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(SWG Evaluation)

[PRELIMINARY] DRAFT NEW REPORT ITU-R M.[IMT-2020.EVAL]

Guidelines for evaluation of radio interface technologies for IMT-2020

1 Introduction

Resolution ITU-R 56 defines a new term “IMT-2020” to those systems, system components, and related aspects that provide far more enhanced capabilities than those described in Recommendation ITU-R M.1645.

In this regard, International Mobile Telecommunications-2020 (IMT-2020) systems are mobile systems that include the new capabilities of IMT that go beyond those of IMT-Advanced. Recommendation ITU-R M.2083 “IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond” identifies capabilities for IMT-2020 which would make IMT-2020 more efficient, fast, flexible, and reliable when providing diverse services in the intended usage scenarios.

The usage scenario of IMT-2020 will extend to enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable and low latency communications (URLLC).

IMT-2020 systems support low to high mobility applications and much enhanced data rates in accordance with user and service demands in multiple user environments. IMT-2020 also has capabilities for enabling massive connections for a wide range of services, and guarantee ultra-reliable and low latency communications for future deployed services even in critical environments.

The capabilities of IMT-2020 include:

– very high peak data rate;

– very high and guaranteed user experienced data rate;

– quite low air interface latency;

– quite high mobility while providing satisfactory quality of service;

– enabling massive connection in very high density scenario;
– very high energy efficiency for network and device side;
– greatly enhanced spectral efficiency;
– significantly larger area traffic capacity;
– high spectrum and bandwidth flexibility;
– ultra high reliability and good resilience capability;
– enhanced security and privacy.

These features enable IMT-2020 to address evolving user and industry needs.

The capabilities of IMT-2020 systems are being continuously enhanced in line with user and industry trends, and technology developments.

2 Scope

This Report provides guidelines for the procedure, methodology and the criteria (technical, spectrum and service) to be used in evaluating the candidate IMT-2020 radio interface technologies (RITs) or Set of RITs (SRITs) for a number of test environments. These test environments are chosen to simulate closely the more stringent radio operating environments. The evaluation procedure is designed in such a way that the overall performance of the candidate RITs/SRITs may be fairly and equally assessed on a technical basis. It ensures that the overall IMT-2020 objectives are met.

This Report provides, for proponents, developers of candidate RITs/SRITs and independent evaluation groups, the common evaluation methodology and evaluation configurations to evaluate the candidate RITs/SRITs and system aspects impacting the radio performance.

This Report allows a degree of freedom so as to encompass new technologies. The actual selection of the candidate RITs/SRITs for IMT-2020 is outside the scope of this Report.

The candidate RITs/SRITs will be assessed based on those evaluation guidelines. If necessary, additional evaluation methodologies may be developed by each independent evaluation group to complement the evaluation guidelines. Any such additional methodology should be shared between independent evaluation groups and sent to the Radiocommunication Bureau as information in the consideration of the evaluation results by ITU-R and for posting under additional information relevant to the independent evaluation group section of the ITU-R IMT-2020 web page (http://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Pages/submission-eval.aspx).

3 Structure of the Report

Section 4 provides a list of the documents that are related to this Report.

Section 5 describes the evaluation guidelines.

Section 6 lists the criteria chosen for evaluating the RITs.

Section 7 outlines the procedures and evaluation methodology for evaluating the criteria.

Section 8 defines the tests environments for envisaged usage scenarios for evaluation; the evaluation configurations which shall be applied when evaluating IMT-2020 candidate RITs/SRITs are also given in this section.

Section 9 describes modeling approach for the evaluation.

Section 10 provides a list of acronyms and abbreviations.

Annex 1 provides a description of channel models used in this report

Annex 2 provides a description of linear cell layouts for high speed vehicular mobility at 500 km/h under Rural-eMBB test environment

4 Related ITU-R documents

Recommendation ITU-R M.2083

Report ITU-R M.2135-1

Report ITU-R M.2320

Report ITU-R M.2370

Report ITU-R M.2376

Resolution ITU-R 56-2

Resolution ITU-R 65

Report ITU-R M.[IMT-2020.TECH PERF REQ]

Report ITU-R M.[IMT-2020.SUBMISSION]

Document IMT-2020/1

Document IMT-2020/2

5 Evaluation guidelines

IMT-2020 can be considered from multiple perspectives: users, manufacturers, application developers, network operators, service and content providers, and, finally, the usage scenarios – which are extensive. Therefore candidate RITs/SRITs for IMT-2020 must be capable of being applied in a much broader variety of usage scenarios and supporting a much broader range of environments, significantly more diverse service capabilities as well as technology options. Consideration of every variation to encompass all situations is, however, not possible; nonetheless the work of the ITU-R has been to determine a representative view of IMT-2020 consistent with the process defined in Resolution ITU-R 65, *Principles for the process of future development of IMT-2020 and beyond*, and the key technical performance requirements defined in Report ITU-R M.[IMT-2020.TECH PERF REQ] – *Minimum requirements related to technical performance for IMT-2020 radio interface(s)*.

The parameters presented in this Report are for the purpose of consistent definition, specification, and evaluation of the candidate RITs/SRITs for IMT-2020 in ITU-R in conjunction with the development of Recommendations and Reports such as the framework and key characteristics and the detailed specifications of IMT-2020. These parameters have been chosen to be representative of a global view of IMT-2020 but are not intended to be specific to any particular implementation of an IMT-2020 technology. 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.

Further consideration has been given in the choice of parameters to balancing the assessment of the technology with the complexity of the simulations while respecting the workload of an evaluator or technology proponent.

This procedure deals only with evaluating radio interface aspects. It is not intended for evaluating system aspects (including those for satellite system aspects).

The following principles are to be followed when evaluating radio interface technologies for IMT-2020:

− Evaluations of proposals can be through simulation, analytical and inspection procedures.

− The evaluation shall be performed based on the submitted technology proposals, and should follow the evaluation guidelines, using the evaluation methodology and the evaluation configurations defined in this Report.

− Evaluations through simulations contain both system-level and link-level simulations. Independent evaluation groups may use their own simulation tools for the evaluation.

− In case of evaluation through analysis, the evaluation is to be based on calculations which use the technical information provided by the proponent.

− In case of evaluation through inspection the evaluation is to be based on statements in the proposal.

The following options are foreseen for proponents and independent external evaluation groups doing the evaluations.

− Self-evaluation must be a complete evaluation (to provide a fully complete compliance template) of the technology proposal.

− An external evaluation group may perform complete or partial evaluation of one or several technology proposals to assess the compliance of the technologies with the minimum requirements of IMT-2020.

− Evaluations covering several technology proposals are encouraged.

6 Overview of characteristics for evaluation

The characteristics chosen for evaluation are explained in detail in Report ITU-R M.[IMT-2020.SUBMISSION −Requirements, evaluation criteria and submission templates for the development of IMT-2020], § 3, including service aspect requirements, spectrum aspect requirements, and technical performance requirements , the last of which are based on Report ITU-R M.[IMT-2020.TECH PERF REQ]. These are summarized in Table 6-1, together with their high level assessment method:

− Simulation (including system-level and link-level simulations, according to the principles of the simulation procedure given in § 7.1).

− Analytical (via calculation or mathematical analysis).

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

Summary of evaluation methodologies

Characteristic for evaluation	**High-level assessment method**	**Evaluation methodology in this report**	**Related section of Reports ITU-R M.[IMT-2020.TECH PERF REQ] and ITU-R M.[IMT-2020.SUBMISSION]**
Peak data rate	Analytical	§ 7.2.2	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.1
Peak spectral efficiency	Analytical	§ 7.2.1	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.2
User experienced data rate	Analytical for single band and single layer; Simulation for multi-layer	§ 7.2.3	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.3
5th percentile user spectral efficiency	Simulation	§ 7.1.2	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.4
Average spectral efficiency	Simulation	§ 7.1.1	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.5
Area traffic capacity	Analytical	§ 7.2.4	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.6
User plane latency	Analytical	§ 7.2.6	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.7.1
Control plane latency	Analytical	§ 7.2.5	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.7.2
Connection density	Simulation	§ 7.1.3	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.8
Energy efficiency	Inspection	§ 7.3.2	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.9
Reliability	Simulation	§ 7.1.5	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.10
Mobility	Simulation	§ 7.1.4	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.11
Mobility interruption time	Analytical	§ 7.2.7	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.12
Bandwidth	Inspection	§ 7.3.1	Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.13
Support of wide range of services	Inspection	§ 7.3.3	Report ITU-R M.[IMT-2020.SUBMISSION], § 3.1
Supported spectrum band(s)/range(s)	Inspection	§ 7.3.4	Report ITU-R M.[IMT-2020.SUBMISSION], § 3.2

Section 7 defines the evaluation methodology for assessing each of these criteria.

