.5.1.18	**Privacy, authorization, encryption, authentication and legal intercept schemes**
8.2.5.1.18.1	Any privacy, authorization, encryption, authentication and legal intercept schemes that are enabled in the radio interface technology should be described. Describe whether any synchronization is needed for privacy and encryptions mechanisms used in the RIT. Describe how the RIT may be protected against attacks, for example: – man in the middle; – replay; – denial of service.
8.2.5.1.19	**Frequency planning**

TABLE 2 (*continued*)

Item	Item to be described
8.2.5.1.19.1	How does the RIT support adding new cells or new RF carriers? Provide details.
8.2.5.1.20	**Interference mitigation within radio interface**
8.2.5.1.20.1	Does the proposal support Interference mitigation? If so, describe the corresponding mechanism.
8.2.5.1.20.2	What is the signalling, if any, which can be used for inter-beam interference mitigation?
8.2.5.1.20.3	*Link level interference mitigation* Describe the feature or features used to mitigate inter-symbol interference.
8.2.5.1.20.4	Describe the approach taken to cope with multipath propagation effects (e.g. via equalizer, rake receiver, cyclic prefix, etc.).
8.2.5.1.20.5	Diversity techniques Describe the diversity techniques supported in the MS and at the BS, including micro diversity and macro diversity, characterizing the type of diversity used, for example: – Time diversity: repetition, Rake-receiver, etc. – Space diversity:multiple sectors, etc. – Frequency diversity: frequency hopping (FH), wideband transmission, etc. – Code diversity: multiple PN codes, multiple FH code, etc. – Multi-user diversity: proportional fairness (PF), etc. – Other schemes. Characterize the diversity combining algorithm, for example, switched diversity, maximal ratio combining, equal gain combining. Provide information on the receiver/transmitter RF configurations, for example: – number of RF receivers; – number of RF transmitters.
8.2.5.1.21	**Synchronization requirements**
8.2.5.1.21.1	Describe RIT's timing requirements, e.g.: – is synchronization between inter-beam signals or inter-satellite signals required? Provide precise information, the type of synchronization, i.e. synchronization of carrier frequency, bit clock, spreading code or frame, and their accuracy; – is space segment-to-network synchronization required? State frequency and timing accuracy of space segment and user equipment transmit signal.
8.2.5.1.21.2	Describe the synchronization mechanisms used in the proposal, including synchronization between a user terminal and a satellite access node (base station).
8.2.5.1.22	**Link budget template** Proponents should provide the link budget results to this description template for the environments supported in the RIT.
8.2.5.1.23	**Other items**
8.2.5.1.23.1	*Coverage extension schemes* Describe the capability to support/coverage extension schemes, such as relays or repeaters.
8.2.5.1.23.2	*Self-organization* Describe any self-organizing aspects that are enabled by the RIT/SRIT.

TABLE 2 (*end*)

Item	Item to be described
8.2.5.1.23.3	Describe the frequency reuse schemes (including reuse factor and pattern) for the assessment of cell spectrum efficiency, cell edge user spectral efficiency.
8.2.5.1.23.4	Is the RIT an evolution of an existing IMT-Advanced technology? Provide details.
8.2.5.1.23.5	Does the proposal satisfy a specific spectrum mask? Provide details. (This information is not intended to be used for sharing studies.)
8.2.5.1.23.6	Describe any user terminal power saving mechanisms used in the RIT.
8.2.5.1.23.7	*Simulation process issues* Describe the methodology used in the analytical approach. Proponent should provide information on the width of confidence intervals of user and satellite system performance metrics of corresponding mean values, and evaluation groups are encouraged to provide this information.
8.2.5.1.24	**Other information** Please provide any additional information that the proponent believes may be useful to the evaluation process.

8.2.5.2 Description template – link budget template

Link budget analysis may depend on the specific system configuration of the satellite systems intended to use the proposed RIT/SRIT. Therefore, proponents should provide appropriate link budget analysis and results, considering their targeted satellite system configurations, as part of the description template. The link budgets should refer to specific test environments to be evaluated for the RIT/SRIT, in order to ease the conduct of the evaluation process by the evaluation groups.

8.2.6 Compliance templates

This section provides templates for the responses that are needed to assess the compliance of a candidate satellite radio interface with the requirements of IMT-2020.

8.2.6.1 Compliance template – service template

Service-related minimum capabilities within the satellite radio interface(s)	Evaluator's comments
Support of a wide range of services Does the proposal support a wide range of services? Yes/No	

8.2.6.2 Compliance template – spectrum template

Spectrum capability requirements	Evaluator's comments
Spectrum bands Is the proposal able to utilize at least one band identified for IMT? Yes/No Specify in which band(s) the candidate satellite radio interface(s) can be deployed	

