Radiocommunication Study Groups

Document 5D/XXX-E
23 January 2025
English only

Spectrum ASPECTS

IAFI[1]

FURTHER UPDATES TO THE WORKING DOCUMENT TOWARDS PRELIMINARY DRAFT NEW REPORT ITU-R M.[IMT-2030.EVAL]

Guidelines for evaluation of radio interface technologies for IMT-2030

1 Introduction

ITU-R Working Party (WP) 5D is working towards a preliminary draft new Report ITU-R M.[IMT-2030.EVAL] on "**Guidelines for evaluation of radio interface technologies for IMT-2030**". This Report provides guidelines for the procedure, the methodology and the criteria (technical, spectrum and service) to be used in evaluating the candidate IMT-2030 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-2030 objectives are met.

2 Proposal

IAFI has proposed updates to this working document as shown in the attachment.

[1] IAFI is a sector Member of ITU-R. For more details, please see https://iafi.in

Source: Document 5D/TEMP/156

Annex 5.2 to
Document 5D/413-E
17 October 2024
English only

Annex 5.2 to Working Party 5D Chair's Report

WORKING DOCUMENT TOWARDS PRELIMINARY DRAFT
NEW REPORT ITU-R M.[IMT-2030.EVAL]

Guidelines for evaluation of radio interface technologies for IMT-2030

Editor notes: this working document as a whole in square brackets for discussion

Editor notes: contents of M.2412 are copied as starting point to facilitate the further input contributions. Input contributions are encouraged in future meetings.

Editor notes: specific notes in square brackets with number of input contribution and the proponent are from input contributions which proposed texts for the working document, but not yet discussed

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Editor's Note: ToC will be here when the working document is stable

1 Introduction

Resolution ITU-R 56 defines a new term "IMT-2030" applicable to those systems, system components, and related aspects that provide far more enhanced capabilities than those described in Recommendation ITU-R M.2083.

In this regard, International Mobile Telecommunications-2030 (IMT-2030) systems are mobile systems that include the new capabilities of IMT that go beyond those of IMT-2020. Recommendation ITU-R M.2160 "Framework and overall objectives of the future development of IMT for 2030 and beyond" identifies capabilities for IMT-2030 which would make IMT-2030 more efficient, fast, flexible, and reliable when providing diverse services in the intended usage scenarios.

Editor notes: these paragraphs and bullets below are more specific and can be kept as starting point for time being. Characteristics would need updates for IMT-2030. Inputs are encouraged.

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 consistent with technology developments.

2 Scope

Editor's note: to further discuss "more stringent radio operating environments"

This Report provides guidelines for the procedure, the methodology and the criteria (technical, spectrum and service) to be used in evaluating the candidate IMT-2030 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-2030 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 to encompass new technologies. The actual selection of the candidate RITs/SRITs for IMT-2030 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-2030 web page (*Editor note: Website URL needs to be added when it ready.)*

3 Structure of the Report

Section 4 provides a list of documents 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.

4 Related ITU-R documents

Resolution ITU-R 56-3

Resolution ITU-R 65-1

Recommendation ITU-R M.2083

Recommendation ITU-R M.2160

Report ITU-R M.2410-0

Report ITU-R M.2411-0

Report ITU-R M.2412

Report ITU-R M.2376-0

Report ITU-R M.2516

Report ITU-R M.2541

Report ITU-R M.[IMT-2030.TECH PERF REQ]

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

Document IMT-2020/1

Document IMT-2020/2

Document IMT-2030/1

Document IMT-2030/2

5 Evaluation guidelines

IMT-2030 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-2030 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-2030 consistent with the process defined in Resolution ITU-R 65–1 - Principles for the process of future development of IMT-2020 and IMT-2030, and the key technical performance requirements defined in Report ITU-R -M.[IMT-2030. TECH PERF REQ] – Minimum requirements related to technical performance for IMT-2030 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-2030 in ITU-R in conjunction with the development of Recommendations and Reports such as the framework, key characteristics and the detailed specifications of IMT-2030. These parameters have been chosen to be representative of a global view of IMT-2030 but are not intended to be specific to any particular implementation of an IMT-2030 technology. They should not be considered as the values that must be used in any deployment of any IMT-2030 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 a 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-2030:

- 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-2030.
- Evaluations covering several technology proposals are encouraged.