7 Evaluation methodology

The submission and evaluation process is defined in Document IMT-2020/2 − Submission, evaluation process and consensus building for IMT-2020.

Evaluation should be performed in compliance with the technical parameters provided by the proponents and the evaluation configurations specified for the test environments in § 8.2 of this Report. Each requirement should be evaluated independently, except for the average spectral efficiency and 5th percentile user spectral efficiency – both of which criteria shall be assessed jointly using the same simulation; consequently, the candidate RITs/SRITs shall fulfil the corresponding minimum requirements jointly. Furthermore, the evaluation parameters used for the system-level simulation used in the mobility evaluation should be the same as the parameters used for system-level simulation for average spectral efficiency and 5th percentile user spectral efficiency.

The evaluation methodology should include the following elements:

1 Candidate RITs/SRITs should be evaluated using reproducible methods including computer simulation, analytical approaches and inspection of the proposal.

2 Technical evaluation of the candidate RITs/SRITs should be made against each evaluation criterion for the required test environments.

3 Candidate RITs/SRITs should be evaluated based on technical descriptions that are submitted using a technologies description template.

In order for the ITU to be in a position to assess the evaluation results of each candidate RIT/SRIT, the following points should be taken into account:

− Use of unified methodology, software, and data sets by the evaluation groups wherever possible, e.g. in the area of channel modelling, link-level simulation, and link-to-system-level interface.

− Evaluation of multiple proposals using a single simulation tool by each evaluation group.

Evaluations of average spectral efficiency, 5th percentile user spectral efficiency, peak spectral efficiency, user experienced data rate, area traffic capacity, peak data rate, mobility, reliability, and connection density of candidate RITs/SRITs should take into account the Layer 1 and Layer 2 overhead information provided by the proponents.

7.1 System simulation procedures

This sub-section provides detailed description of evaluation method for technical performance requirements that uses simulation.

System simulation is simulation of the entire system which may be composed of link-level simulations and/or system-level simulations.

System-level simulation shall be based on the network layout defined in § 8.3 of this Report. The following principles shall be followed in system-level simulation:

− Users are dropped independently with a certain distribution over the predefined area of the network layout throughout the system as described in section 8 of this report.

− UEs (User Equipment) are randomly assigned LOS and NLOS channel conditions according to the applicable channel model defined in Annex 1 of this Report.

− Cell assignment to a UE is based on the proponent's cell selection scheme, which must be described by the proponent.

– The applicable distances between a UE and a base station are defined in Annex 1 of this Report.

– Signal fading and interference from each transmitter into each receiver are computed on an aggregated basis.

– The interference[1] over thermal (IoT) parameter is an uplink design constraint that the proponent must take into account when designing the system such that the average IoT value experienced in the evaluation is equal to or less than 10 dB.

– In simulations based on the full-buffer traffic model, packets are not blocked when they arrive into the system (i.e. queue depths are assumed to be infinite).

– UEs with a required traffic characteristic shall be modelled according to the traffic models defined in Table 8-X1 in § 8.4 of this Report.

– Packets are scheduled with an appropriate packet scheduler(s), or with non-scheduled mechanism when applicable for full buffer and other traffic models separately. Channel quality feedback delay, feedback errors, PDU (protocol data unit) errors and real channel estimation effects inclusive of channel estimation error are modelled and packets are retransmitted as necessary.

– The overhead channels (i.e., the overhead due to feedback and control channels) should be realistically modelled.

– For a given drop the simulation is run and then the process is repeated with UEs dropped at new random locations. A sufficient number of drops is simulated to ensure convergence in the UE and system performance metrics. The proponent should provide information on the width of confidence intervals of UE and system performance metrics of corresponding mean values, and evaluation groups are encouraged to use this information.[2]

– All cells in the system shall be simulated with dynamic channel properties and performance statistics are collected taking into account the wrap-around configuration in the network layout, noting that wrap-around is not considered in the indoor case.

In order to perform less complex system-level simulations, often the simulations are divided into separate ‘link-level’ and ‘system-level’ simulations with a specific link-to-system interface. Another possible way to reduce system-level simulation complexity is to employ simplified interference modelling. Such methods should be sound in principle, and it is not within the scope of this document to describe them.

Evaluation groups are allowed to use their own approaches provided that the used methodologies are:

– well described and made available to the Radiocommunication Bureau and other evaluation groups;

– included in the evaluation report.

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[1] The interference means the effective interference received at the base station.

[2] The confidence interval and the associated confidence level indicate the reliability of the estimated parameter value. The confidence level is the certainty (probability) that the true parameter value is within the confidence interval. The higher the confidence level the larger the confidence interval.

Models for link-level and system-level simulations should include error modelling, e.g., for channel estimation, phase noise and for the errors of control channels that are required to decode the traffic channel (including the feedback channel and channel quality information). The overheads of the feedback channel and the control channel should be modelled according to the assumptions used in the overhead channels' radio resource allocation.

7.1.1 Average spectral efficiency

Let $R_i(T)$ denote the number of correctly received bits by user i ($i = 1,\ldots N$) (downlink) or from user i (uplink) in a system comprising a user population of N users and M Transmission Reception Points (TRxPs). Furthermore, let W denote the channel bandwidth and T the time over which the data bits are received. The average spectral efficiency may be estimated by running system-level simulations over number of drops N_{drops}. Each drop gives a value of $\sum_{i=1}^{N} R_i\,(T)$ denoted as:

$R^{\,(1)}(T), \ldots\ R^{(N_{drops})}\,(T)$ and the estimated average spectral efficiency resulting is given by:

$$\widehat{\mathrm{SE}}_{\mathrm{avg}} = \frac{\sum_{j=1}^{N_{drops}} R^{(j)}\,(T)}{N_{drops}\,T.\mathrm{W}.M} = \frac{\sum_{j=1}^{N_{drops}} \sum_{i=1}^{N} R_i^{(j)}\,(T)}{N_{drops}\,T.\mathrm{W}.M}$$

where $\widehat{\mathrm{SE}}_{\mathrm{avg}}$ is the estimated average spectral efficiency and will approach the actual average with an increasing number of N_{drops} and $R_i^{(j)}\,(T)$ is the simulated total number of correctly received bits for user i in drop j.

The average spectral efficiency is evaluated by system level simulation using the evaluation configuration parameters of Indoor Hotspot-eMBB, Dense Urban-eMBB, and Rural-eMBB test environments as defined in this Report. It should be noted that the average spectral efficiency is evaluated only using a single-layer layout configuration even if a test environment comprises a multi-layer layout configuration.

The results from the system-level simulation are used to derive the average spectral efficiency as defined in Report ITU-R M.[IMT-2020.TECH PERF REQ]. The necessary information is the number of correctly received bits per UE during the active session time the UE is in the simulation. The effective bandwidth is the operating bandwidth normalized appropriately considering the uplink/downlink ratio for TDD system.

Layer 1 and Layer 2 overheads should be accounted for in time and frequency. Examples of Layer 1 overhead include synchronization, guard band and DC subcarriers, guard/switching time (for example, in TDD systems), pilots and cyclic prefix. Examples of Layer 2 overhead include common control channels, HARQ ACK/NACK signalling, channel feedback, random access, packet headers and CRC. It must be noted that in computing the overheads, the fraction of the available physical resources used to model control overhead in Layer 1 and Layer 2 should be accounted for in a non-overlapping way. Power allocation/boosting should also be accounted for in modelling resource allocation for control channels.

7.1.2 5th percentile user spectral efficiency

5th percentile user spectral efficiency is the 5th percentile point of the cumulative distribution function (CDF) of the normalized user throughput, estimated from all possible user locations.

Let user i in drop j correctly decode $R_i^{(j)}\,(T)$ accumulated bits in [0, T]. For non-scheduled duration of user i zero bits are accumulated. During this total time user i receives accumulated service time of $T_i \leqslant T$, where the service time is the time duration between the first packet arrival and when the last packet of the burst is correctly decoded. In case of full buffer, $T_i = T$. Hence the rate normalised by service time T_i and channel bandwidth W of user i in drop j, $r_i^{(j)}$, is:

$$r_i^{(j)} = \frac{R_i^{(j)}(T)}{T_i \cdot W}$$

Running N_{drops} simulations leads to $N_{drops} \times N$ values of $r_i^{(j)}$ of which the lowest 5th percentile point of the CDF is used to estimate the 5th percentile user spectral efficiency.

The 5th percentile user spectral efficiency is evaluated by system level simulation using the evaluation configuration parameters of Indoor Hotspot-eMBB, Dense Urban-eMBB, and Rural-eMBB test environments. It should be noted that the 5th percentile user spectral efficiency is evaluated only using a single-layer layout configuration even if a test environment comprises a multi-layer layout configuration. The 5th percentile user spectral efficiency shall be evaluated using identical simulation assumptions as the average spectral efficiency for that test environment.