8.2.6.3 Compliance template – technical performance template

Minimum technical requirements items	Category			Required value	Value	Requirement met?	Comments
	Usage scenario	Test environment	Downlink or uplink				
Peak data rate	eMBB-s	N/A	Uplink	2 Mbit/s			
			Downlink	70 Mbit/s			
Peak spectral efficiency	eMBB-s	N/A	Uplink	1.5 bit/s/Hz			
			Downlink	3 bit/s/Hz			
User experienced data rate	eMBB-s	Rural	Uplink	100 kbit/s			
			Downlink	1 Mbit/s			
5^{th} percentile user spectral efficiency	eMBB-s	Rural	Uplink	0.003 bit/s/Hz			
			Downlink	0.03 bit/s/Hz			
Average spectral efficiency	eMBB-s	Rural	Uplink	0.1 bit/s/Hz			
			Downlink	0.5 bit/s/Hz			
Area traffic capacity	eMBB-s	Rural	Uplink	1.5 kbit/s/km²			
			Downlink	8 kbit/s/km²			
User Plane latency	eMBB-s	N/A	N/A	10 ms			
Control Plane latency	eMBB-s	N/A	N/A	40 ms			
Connection density	mMTC-s	Rural	N/A	500 devices/km²			
Energy efficiency	eMBB-s	N/A	N/A	High sleep ratio and long sleep duration			
Reliability	HRC-s	Rural	N/A	$1\text{-}10^{-3}$			
Mobility – UE speed	eMBB-s	Rural	N/A	250 km/h			
Mobility - Traffic channel link data rate	eMBB-s	Rural	N/A	0.005 bit/s/Hz			
Mobility interruption time	eMBB-s	N/A	N/A	50 ms			
Bandwidth	N/A	N/A	N/A	At least up to and including 30 MHz			

Annex 1

Minimum requirements of the satellite component of IMT-2020

Parameter	Explanation	Satellite requirement
Downlink peak data rate	Maximum achievable channel data rate under ideal conditions	70 Mbit/s
Uplink peak data rate		2 Mbit/s
Downlink user experienced data rate	Data rate maintained for 9 % of the time	1 Mbit/s
Uplink user experienced data rate		100 kbit/s
Downlink peak spectral efficiency	Number of bits of data per Hz in a band	3 bit/s/Hz
Uplink peak spectral efficiency		1.5 bit/s/Hz
Downlink average spectral efficiency	Average channel spectral efficiency	0.5 bit/s/Hz
Uplink average spectral efficiency		0.1 bit/s/Hz

Parameter	Explanation	Satellite requirement
Downlink 5^{th} percentile user spectral efficiency	5% point of the CDF of the number of correctly received bits, divided by the channel bandwidth	0.03 bit/s/Hz
Uplink 5^{th} percentile user spectral efficiency		0.003 bit/s/Hz
User plane latency	The time required for a packet to traverse the network from a source to a destination	10 ms
Control plane latency	Transition time from idle state to active state	40 ms
Mobility	Maximum moving speed allowed to maintain service transmission and QoS requirements	250 km/h
Connection density	Total amount of connected MTD devices per unit area	$500/km^2$
Area traffic capacity	Overall traffic in a coverage area	8 $kbit/s/km^2$ (DL)
		1.5 $kbit/s/km^2$ (UL)
Reliability	Capability of transmitting traffic with high success probability	$1\text{-}10^{-3}$

NOTE: The minimum performance requirements for the terrestrial component of IMT-2020 can be found in Report ITU-R M.2410.

Annex 2
(for information only)

Potential performance requirements for satellite component radio interface of IMT-2020 supporting channel bandwidth up to 400 MHz

Potential systems intended to provide satellite component of IMT-2020 services in frequency bands identified for this purpose, utilizing terminals capable of a channel bandwidth up to 400 MHz may be able to support some of the requirements found in § 7.2. Potential requirements for peak data rate and peak spectral efficiency can be found in the Tables below.

Terminal types	Directional terminal (1)
Peak data rate (DL)	900 Mbit/s
Peak data rate (UL)	900 Mbit/s

Terminal types	Directional terminal (1)
Peak spectral efficiency (DL)	2.3 bit/s/Hz
Peak spectral efficiency (UL)	2.3 bit/s/Hz

(1) These requirements were derived using an assignable bandwidth of 400 MHz over one satellite beam.

The example system parameters that may be used in the eMBB-s evaluation for a potential system intended to provide satellite component of IMT-2020 services in frequency bands identified for this purpose are shown in Table 3 below.

TABLE 3

Example system parameters for evaluation process

Parameters	**Values/Types/Configurations**
	Rural-eMBB-s
Terminal type	Directional
Satellite orbit configuration	LEO, 600 km altitude
Spot beam pattern	Hexagonal pattern, at least 19 spot beams Influence of adjacent beam interference on the results should be accounted for, e.g. by collecting statistics only from the inner spot beams
Service link frequency	To be reported by the proponent
Channel bandwidth	400 MHz
Satellite 3 dB beam width	1.76 degrees
Satellite EIRP density	4 dBW/MHz
Satellite antenna gain	38.5 dBi
Satellite G/T	13 dB/K
Device Deployment	100% outdoor, randomly and uniformly distributed over the area
UE density	10 UEs per spot beam
UE mobility model	For mobility evaluations: fixed and identical speed of 250 km/h of all UEs, randomly and uniformly distributed direction.
Traffic model	Full buffer
UE antenna height	1.5 m