6 Overview of characteristics for evaluation

The characteristics chosen for evaluation are explained in detail in § XX of Report ITU-R M.[IMT-2030.SUBMISSION] including service aspect requirements, spectrum aspect requirements, and technical performance requirements, the last of which are based on Report ITU-R M.[IMT-2030.TECH PERF REQ]. These are summarized in Table XX, 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 §xxx below).
- Analytical (via calculation or mathematical analysis).

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

Editor note: the table below in blank is to be filled in depending on the input contribution.

TABLE XX

Summary of evaluation methodologies

Characteristic for evaluation	**High-level assessment method**	**Evaluation methodology in this Report**	**Related section of Reports ITU-R M.[IMT-2030.TECH PERF REQ] and ITU-R M.[IMT-2030. SUBMISSION]**

Editor note: M.2412 as model only to better understand the format

Characteristic for evaluation	**High-level assessment method**	**Evaluation methodology in this Report**	**Related section of Reports ITU-R M.2410-0 and ITU-R M.2411-0**
Peak data rate	Analytical	§ 7.2.2	Report ITU-R M.2410-0, § 4.1
Peak spectral efficiency	Analytical	§ 7.2.1	Report ITU-R M.2410-0, § 4.2
User experienced data rate	Analytical for single band and single layer; Simulation for multi-layer	§ 7.2.3	Report ITU-R M.2410-0, § 4.3
5th percentile user spectral efficiency	Simulation	§ 7.1.2	Report ITU-R M.2410-0, § 4.4
Average spectral efficiency	Simulation	§ 7.1.1	Report ITU-R M.2410-0, § 4.5
Area traffic capacity	Analytical	§ 7.2.4	Report ITU-R M.2410-0, § 4.6
User plane latency	Analytical	§ 7.2.6	Report ITU-R M.2410-0, § 4.7.1
Control plane latency	Analytical	§ 7.2.5	Report ITU-R M.2410-0, § 4.7.2
Connection density	Simulation	§ 7.1.3	Report ITU-R M.2410-0, § 4.8
Energy efficiency	Inspection	§ 7.3.2	Report ITU-R M.2410-0, § 4.9
Reliability	Simulation	§ 7.1.5	Report ITU-R M.2410-0, § 4.10
Mobility	Simulation	§ 7.1.4	Report ITU-R M.2410-0, § 4.11
Mobility interruption time	Analytical	§ 7.2.7	Report ITU-R M.2410-0, § 4.12
Bandwidth	Inspection	§ 7.3.1	Report ITU-R M.2410-0, § 4.13
Support of wide range of services	Inspection	§ 7.3.3	Report ITU-R M.2411-0, § 3.1
Supported spectrum band(s)/range(s)	Inspection	§ 7.3.4	Report ITU-R M.2411-0, § 3.2

[5D/375 Qualcomm's Note

Characteristic for evaluation		High-level assessment method	Evaluation methodology in this Report	Related section of Reports ITU-R M.[IMT-2030.TPR]
…				
Sensing related capabilities	Detectability	Simulation	TBA	TBA
	Location accuracy	Simulation	TBA	TBA
	Velocity accuracy	Simulation	TBA	TBA
	Resolution	Analytical	TBA	TBA
…				

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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-2030/2 − Submission, evaluation process and consensus building for IMT-2030.

The evaluation should be performed in compliance with the technical parameters provided by the proponents and the evaluation configurations specified for the test environments in § xx 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 the 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 § xx 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 § xx of this Report;
- UEs (User Equipment) are randomly assigned LOS and NLOS channel conditions according to the applicable channel model defined in xx 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[2] over thermal parameter is an uplink design constraint that the proponent must take into account when designing the system such that the average interference over thermal 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 characteristics shall be modelled according to the traffic models defined in Table x in § xx 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

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

of corresponding mean values, and evaluation groups are encouraged to use this information;[3]

– 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.

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,…N) (downlink) or from user i (uplink) in a system comprising a user population of N users and M Transmission Reception Points (TRxPs). Further, 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:

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

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

where $\hat{SE}_{avg}$ 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 xxx test environments as defined in this Report. It should be noted that

[3] 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.