The results from the system-level simulation are used to derive the 5th percentile user spectral efficiency as defined in Report ITU-R M.[IMT-2020.TECH PERF REQ]. The necessary information is the number of correctly received bits per UE during the active session time the UE is in the simulation. The effective bandwidth is the operating bandwidth normalized appropriately considering the uplink/downlink ratio for TDD system.

Layer 1 and Layer 2 overheads should be accounted for in time and frequency. Example of Layer 1 and Layer 2 overheads can be found in § 7.1.1 for "Average spectral efficiency".

7.1.3 Connection density

There are two possible evaluation methods to evaluate connection density requirement defined in ITU-R M.[IMT-2020.TECH PERF REQ].

− Non-full buffer system-level simulation.

− Full-buffer system-level simulation followed by link-level simulation.

The following steps are used to evaluate the connection density based on non-full buffer system-level simulation. Traffic model used in this method is defined in Table 8-X1 in § 8.4 of this Report.

Step 1: Set system user number per TRxP as N.

Step 2: Generate the user packet according to the traffic model.

Step 3: Run non-full buffer system-level simulation to obtain the packet outage rate. The outage rate is defined as the ratio of the number of packets that failed to be delivered to the destination receiver within a transmission delay of less than or equal to 10s to the total number of packets generated in the step 2.

Step 4: Change the value of N and repeat step2-3 to obtain the system user number per TRxP N' satisfying the packet outage rate of 1%.

Step 5: Calculate connection density by equation $C = N' / A$, where the TRxP area A is calculated as $A = \text{ISD}^2 \times \text{sqrt}(3)/6$, and ISD is the inter-site distance.

The requirement is fulfilled if the connection density C is greater than or equal to the connection density requirement defined in ITU-R M.[IMT-2020.TECH PERF REQ].

The simulation bandwidth used to fulfill the requirement should be reported. Additionally, it is encouraged to report the connection efficiency (measured as N' divided by simulation bandwidth) for the achieved connection density.

The following steps are used to evaluate the connection density based on full-buffer system-level simulation followed by link-level simulation.

Step 1: Perform full-buffer system-level simulation using the evaluation parameters for Urban Macro-mMTC test environment, determine the uplink $SINR_i$ for each percentile i=1…99 of the distribution over users, and record the average allocated user bandwidth W_{user}.

- In case UE multiplexing on the same time/frequency resource is modelled in this step, record the average number of multiplexed users N_{mux}. N_{mux} = 1 for no UE multiplexing.

Step 2: Perform link-level simulation and determine the achievable user data rate R_i for the recoded $SINR_i$ and W_{user} values.

- In case UE multiplexing on the same time/frequency resource is modelled in this step, record the average number of multiplexed users $n_{mux,i}$ under $SINR_i$. The achievable data rate for this case is derived by $R_i = Z_i/n_{mux,i}$, where aggregated bit rate Z_i is the summed bit rate of $n_{mux,i}$ users on W_{user}. $n_{mux,i}$ = 1 for no UE multiplexing.

Step 3: Calculate the packet transmission delay of a user as $D_i = S/R_i$, where S is the packet size.

Step 4: Calculate the traffic generated per user as $T = S/T_{inter\text{-}arrival}$, where $T_{inter\text{-}arrival}$ is the inter-packet arrival time.

Step 5: Calculate the long-term frequency resource requested under $SINR_i$ as $B_i = T/(R_i/W_{user})$.

Step 6: Calculate the number of supported connections per TRxP, $N = W$ / mean(B_i). W is the simulation bandwidth. The mean of B_i may be taken over the best 99% of the $SINR_i$ conditions.

- In case UE multiplexing is modelled in Step 1, $N = N_{mux} \times W$ / mean(B_i). In case UE multiplexing is modelled in Step 2, $N = W$ / mean($B_i/n_{mux,i}$).

Step 7: Calculate the connection density as $C = N / A$, where the TRxP area A is calculated as $A = \text{ISD}^2 \times \text{sqrt}(3)/6$, and ISD is the inter-site distance.

The requirement is fulfilled if the 99th percentile of the delay per user D_i is less than or equal to 10s, and the connection density is greater than or equal to the connection density requirement defined in ITU-R M.[IMT-2020.TECH PERF REQ].

The simulation bandwidth used to fulfill the requirement should be reported. Additionally, it is encouraged to report the connection efficiency (measured as N divided by simulation bandwidth) for the achieved connection density.

7.1.4 Mobility

Mobility shall be evaluated under Indoor Hotspot-eMBB, Dense Urban-eMBB, and Rural-eMBB test environments using the same evaluation parameters and configuration selected for the evaluation of average spectral efficiency and 5th percentile user spectral efficiency. Under Rural-eMBB test environment, target values for both mobility of 120 km/h and 500 km/h in Table 4 of § 4.11 in Report ITU-R M.[IMT-2020.TECH PERF REQ] shall be achieved to fulfill mobility requirements of Rural-eMBB test environment.

The evaluator shall perform the following steps in order to evaluate the mobility requirement.

Step 1: Run uplink system-level simulations, identical to those for average spectral efficiency, and 5th percentile user spectral efficiency except for speeds taken from Table 4 of Report ITU-R M.[IMT-2020.TECH PERF REQ], using link level simulations and a link-to-system interface appropriate for these speed values, for the set of selected test environment(s) associated with the candidate RITs/SRITs and collect overall statistics for uplink $SINR$ values, and construct CDF over these values for each test environment.

Step 2: Use the CDF for the test environment(s) to save the respective 50th-percentile *SINR* value.

Step 3: Run new uplink link-level simulations for the selected test environment(s) for either NLOS or LOS channel conditions using the associated speeds in Table 4 of Report ITU-R M.[IMT-2020.TECH PERF REQ], as input parameters, to obtain link data rate and residual packet error ratio as a function of *SINR*. The link-level simulation shall use air interface configuration(s) supported by the proposal and take into account retransmission, channel estimation and phase noise impact.

Step 4: Compare the uplink spectral efficiency values (link data rate normalized by channel bandwidth) obtained from Step 3 using the associated *SINR* value obtained from Step 2 for selected test environments, with the corresponding threshold values in the Table 4 of Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.11.

Step 5: The proposal fulfils the mobility requirement if the spectral efficiency value is larger than or equal to the corresponding threshold value and if also the residual decoded packet error ratio is less than 1%, for all selected test environments. For the selected test environment it is sufficient if one of the spectral efficiency values (of either NLOS or LOS channel conditions) fulfil the threshold.

Similar methodology can be used for downlink in case this is additionally evaluated.

7.1.5 Reliability

The evaluator shall perform the following steps in order to evaluate the reliability requirement using system-level simulation followed by link-level simulations.

Step 1: Run downlink or uplink full buffer system-level simulations of candidate RITs/SRITs using the evaluation parameters of Urban Macro-URLLC test environment see § 8.4.1, and collect overall statistics for downlink or uplink *SINR* values, and construct CDF over these values.

Step 2: Use the CDF for the Urban Macro-URLLC test environment to save the respective 5th percentile downlink or uplink *SINR* value.

Step 3: Run corresponding link-level simulations for either NLOS or LOS channel conditions using the associated parameters in the Table 8-X2 of this report, § 8.4, to obtain success probability, which equals to (1-P_e), where P_e is the residual packet error ratio within maximum delay time as a function of *SINR* taking into account retransmission.

Step 4: The proposal fulfils the reliability requirement if at the 5th percentile downlink or uplink *SINR* value of *Step 2* and within the required delay, the success probability derived in *Step 3* is larger than or equal to the required success probability. It is sufficient to fulfil the requirement in either downlink or uplink in either NLOS or LOS channel conditions.

7.2 Analytical approach

For sections § 7.2.1 to § 7.2.7 below, a straight forward calculation based on the definition in Report ITU-R M.[IMT-2020.TECH PERF REQ] will be enough to evaluate them. The evaluation shall describe how this calculation has been performed. Evaluation groups should follow the calculation provided by proponents if it is justified properly.

7.2.1 Peak spectral efficiency calculation

The peak spectral efficiency is calculated as specified in Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.2. The proponent should report the assumed frequency band(s) of operation and channel bandwidth, for which the peak spectral efficiency value is achievable. For TDD, the channel bandwidth information should include the effective bandwidth, which is the operating bandwidth normalized appropriately considering the uplink/downlink ratio.

The antenna configuration to be used for peak spectral efficiency is defined in Table 8-X1 of this Report, § 8.4. Layer 1 and Layer 2 overhead should be accounted for in time and frequency, in the same way as assumed for the "Average spectral efficiency".

Proponents should demonstrate that the peak spectral efficiency requirement can be met for, at least, one of the carrier frequencies assumed in the test environments under the eMBB usage scenario.

7.2.2 Peak data rate calculation

The peak data rate is calculated as specified in Report ITU-R M.[IMT-2020.TECH PERF REQ] § 4.1, using peak spectral efficiency and maximum assignable channel bandwidth.

Peak spectral efficiency and maximum assignable channel bandwidth may have different values in different frequency bands. The peak data rate may be summed over multiple bands in case of bandwidth aggregated across multiple bands.

The proponent should report the peak data rate value achievable by the candidate RITs/SRITs and identify the assumed frequency band(s) of operation, the maximum assignable channel bandwidth in that band(s) and the main assumptions related to the peak spectral efficiency over the assumed frequency band(s) (e.g., antenna configuration).

Proponents should demonstrate that the peak data rate requirement can be met for, at least, one carrier frequency or a set of aggregated carrier frequencies (where it is the case), assumed in the test environments under the eMBB usage scenario

7.2.3 User experienced data rate

The evaluation is conducted in Dense Urban-eMBB test environment.

For one frequency band and one TRxP layer, user experienced data rate is derived analytically from the 5th percentile user spectral efficiency according to equation (3) defined in Report ITU-R M.[IMT-2020.TECH PERF REQ]. The bandwidth used should be reported by the proponent.

In case of multi-layer configuration, system level simulation is used. In this case, the single user data rate may be aggregated over layers and/or bands. The user experienced data rate is derived from the 5th percentile point of the CDF of single user data rate.

7.2.4 Area traffic capacity

The evaluation is conducted in Indoor Hotspot-eMBB test environment where a single band is considered.

Area traffic capacity is derived based on the achievable average spectral efficiency, TRxP 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:

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

7.2.5 Control plane latency calculation

The proponent should provide the elements and their values in the calculation of the control plane latency. Table X-Y provides an example of the elements in the calculation of the control plane latency.

TABLE X-Y

Example of Control plane latency analysis template

Step	Description	Value
1	Random access procedure	
2	UL synchronization	
3	Connection establishment + HARQ retransmission	
4	Data bearer establishment + HARQ retransmission	
	Total control plane latency	

7.2.6 User plane latency calculation

The proponent should provide the elements and their values in the calculation of the user plane latency, for both UL and DL. Table X-X provides an example of the elements in the calculation of the user plane latency.

TABLE X-X

Example of user-plane latency analysis template

Step	Description	Value
1	UE processing delay	
2	Frame alignment	
3	TTI for data packet transmission	
4	HARQ retransmission	
5	BS processing delay	
-	Total one way user plane latency	

7.2.7 Mobility interruption time

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.

7.3 Inspection approach

Inspection is conducted by reviewing the functionality and parameterization of a proposal.

7.3.1 Bandwidth

The support of maximum bandwidth required in Report ITU-R M.[IMT-2020.TECH PERF REQ], § 4.13 is verified by inspection of the proposal.

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

The requirements for bandwidth or the bandwidth numbers demonstrated by the proponent do not pose any requirements or limitations for other Technical Performance Requirements that depend on bandwidth. If any other requirement requires a higher bandwidth, the capability to reach that bandwidth should be described as well.

7.3.2 Energy efficiency

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 in Report ITU-R M.[IMT-2020.TECH PERF REQ] 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.

7.3.3 Support of wide range of services

There are elements of the minimum technical performance requirements identified within Report ITU-R M.[TECH PERF REQ] that indicate whether or not the candidate RITs/SRITs are capable of enabling certain services and performance targets, as envisioned in Recommendation ITU-R M.2083.

The support of a wide range of services is verified by inspection of the candidate RITs/SRITs ability to meet the minimum technical performance requirements for various usage scenarios and their associated test environments.

7.3.4 Supported spectrum band(s)/range(s)

The spectrum band(s) and/or range(s) that the candidate RITs/SRITs can utilize is verified by inspection.

8 Test environments and evaluation configurations

This section describes the test environments and the related evaluation configurations (including simulation parameters) necessary to evaluate the performance criteria of candidate RITs/SRITs (details of test environments and channel models can be found in Annex 1).

These predefined test environments are used in order to evaluate the requirements for the technology proposals. IMT-2020 is to cover a wide range of performance in a wide range of environments. Although it should be noted that thorough testing and evaluation is prohibitive, these test environments have therefore been chosen such that typical and different deployments are modelled and critical questions in system design and performance can be investigated. Focus is thus on scenarios testing limits of performance.

8.1 Usage Scenarios

As defined in Recommendation ITU-R M.2083, IMT-2020 is envisaged to expand and support diverse usage scenarios and applications that will continue beyond IMT-Advanced. There are three usage scenarios for IMT-2020 as follows:

– **Enhanced Mobile Broadband (eMBB)**: This usage scenario will come with new application areas and requirements in addition to existing Mobile Broadband applications for improved performance and an increasingly seamless user experience. This usage scenario covers a range of cases, including wide-area coverage and hotspot, which have different requirements.

– **Massive machine type communications (mMTC)**: This usage scenario is characterized by a very large number of connected devices typically transmitting a relatively low volume of non-delay-sensitive data.

– **Ultra-reliable and low latency communications (URLLC)**: This usage scenario has stringent requirements for capabilities such as throughput, latency and availability. Some examples include wireless control of industrial manufacturing or production processes, remote medical surgery, distribution automation in a smart grid, transportation safety, etc.

8.2 Test environments

A test environment reflects a combination of geographic environment and usage scenario. There are five selected test environments for IMT-2020 as follows:

– ***Indoor Hotspot-eMBB***: An indoor isolated environment at offices and/or in shopping malls based on stationary and pedestrian users with very high user density.

– ***Dense Urban-eMBB***: An urban environment with high user density and traffic loads focusing on pedestrian and vehicular users.

– ***Rural-eMBB****:* A rural environment with larger and continuous wide area coverage, supporting pedestrian, vehicular and high speed vehicular users.

– ***Urban Macro–mMTC*****:** An urban macro environment targeting continuous coverage focusing on a high number of connected machine type devices.

– ***Urban Macro–URLLC*****:** An urban macro environment targeting ultra-reliable and low latency communications.

The mapping of the five test environments and the three usage scenarios is given in Table Z-Z.

TABLE Z-Z

Mapping of test environments and usage scenarios

Usage scenarios	eMBB			mMTC	URLLC
Test environments	Indoor Hotspot - eMBB	Dense Urban – eMBB	Rural – eMBB	Urban Macro – mMTC	Urban Macro – URLLC

8.3 Network layout

No specific topographical details are taken into account in Dense Urban - eMBB (macro layer) Rural-eMBB, Urban Macro-mMTC, and Urban Macro-URLLC test environments. In the above cases, base stations (BSs) / sites are placed in a regular grid, following hexagonal layout. The simulation will be a wrap-around configuration of 19 sites, each of 3 TRxPs (cells). A basic hexagon layout for the example of three TRxPs per site is the same as shown in Figure 1 in § 8.3 of Report ITU-R M.2135-1, where also basic geometry (antenna boresight, cell range, and ISD) is defined. UEs are distributed uniformly over the whole area.

In the following network topology for the selected test environments is described.

8.3.1 Indoor Hotspot-eMBB

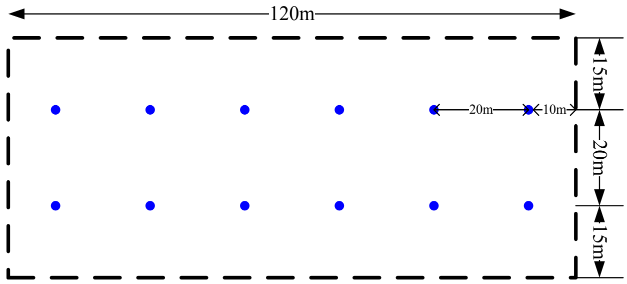
The Indoor Hotspot-eMBB test environment consists of one floor of a building. The height of the floor is 3 m. The floor has a surface of 120 m ×50 m and 12 BSs/sites which are placed in 20 meter spacing as shown in Figure X1-A, with a LOS probability as defined by channel model in Annex 1,

§ 3.4, Table 3-8. In Figure X1-A, internal walls are not explicitly shown but are modeled via the stochastic LOS probability model.

The type of site deployed (e.g. one TRxP per site or 3 TRxPs per site) is not defined and should be reported by the proponent.