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-2030.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 $T_i \leq T$, 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:

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

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 xxx 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-2030.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 and Layer 2 overheads can be found in §xx for average spectral efficiency.

7.1.3 Connection density

[5D/338 CHN's note: one view is to reuse the text in IMT-2020 Report M.2412 as a baseline to evaluate connection density under Urban Macro - MC test environment only, and necessary updates could be considered. Another view is that in addition to IoT connection density of IMT-2030, it is proposed to add a new metric for the evaluation of XR connection density for Dense Urban - IC and/or Indoor Hotspot -IC test environment, need more discussion.]

M.2412

There are two possible evaluation methods to evaluate connection density requirement defined in ITU-R M.[IMT-2030.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 x in § xx 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 *Step 2*.

Step 4: Change the value of N and repeat *Step 2-3* 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 Report ITU-R M.[IMT-2030.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. Traffic model used in this method is defined in Table x in §xx of this Report.

Step 1: Perform full-buffer system-level simulation using the evaluation parameters for xxx test environments, 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 $D_{\text{i}} = S/R_{\text{i}}$, where S is the packet size.

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

Step 5: Calculate the long-term frequency resource requested under $SINR_i$ as $B_{\text{i}} = T/(R_{\text{i}}/W_{\text{user}})$.

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

Step 7: Calculate the connection density as $C = N / A$, where the TRxP area A is calculated as A = ISD^2 × 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 Report ITU-R M.[IMT-2030.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 xxx test environment using the same evaluation parameters and configuration selected for the evaluation of average spectral efficiency and 5th percentile user spectral efficiency. Under xxx test environment, target values for both mobility of 120 km/h and 500 km/h in Table x of Report ITU-R M.[IMT-2030.TECH PERF REQ]. shall be achieved to fulfill mobility requirements of Rural-IC 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 x of Report ITU-R M.[IMT-2030.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 x of Report ITU-R M.[IMT-2030.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 x of Report ITU-R M.[IMT-2030.TECH PERF REQ].

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 (using either NLOS or LOS channel conditions) fulfils 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 xxx test environment see § xx below, and collect overall statistics for downlink or uplink *SINR* values, and construct CDF over these values.

Step 2: Use the CDF for the xxx 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 x of this Report, 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, using either NLOS or LOS channel conditions.

[5D/338 CHN's note

7.1.6 Energy efficiency (if quantitative metric is defined)

CHN's note: if energy efficiency is evaluated using simulation, then it should be moved from Inspection approach to Simulation approach, and this section is the placeholder.

7.1.7 Positioning

CHN's note: Positioning is preferred to be evaluated under ISAC test environments, for example, Indoor Factory - ISAC, it is not precluded to consider other possibility of associated usage scenario.

7.1.8 Sensing

CHN's note: Sensing should be evaluated under ISAC test environments using system-level simulation or system-level simulation followed by link-level simulation. Relevant sensing performance metrics can be acquired from sensing signal processing results which is obtained based on the sensing transmit and receive signals.

[7.1.9 AI

CHN's note: if AI is evaluated using simulation, then it should be evaluated under AIAC test environments, for example, Dense Urban - AIAC. If AI is evaluated using analytical or inspection approach, it should be moved to related section in 7.2 or 7.3.]

]

7.2 Analytical approach

For §§ xx to xx below, a straight forward calculation based on the definition in Report ITU-R M.[IMT-2030.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 § xx of Report ITU-R M.[IMT-2030.TECH PERF REQ]. 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 x of this Report. 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 xx usage scenario.

7.2.2 Peak data rate calculation

The peak data rate is calculated as specified in § xx of Report ITU-R M.[IMT-2030.TECH PERF REQ], 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 xx usage scenario

7.2.3 User experienced data rate calculation

The evaluation is conducted in xxx 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-2030.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 calculation

The evaluation is conducted in xxx 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 provides an example of the elements in the calculation of the control plane latency.

TABLE x

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 provides an example of the elements in the calculation of the user plane latency.

TABLE 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 calculation

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 § xx of Report ITU-R M.[IMT-2030.TECH PERF REQ], 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 (if qualitative metric is defined)

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-2030.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.[IMT-2030.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.2160.

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 xx of this Report).