FIGURE X1-A

Indoor Hotspot sites layout



8.3.2 Dense Urban-eMBB

In the dense-urban case, no specific topographical details are taken into account. The deployment consists of two layers, a macro layer and a micro layer. The macro-layer base stations are placed in a regular grid, following hexagonal layout with three sectors each, as shown in Figure X2 below. For the micro layer, there are 3 micro sites randomly dropped in each macro TRxP area (see Figure X3). The micro-layer deployment (e.g. 3 micro sites per macro TRxP and there is either one or 3 TRxPs at each micro site) is not defined but should be reported by the proponent. The proponent should describe micro-layer base stations placement method.

FIGURE X2

Sketch of hexagonal site layout

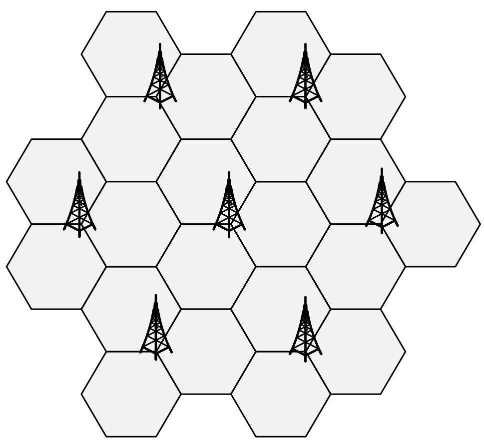
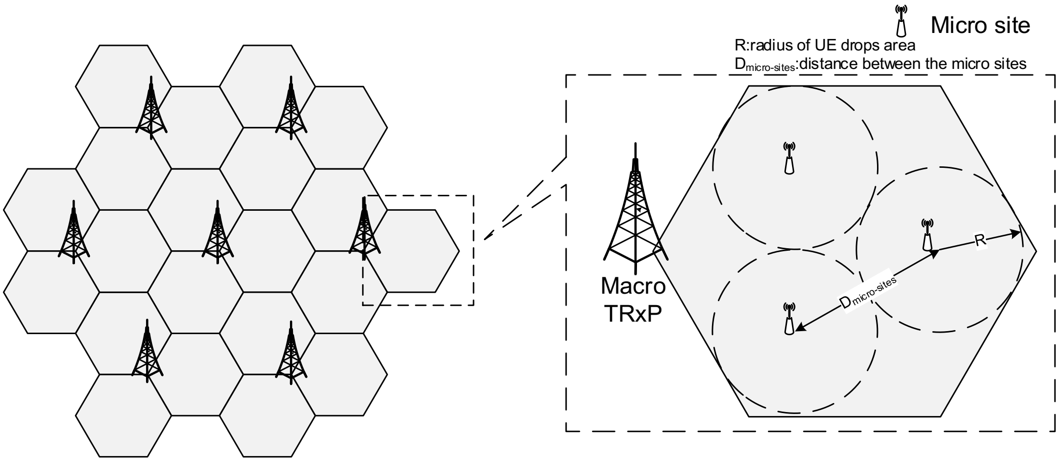


FIGURE X3

Example sketch of dense urban-eMBB layout



8.3.3 Rural-eMBB

In Rural-eMBB test environment, the BSs/sites are placed in a regular grid, following hexagonal layout with three TRxPs each, as in the macro layer of the Dense Urban–eMBB test environment, as shown in Figure X2. For evaluation of the mobility, the same topographical details of hexagonal layout are applied to both 120 km/h and 500 km/h mobility.

For 500 km/h mobility, additional evaluations are encouraged using linear cell layout configuration(s) defined in Annex 2.

8.3.4 Urban Macro-mMTC and Urban Macro-URLLC

In the Urban Macro-mMTC and Urban Macro-URLLC test environments, the BSs/sites are placed in a regular grid, following hexagonal layout with three TRxPs each, as in the Dense Urban-eMBB macro layer and Rural-eMBB test environment; this is shown in Figure X2.

8.4 Evaluation configurations

Evaluation configurations are defined for the selected test environments. The configuration parameters shall be applied in analytical and simulation assessments of candidate RITs/SRITs. For the cases when there are multiple evaluation configurations under the selected test environment, one of the evaluation configurations under that test environment can be used to test the candidate RITs/SRITs. The technical performance requirement corresponding to that test environment is fulfilled if this requirement is met for one of the evaluation configurations under that specific test environment.

In addition, for the Rural-eMBB test environment, the average spectral efficiency value should meet the threshold values for the LMLC evaluation configuration with ISD of 6000 m and either evaluation configuration with ISD of 1732 m.

For system level simulation, there are two channel model variants of primary module for IMT-2020 evaluation: (1) channel model A and (2) channel model B. Proponents can select either channel model A or B to evaluate the candidate RITs/SRITs. The technical performance requirement corresponding to a test environment is fulfilled if this requirement is met for either channel model A or B for that specific test environment. The same channel model variant should be used to evaluate all the test environments.

The configuration parameters (and also the propagation and channel models in Annex 1) are solely for the purpose of consistent evaluation of the candidate RITs/SRITs and relate only to specific test environments designed for these evaluations. Therefore, the configuration parameters should not be considered as those 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. Some configuration parameters are specified in terms of a range of values. This is done to provide some flexibility in the evaluation process. It should be noted that in such cases, meeting the technical performance requirements are not necessarily associated with the lowest/highest value in the range.

TABLE 8-X1

(1) Evaluation configurations for Indoor Hotspot-eMBB test environment

Parameters	Indoor Hotspot-eMBB		
	Spectral Efficiency, Mobility, and Area Traffic Capacity Evaluations		
	Configuration A	Configuration B	Configuration C
Baseline evaluation configuration parameters			
Carrier frequency for evaluation	4 GHz	30 GHz	70 GHz
BS antenna height	3 m	3 m	3 m
Total transmit power per TRxP	24 dBm for 20 MHz; 21 dBm for 10 MHz	23 dBm for 80 MHz bandwidth; 20 dBm for 40 MHz bandwidth EIRP should not exceed 58 dBm	21 dBm for 80 MHz bandwidth 18 dBm for 40 MHz bandwidth EIRP should not exceed 58 dBm
UE power class	23 dBm	23 dBm EIRP should not exceed 43 dBm	21 dBm EIRP should not exceed 43 dBm
Additional parameters for system-level simulation			
Inter-site distance	20 m	20 m	20 m
Number of antenna elements per TRxP	Up to 256 Tx/Rx	Up to 256 Tx/Rx	Up to 1024 Tx/Rx
Number of UE antenna elements	Up to 8 Tx/Rx	Up to 32 Tx/Rx	Up to 64 Tx/Rx
Device deployment	Randomly and uniformly distributed over area 100% indoor	Randomly and uniformly distributed over area 100% indoor	Randomly and uniformly distributed over area 100% indoor
UE mobility model	Fixed and identical speed |v| of all UEs, randomly and uniformly distributed direction	Fixed and identical speed |v| of all UEs, randomly and uniformly distributed direction	Fixed and identical speed |v| of all UEs, randomly and uniformly distributed direction
UE speeds of interest	100% indoor, 3 km/h	100% indoor, 3 km/h	100% indoor, 3 km/h
Inter-site interference modeling	Explicitly modelled	Explicitly modelled	Explicitly modelled
BS noise figure	5 dB	7 dB	7 dB
UE noise figure	7 dB	10 dB[3]	10 dB[3]
BS antenna element gain	8 dBi	5 dBi	5 dBi
UE antenna element gain	0 dBi	5 dBi	5 dBi
Thermal noise level	-174 dBm/Hz	-174 dBm/Hz	-174 dBm/Hz
Traffic model	Full buffer	Full buffer	Full buffer
Simulation bandwidth	20 MHz for TDD, 10 MHz+10 MHz for FDD	80 MHz for TDD, 40 MHz+40 MHz for FDD	80 MHz for TDD, 40 MHz+40 MHz for FDD
UE density	10 UEs per TRxP randomly and uniformly dropped throughout the geographical area	10 UEs per TRxP randomly and uniformly dropped throughout the geographical area	10 UEs per TRxP randomly and uniformly dropped throughout the geographical area
UE antenna height	1.5 m	1.5 m	1.5 m

[3] 10 dB for 30 GHz / 70 GHz is assumed for high performance UE. Higher UE noise figure values can be considered by the proponent, e.g. 13 dB for 30 GHz / 70 GHz.