These predefined test environments are used in order to evaluate the requirements for the technology proposals. IMT-2030 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 aspects 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.2160, IMT-2030 is envisaged to expand and support diverse usage scenarios and applications that will continue beyond IMT-2020. There are six usage scenarios for IMT-2030 as follows:

– **Immersive Communication**: This usage scenario extends the enhanced Mobile Broadband (eMBB) of IMT-2020 and covers use cases which provide a rich and interactive video (immersive) experience to users, including the interactions with machine interfaces.

  This usage scenario covers a range of environments, including hotspots, urban and rural, which arise with additional and new requirements compared with those of eMBB from IMT-2020.

  Typical use cases include communication for immersive XR, remote multi-sensory telepresence, and holographic communications. Supporting mixed traffic of video, audio, and other environment data in a time-synchronized manner is an integral part of immersive communications, including also stand-alone support of voice.

  Capabilities that aim for enhanced spectrum efficiency and consistent service experiences along with leveraging the balance between higher data rates and increased mobility in various environments are essential. Certain immersive communication use cases may also require support of high reliability and low latency for responsive and accurate interaction with real and virtual objects, as well as larger system capacity for simultaneously connecting numerous devices.

– **Hyper Reliable and Low-Latency Communication**: This usage scenario extends the Ultra-Reliable and Low-Latency Communication (URLLC) of IMT-2020 and covers specialized use cases that are expected to have more stringent requirements on reliability and latency. This is typically for time-synchronized operations, where failure to meet these requirements could lead to severe consequences for the applications.

  Typical use cases include communications in an industrial environment for full automation, control and operation. These types of communications can help in realizing various applications such as machine interactions, emergency services, tele-medicine, and monitoring for electrical power transmission and distribution.

  This usage scenario would require support of enhanced reliability and low latency, and depending on the use case, precise positioning, and connection density.

– **Massive Communication**: This usage scenario extends massive Machine Type Communication (mMTC) of IMT-2020 and involves connection of massive number of devices or sensors for a wide range of use cases and applications.

  Typical use cases include expanded and new applications in smart cities, transportation, logistics, health, energy, environmental monitoring, agriculture, and many other areas such as those requiring a variety of IoT devices without battery or with long-life batteries.

  This usage scenario would require support of high connection density, and depending on use cases, different data rates, low power consumption, mobility, extended coverage, and high security and reliability.

– **Ubiquitous Connectivity**: This usage scenario is intended to enhance connectivity with the aim to bridge the digital divide. Connectivity could be enhanced, inter alia, through interworking with other systems (see § 5.1.2).

  One focus of this usage scenario is to address presently uncovered or scarcely covered areas, particularly rural, remote and sparsely populated areas.

  Typical use cases include, but not limited to, IoT and mobile broadband communication.

– **Artificial Intelligence and Communication**: This usage scenario would support distributed computing and AI applications. Typical use cases include IMT-2030 assisted automated driving, autonomous collaboration between devices for medical assistance applications, offloading of heavy computation operations across devices and networks, creation of and prediction with digital twins, and others.

  This usage scenario would require support of high area traffic capacity and user experienced data rates, as well as low latency and high reliability, depending on the specific use case. Besides communication aspects, this usage scenario is expected to include a set of new capabilities related to the integration of AI and compute functionalities into IMT-2030, including data acquisition, preparation and processing from different sources, distributed AI model training, model sharing and distributed inference across IMT systems, and computing resource orchestration and chaining.

– **Integrated Sensing and Communication**: This usage scenario facilitates new applications and services that require sensing capabilities. It makes use of IMT-2030 to offer wide area multi-dimensional sensing that provides spatial information about unconnected objects as well as connected devices and their movements and surroundings.

  Typical use cases include IMT-2030 assisted navigation, activity detection and movement tracking (e.g. posture/gesture recognition, fall detection, vehicle/pedestrian detection), environmental monitoring (e.g. rain/pollution detection), and provision of sensing data/information on surroundings for AI, XR and digital twin applications.

  Along with the provided communication capabilities, this usage scenario requires support of high-precision positioning and sensing-related capabilities, including range/velocity/angle estimation, object and presence detection, localization, imaging and mapping.