1 **(2) Evaluation configurations for Dense Urban-eMBB test environment**

Parameters	Dense Urban-eMBB		
	Spectral Efficiency and Mobility Evaluations		User Experienced Data Rate Evaluation
	Configuration A	Configuration B	Configuration C
Baseline evaluation configuration parameters			
Carrier frequency for evaluation	1 layer (Macro) with 4 GHz	1 layer (Macro) with 30 GHz	✓ 1 or 2 layers (Macro + Micro). ✓ 4 GHz & 30 GHz available in Macro & Micro layers
BS antenna height	25 m	25 m	25 m for macro sites and 10 m for micro sites
Total transmit power per TRxP	44 dBm for 20 MHz bandwidth 41 dBm for 10 MHz bandwidth	40 dBm for 80 MHz bandwidth 37 dBm for 40 MHz bandwidth EIRP should not exceed 73 dBm	✓ Macro 4GHz: 44 dBm for 20 MHz bandwidth 41 dBm for 10 MHz bandwidth ✓ Macro 30 GHz: 40 dBm for 80 MHz bandwidth 37 dBm for 40 MHz bandwidth EIRP should not exceed 73 dBm ✓ Micro 4GHz: 33 dBm for 20MHz bandwidth 30 dBm for 10MHz bandwidth ✓ Micro 30GHz: 33 dBm for 80 MHz bandwidth 30 dBm for 40 MHz bandwidth EIRP should not exceed 68 dBm
UE power class	23 dBm	23 dBm, EIRP should not exceed 43 dBm	4 GHz: 23 dBm 30 GHz: 23 dBm, EIRP should not exceed 43 dBm
Percentage of high loss and low loss building type (Note 1)	20% high loss, 80% low loss	20% high loss, 80% low loss	20% high loss, 80% low loss
Additional parameters for system-level simulation			
Inter-site distance	200 m	200 m	Macro layer: 200 m (Note: density and layout of Micro layer are in section 8.3)
Number of antenna elements per TRxP	Up to 256 Tx/Rx	Up to 256 Tx/Rx	Up to 256 Tx/Rx
Number of UE antenna elements	Up to 8 Tx/Rx	Up to 32 Tx/Rx	4 GHz: Up to 8 Tx/Rx 30 GHz: Up to 32 Tx/Rx
Device deployment	80% indoor, 20% outdoor (in-car) Randomly and uniformly distributed over area under Macro layer	80% indoor, 20% outdoor (in-car) Randomly and uniformly distributed over area under Macro layer	80% indoor, 20% outdoor (in-car) Randomly and uniformly distributed over area under Macro layer
UE mobility model	Fixed and identical speed |v| of all UEs of the same mobility class, randomly and uniformly distributed direction.	Fixed and identical speed |v| of all UEs of the same mobility class, randomly and uniformly distributed direction.	Fixed and identical speed |v| of all UEs of the same mobility class, randomly and uniformly distributed direction.
UE speeds of interest	Outdoor users (in-car): 30 km/h Indoor users: 3km/h	Outdoor users (in-car): 30 km/h Indoor users: 3 km/h	Outdoor users (in-car): 30 km/h Indoor users: 3 km/h

Parameters	Dense Urban-eMBB		
	Spectral Efficiency and Mobility Evaluations		User Experienced Data Rate Evaluation
	Configuration A	Configuration B	Configuration C
Inter-site interference modeling	Explicitly modelled	Explicitly modelled	Explicitly modelled
BS noise figure	5 dB	7 dB	4 GHz: 5 dB 30 GHz: 7 dB
UE noise figure	7 dB	10 dB[4]	4 GHz: 7 dB 30 GHz: 10 dB[4]
BS antenna element gain	8 dBi	8 dBi	4 GHz: 8 dBi 30 GHz: Macro TRxP: 8 dBi
UE antenna element gain	0 dBi	5 dBi	4 GHz: 0 dBi 30 GHz: 5 dBi
Thermal noise level	-174 dBm/Hz	-174 dBm/Hz	-174 dBm/Hz
Traffic model	Full buffer	Full buffer	Full buffer
Simulation bandwidth	20 MHz for TDD, 10 MHz+10 MHz for FDD	80 MHz for TDD, 40 MHz+40 MHz for FDD	4 GHz: 20MHz for TDD, 10 MHz+10 MHz for FDD 30 GHz: 80 MHz for TDD, 40 MHz+40 MHz for FDD
UE density	10 users per TRxP Randomly and uniformly distributed over area under Macro layer	10 users per TRxP Randomly and uniformly distributed over area under Macro layer	10 users per TRxP for multi-layer case, randomly and uniformly dropped within a cluster. The proponent reports the size of the cluster
UE antenna height	Outdoor UTs: 1.5 m Indoor UTs: $3(n_{fl} – 1) + 1.5$; $n_{fl} \sim$ uniform$(1,N_{fl})$ where $N_{fl} \sim$ uniform(4,8)	Outdoor UTs: 1.5 m Indoor UTs: $3(n_{fl} – 1) + 1.5$; $n_{fl} \sim$ uniform$(1,N_{fl})$ where $N_{fl} \sim$ uniform(4,8)	Outdoor UTs: 1.5 m Indoor UTs: $3(n_{fl} – 1) + 1.5$; $n_{fl} \sim$ uniform$(1,N_{fl})$ where $N_{fl} \sim$ uniform(4,8)

(3) Evaluation configurations for Rural-eMBB test environment

Parameters	Rural-eMBB		
	Spectral Efficiency and Mobility Evaluations		Average Spectral Efficiency Evaluation
	Configuration A	Configuration B	Configuration C (LMLC)
Baseline evaluation configuration parameters			
Carrier frequency for evaluation	700 MHz	4 GHz	700 MHz
BS antenna height	35 m	35 m	35 m
Total transmit power per TRxP	49 dBm for 20 MHz; 46 dBm for 10 MHz	49 dBm for 20 MHz; 46 dBm for 10 MHz	49 dBm for 20 MHz; 46 dBm for 10 MHz
UE power class	23 dBm	23 dBm	23 dBm
Percentage of high loss and low loss building type	100% low loss	100% low loss	100% low loss

[4] 10 dB for 30 GHz is assumed for high performance UE. Higher UE noise figure values can be considered by the proponent, e.g. 13 dB for 30 GHz.

Parameters	**Rural-eMBB**		
	Spectral Efficiency and Mobility Evaluations		**Average Spectral Efficiency Evaluation**
	Configuration A	**Configuration B**	**Configuration C (LMLC)**
Additional parameters for system-level simulation			
Inter-site distance	1732 m	1732 m	6000 m
Number of antenna elements per TRxP	Up to 64 Tx/Rx	Up to 256 Tx/Rx	Up to 64 Tx/Rx
Number of UE antenna elements	Up to 4 Tx/Rx	Up to 8 Tx/Rx	Up to 4 Tx/Rx
Device deployment	50% indoor, 50% outdoor (in-car) Randomly and uniformly distributed over area	50% indoor, 50% outdoor (in-car) Randomly and uniformly distributed over area	40% Indoor, 40% outdoor (pedestrian), 20% outdoor (in-car) Randomly and uniformly distributed over area
UE mobility model	Fixed and identical speed |v| of all UEs, randomly and uniformly distributed direction	Fixed and identical speed |v| of all UEs, randomly and uniformly distributed direction	Fixed and identical speed |v| of all UEs, randomly and uniformly distributed direction
UE speeds of interest	Indoor users: 3 km/h; Outdoor users (in-car): 120 km/h; 500 km/h for evaluation of mobility in high-speed case	Indoor users: 3 km/h; Outdoor users (in-car): 120 km/h; 500 km/h for evaluation of mobility in high-speed case	Indoor user: 3 km/h; Outdoor user (pedestrian): 3 km/h; Outdoor users (in-car): 30 km/h
Inter-site interference modeling	Explicitly modelled	Explicitly modelled	Explicitly modelled
BS noise figure	5 dB	5 dB	5 dB
UE noise figure	7 dB	7 dB	7 dB
BS antenna element gain	8 dBi	8 dBi	8 dBi
UE antenna element gain	0 dBi	0 dBi	0 dBi
Thermal noise level	-174 dBm/Hz	-174 dBm/Hz	-174 dBm/Hz
Traffic model	Full buffer	Full buffer	Full buffer
Simulation bandwidth	20 MHz for TDD, 10 MHz+10 MHz for FDD	20 MHz for TDD, 10 MHz+10 MHz for FDD	20 MHz for TDD, 10 MHz+10 MHz for FDD
UE density	10 UEs per TRxP	10 UEs per TRxP	10 UEs per TRxP
UE antenna height	1.5 m	1.5 m	1.5 m

(4) Evaluation configurations for Urban Macro-mMTC test environments

Parameters	**Urban Macro–mMTC**	
	Connection Density Evaluation	
	Configuration A	**Configuration B**
Baseline evaluation configuration parameters		
Carrier frequency for evaluation	700 MHz	700 MHz
BS antenna height	25 m	25 m
Total transmit power per TRxP[5]	49 dBm for 20 MHz bandwidth 46 dBm for 10 MHz bandwidth	49 dBm for 20 MHz bandwidth 46 dBm for 10 MHz bandwidth
UE power class	23 dBm	23 dBm

[5] This parameter(s) is/are used for cell association.

Parameters	Urban Macro–mMTC Connection Density Evaluation Configuration A	Urban Macro–mMTC Connection Density Evaluation Configuration B
Baseline evaluation configuration parameters		
Percentage of high loss and low loss building type (Note 1)	20% high loss, 80% low loss	20% high loss, 80% low loss
Additional parameters for system-level simulation		
Inter-site distance	500 m	1732 m
Number of antenna elements per TRxP	Up to 64 Tx/Rx	Up to 64 Tx/Rx
Number of UE antenna elements	Up to 2 Tx Up to 2 Rx	Up to 2 Tx Up to 2 Rx
Device deployment	80% indoor, 20% outdoor	80% indoor, 20% outdoor
UE mobility model	Fixed and identical speed |v| of all UEs of the same mobility class, randomly and uniformly distributed direction.	Fixed and identical speed |v| of all UEs of the same mobility class, randomly and uniformly distributed direction.
UE speeds of interest	3 km/h for indoor and outdoor	3 km/h for indoor and outdoor
Inter-site interference modelling	Explicitly modelled	Explicitly modelled
BS noise figure	5 dB	5 dB
UE noise figure	7 dB	7 dB
BS antenna element gain	8 dBi	8 dBi
UE antenna element gain	0 dBi	0 dBi
Thermal noise level	-174 dBm/Hz	-174 dBm/Hz
Traffic model	With layer 2 PDU(Protocol Data Unit) message size of 32 bytes: 1 message/day/device or 1 message/2 hours/device[6] 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[6] Packet arrival follows Poisson arrival process for non-full buffer system level simulation
Simulation bandwidth	Up to 10 MHz	Up to 50 MHz
UE density	✓ Not applicable for non-full buffer system level simulation as evaluation methodology of connection density ✓ For full buffer system level simulation followed by link level simulation,10 UEs per TRxP for SINR CDF distribution derivation	✓ Not applicable for non-full buffer system level simulation as evaluation methodology of connection density ✓ For full buffer system level simulation followed by link level simulation,10 UEs per TRxP for SINR CDF distribution derivation
UE antenna height	1.5m	1.5 m

1

[6] Higher traffic loads are encouraged.

(5) Evaluation configurations for Urban Macro-URLLC test environments

Parameters	Urban Macro–URLLC	
	Reliability Evaluation	
	Configuration A	Configuration B
Baseline evaluation configuration parameters		
Carrier frequency for evaluation	4 GHz	700 MHz
BS antenna height	25 m	25 m
Total transmit power per TRxP	49 dBm for 20 MHz bandwidth 46 dBm for 10 MHz bandwidth	49 dBm for 20 MHz bandwidth 46 dBm for 10 MHz bandwidth
UE power class	23 dBm	23 dBm
Percentage of high loss and low loss building type (Note 1)	100% low loss	100% low loss
Additional parameters for system-level simulation		
Inter-site distance	500 m	500 m
Number of antenna elements per TRxP[1]	Up to 256Tx/Rx	Up to 64 Tx/Rx
Number of UE antenna elements	Up to 8Tx/Rx	Up to 4Tx/Rx
Device deployment	80% outdoor, 20% indoor	80% outdoor, 20% indoor
UE mobility model	Fixed and identical speed |v| of all UEs, randomly and uniformly distributed direction	Fixed and identical speed |v| of all UEs, randomly and uniformly distributed direction
UE speeds of interest	3 km/h for indoor and 30km/h for outdoor	3 km/h for indoor and 30km/h for outdoor
Inter-site interference modelling	Explicitly modelled	Explicitly modelled
BS noise figure	5 dB	5 dB
UE noise figure	7 dB	7 dB
BS antenna element gain	8 dBi	8 dBi
UE antenna element gain	0 dBi	0 dBi
Thermal noise level	-174 dBm/Hz	-174 dBm/Hz
Traffic model	Full buffer (Note: it is for SINR CDF distribution derivation)	Full buffer (Note: it is for SINR CDF distribution derivation)
Simulation bandwidth	Up to 100 MHz Note: This value is used for SINR CDF distribution derivation	Up to 40 MHz Note: This value is used for SINR CDF distribution derivation
UE density	10 UEs per TRxP for SINR CDF distribution derivation	10 UEs per TRxP for SINR CDF distribution derivation
UE antenna height	1.5 m	1.5 m

NOTE 1: High loss buildings are sometimes referred to as thermally efficient. Low loss buildings are sometimes referred to as traditional. Percentages of high loss and low loss building type can vary according to the actual distribution of building types. In the future, the percentage of high-loss building is expected to increase, so this factor would have to be taken into account in later evaluation activities. It is used only in the appropriate channel model variant as required.

NOTE 2: The carrier frequency of 700 MHz represents frequency ranges of 450 MHz - 960 MHz; 4 GHz represents ~~a~~ frequency ranges of 3 GHz - 6 GHz; 30 GHz represents frequency ranges of 24.25 GHz ~~to~~ 52.6 GHz; 70 GHz represents frequency ranges of 66 GHz -86 GHz.

NOTE 3: For Rural-eMBB, the frequency ranges represented by 700 MHz, and its related configuration parameters, can also be assumed for a carrier frequency of 1.4 GHz. It is assumed that number of BS antenna elements is up to 256 Tx/Rx and number of UE antenna elements is up to 8 Tx/Rx.

NOTE 4: The simulation bandwidth of TDD also applies to duplexing schemes other than FDD and TDD as total simulation bandwidth for uplink plus downlink. Detailed division of downlink and uplink shall be reported.

TABLE 8-X2

**Additional parameters for link level simulation
(for mobility, reliability requirement)**

Parameters	**Indoor hotspot-eMBB**	**Dense Urban-eMBB**	**Rural-eMBB**	**Urban Macro–mMTC**	**Urban Macro–URLLC**
Evaluated service profiles	Full buffer best effort	Full buffer best effort	Full buffer best effort	Full buffer best effort	Full buffer best effort
Simulation bandwidth	10 MHz	10 MHz	10 MHz	For ISD = 500 m, up to 10 MHz; For ISD = 1732 m, up to 50 MHz	Up to 40 MHz (for carrier frequency of 700 MHz) Up to 100 MHz (for carrier frequency of 4 GHz)
Number of users in simulation	1	1	1	≥1	1
Packet size	N.A.	N.A.	N.A.	32 bytes at Layer 2 PDU	32 bytes at Layer 2 PDU
Inter-packet arrival time	N.A.	N.A.	N.A.	1 message/day/device or 1 message/2 hours/device	N.A.

TABLE 8-X3

Additional channel model parameters for link level simulation

Parameters	**Indoor hotspot-eMBB (for Mobility)**	**Dense Urban-eMBB (for Mobility)**	**Rural-eMBB (for Mobility)**	**Urban Macro–mMTC (for Connection density)**	**Urban Macro–URLLC (for Reliability)**
Link level Channel model	NLOS: CDL/ TDL-i LOS: CDL/TDL-iv	NLOS: CDL/ TDL-iii LOS: CDL/TDL-v	NLOS: CDL/ TDL-iii LOS: CDL/TDL-v	NLOS: TDL-iii LOS: TDL-v	NLOS: TDL-iii LOS: TDL-v
Delay spread scaling parameter $DS_{desired}$ (s)	Log10($DS_{desired}$) $=\mu_{lgDS}$ in Table 4-7 (InH) in Annex 1	Log10($DS_{desired}$) $=\mu_{lgDS}$ in Table 4-9 (UMa) in Annex 1	Log10($DS_{desired}$) $=\mu_{lgDS}$ in Table 4-13 (RMa) in Annex 1	Log10($DS_{desired}$) $=\mu_{lgDS}$ in Table 4-9 (UMa) in Annex 1	Log10($DS_{desired}$) $=\mu_{lgDS}$ in Table 4-9 (UMa) in Annex 1
AoA, AoD, ZoA angular spreads scaling parameter $AS_{desired}$ (degree)	Log10($AS_{desired}$) $=\mu_{lgASA}$ /μ_{lgASD} /μ_{lgZSA} in Table 4-7 (InH) in Annex 1	Log10($AS_{desired}$) $=\mu_{lgASA}$ /μ_{lgASD} /μ_{lgZSA} in Table 4-9 (UMa) in Annex 1	Log10($AS_{desired}$) $=\mu_{lgASA}$ /μ_{lgASD} /μ_{lgZSA} in Table 4-13 (RMa) in Annex 1	Log10($AS_{desired}$) $=\mu_{lgASA}$ /μ_{lgASD} /μ_{lgZSA} in Table 4-9 (UMa) in Annex 1	Log10($AS_{desired}$) $=\mu_{lgASA}$ /μ_{lgASD} /μ_{lgZSA} in Table 4-9 (UMa) in Annex 1
ZoD angular spreads scaling parameter $AS_{desired}$ (degree)	Log10($AS_{desired}$) $=\mu_{lgZSD}$ in Table 4-8 (InH) in Annex 1	Log10($AS_{desired}$) $=\mu_{lgZSD}$ in Table 4-10 (UMa) in Annex 1	Log10($AS_{desired}$) $=\mu_{lgZSD}$ in Table 4-14 (RMa) in Annex 1	Log10($AS_{desired}$) $=\mu_{lgZSD}$ in Table 4-10 (UMa) in Annex 1	Log10($AS_{desired}$) $=\mu_{lgZSD}$ in Table 4-10 (UMa) in Annex 1

NOTE 1: The use of TDL or CDL is up to the proponent/evaluator.

NOTE 2: Delay spreads and angular spreads (for AoA, AoD, ZoA, and ZoD) in link level channel model are scaled to the median values for the environment and channel type (LOS/NLOS) evaluated, and system level channel model (model A or model B) selected.

8.5 Antenna characteristics

This sub-section specifies the antenna characteristics, e.g. antenna pattern, gain, side-lobe level, orientation, etc., for antennas at the base station (BS) and the UE, which shall be applied for the evaluation in test environments with the hexagonal grid layouts and/or the non-hexagonal layouts. The characteristics do not form any kind of requirements and should be used only for the evaluation.

[Editor's note: further check the consistency of use of symbols and panel figures with Channel modelling]

8.5.1 BS antenna

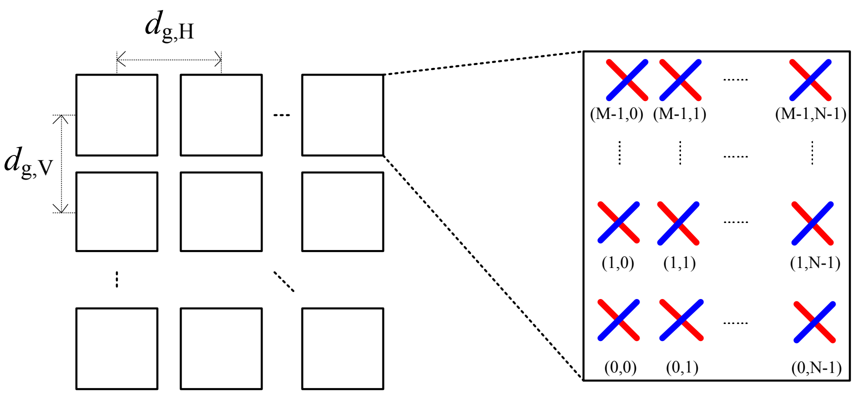
– BS antennas are modelled having one or multiple antenna panels, where an antenna panel has one or multiple antenna elements placed vertically, horizontally or in a two-dimensional array within each panel.

– An antenna panel has $M\times N$ antenna elements, where N is the number of columns and M is the number of antenna elements with the same polarization in each column. The antenna elements are uniformly spaced with a center-to-center spacing of d_H and d_V. in the horizontal and vertical directions, respectively. The $M\times N$ elements may either be single polarized or dual polarized.

– When the BS has multiple antenna panels, a uniform rectangular panel array is modeled, comprising M_gN_g antenna panels where M_g is number of panels in a column and N_g is number of panels in a row. Antenna panels are uniformly spaced with a center-to-center spacing of $d_{g,H}$ and $d_{g,V}$ in the horizontal and vertical direction respectively. See Figure X for an illustration of the BS antenna model.

FIGURE X

BS antenna model



The proponent and evaluator shall report the antenna polarization and the value of M, N, M_g, N_g, (d_H, d_V) and ($d_{g,H}$, $d_{g,V}$) in their evaluation, respectively.

For antenna element pattern, the general form of antenna element horizontal radiation pattern is specified as

$$A_{E,H}(\varphi'') = -\min\left\{12\left(\frac{\varphi''}{\varphi_{3\mathrm{dB}}}\right)^2, SLA\right\}$$

where $-180^\circ \leq \varphi'' \leq 180^\circ$, min [.] denotes the minimum function, φ_{3dB} is the horizontal 3 dB beamwidth and SLA is the maximum side lobe level attenuation. The general form of antenna element vertical radiation pattern is specified as

$$A_{E,V}(\theta'') = -\min\left\{12\left(\frac{\theta'' - \theta_{tilt}}{\theta_{3\mathrm{dB}}}\right)^2, SLA\right\}$$

where $0^\circ \leq \theta'' \leq 180^\circ$, θ_{3dB} is the vertical 3 dB beamwidth and θ_{tilt} is the tilt angle. Note that $\theta'' = 0^\circ$ points to the zenith and $\theta'' = 90^\circ$ points to the horizon. The combined vertical and horizontal antenna element pattern is then given as

$$A''(\theta'', \varphi'') = -\min\left\{-\left\lfloor A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right\rfloor, SLA\right\}$$

where $A''(\theta'', \varphi'')$ is the the relative antenna gain (dB) of an antenna element in the direction (θ'', φ'').

The BS side antenna element pattern for Dense urban – eMBB (macro TRxP), Rural – eMBB, Urban macro – mMTC and Urban macro – URLLC test environments are provided in Table 8-y1.

For Indoor Hotspot-eMBB test environment, the BS side antenna element pattern is provided in Table 8-Y2.

TABLE 8-Y1

3-Sector BS antenna radiation pattern

Parameter	Values
Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 65^0, SLA_V = 30$
Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 65^0, A_m = 30$
Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
Maximum directional gain of an antenna element $G_{E,max}$	8 dBi

TABLE 8-Y2

Indoor BS antenna radiation pattern - Ceiling mount antenna pattern

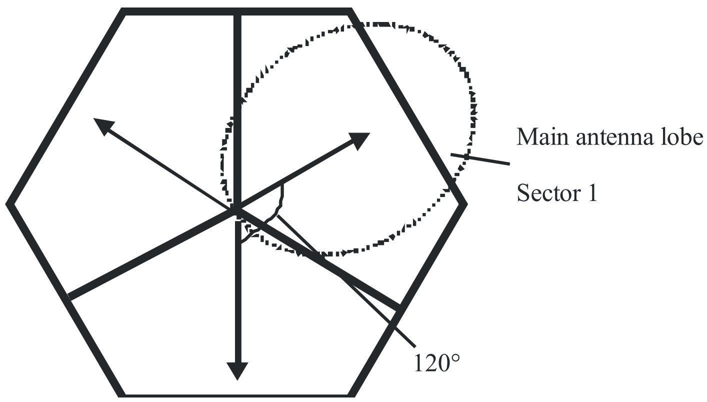
Parameter	Values
Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 90^0, SLA_V = 25$
Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 90^0, A_m = 25$
Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
Maximum directional gain of an antenna element GE,max	5 dBi

8.5.1.1 BS antenna orientation

The antenna bearing is defined as the angle between the main antenna lobe centre and a line directed due east given in degrees. The bearing angle increases in a clockwise direction. Figure Y shows the hexagonal cell and its three sectors with the antenna bearing orientation proposed for the simulations with three sector sites. The centre directions of the main antenna lobe in each sector point to the corresponding side of the hexagon.

FIGURE Y

Antenna bearing orientation diagram



8.5.2 UE antenna

There are two options for UE side antenna element pattern. For 4 GHz and 700 MHz evaluation, Omni-directional antenna element is assumed.

For 30 GHz and 70 GHz evaluation, the directional antenna panel is assumed. In this case, the antenna pattern is defined in Table 8-Y3, and the $M_g N_g$ antenna panels may have different orientations. Introduce $\left(\Omega_{m_g,n_g}, \Theta_{m_g,n_g}\right)$ as the orientation angles of the panel $\left(m_g, n_g\right)$ $0 \le m_g < M_g, 0 \le n_g < N_g$, where the orientation of the first panel $\left(\Omega_{0,0}, \Theta_{0,0}\right)$ is defined as the UE orientation, Ω_{m_g,n_g} is the array bearing angle and Θ_{m_g,n_g} is the array downtilt angle defined in Annex 1, section 4 (coordinate system).

TABLE 8-Y3

UE antenna radiation pattern model for 30 GHz and 70 GHz

Parameter	Values
Antenna element radiation pattern in θ'' dim (dB)	$A_{E,V}(\theta'') = -\min\left[12\left(\frac{\theta'' - 90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 90^0, SLA_V = 25$
Antenna element radiation pattern in φ'' dim (dB)	$A_{E,H}(\varphi'') = -\min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 90^0, A_m = 25$
Combining method for 3D antenna element pattern (dB)	$A''(\theta'', \varphi'') = -\min\left\{-\left\lfloor A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right\rfloor, A_m\right\}$
Maximum directional gain of an antenna element $G_{E,max}$	5 dBi