8.2 Test environments

Group 1:

A test environment reflects a combination of geographic environment and usage scenario. There are [TBD] selected test environments for IMT-2030 as follows:

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

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

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

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

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

Editor note: There are different views regarding the following test environment proposal. Input contributions are encouraged to elaborate the necessity to add this TE.

– ***Indoor Factory–MC***

Editor note: To further discuss the option below and see if it necessary to be added or replace the existing test environment of Urban-Macro-HRLLC from IMT-2020. The geographic environment needs further discussion to confirm the name, e.g. hospital. Input contributions are encouraged to elaborate the below option.

– ***Indoor [Factory]–HRLLC***

Group 2:

Ubiquitous Connectivity (UC)

Editor note: There are different views regarding the following test environment proposal. Input contributions are encouraged to elaborate the necessity to add this TE.

– Rural-UC

Integrated Sensing and communication (ISAC)

Editor note: Discussions on TPR(s) regarding to this usage scenario are going on in SWG Radio Aspects. It is not yet sure whether test environment(s) is/are needed or not. The following considerations from current input contributions are listed below for further discussion. Input contributions on the views of test environment(s) under ISAC with proposed associated TPR, evaluation configurations and evaluation methodologies are encouraged for the next meeting.

Indoor

– *Indoor-ISAC*
– *Indoor Factory–ISAC*
– *Indoor Hotspot–ISAC*

Outdoor

– *Outdoor-ISAC*
– *Dense Urban–ISAC*
– *Rural–ISAC*
– *Urban macro – ISAC*

[5D/338 CHN's note:

– ***Dense Urban–ISAC:*** *An urban environment with high sensing-target density focusing on objects such as vehicles, UAVs, humans, environment objects, etc.*
– ***Indoor Factory–ISAC:*** *An indoor isolated environment at factory halls focusing on devices and objects such as machinery, assembly lines, storage shelves, AGVs, humans, environment objects, etc.*

– ***Rural–ISAC:*** *A rural environment with larger and continuous wide area sensing coverage, focusing on objects such as vehicles, UAVs, humans, environment objects, etc.*

– ***Indoor Hotspot–ISAC:*** *An indoor isolated environment at offices, and/or at homes, and/or in shopping malls focusing on objects such as humans.]*

AI and Communication (AIAC)

Editor note: Discussions on TPR(s) regarding to this usage scenario are going on in SWG Radio Aspects. It is not yet sure whether test environment(s) is/are needed or not. The following considerations from current input contributions are listed below for further discussion. Input contributions on the views of test environment(s) under AIAC with proposed associated TPR, evaluation configurations and evaluation methodologies are encouraged for the next meeting.

– *Dense Urban–AIAC*

Editor note: using the following table from M.2412 as a model for further input.

The mapping of the xx test environments and the xx usage scenarios is given in Table x.

TABLE x

Mapping of test environments and usage scenarios

Usage scenarios					
Test environments					

8.3 Network layout

No specific topographical details are taken into account in Dense Urban - IC (macro layer) Rural-IC, Urban Macro-MC, and Urban Macro-HRLLC 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 Fig. x in § xx 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.

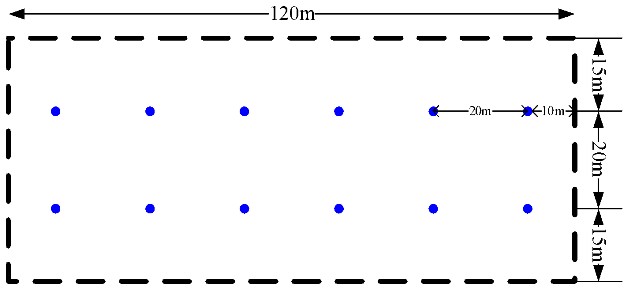
8.3.1 Indoor Hotspot-IC

The Indoor Hotspot-IC 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 Fig. x, with a LOS probability as defined by channel model in xx, Table x. In Fig. x, 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 X

Indoor Hotspot sites layout



8.3.2 Dense Urban-IC

The Dense Urban-IC test environment 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 TRxPs each, as shown in Fig. x below. For the micro layer, there are 3 micro sites randomly dropped in each macro TRxP area (see Fig. x). The micro-layer deployment (e.g. three micro sites per macro TRxP and there is either one or three 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 X

Sketch of hexagonal site layout

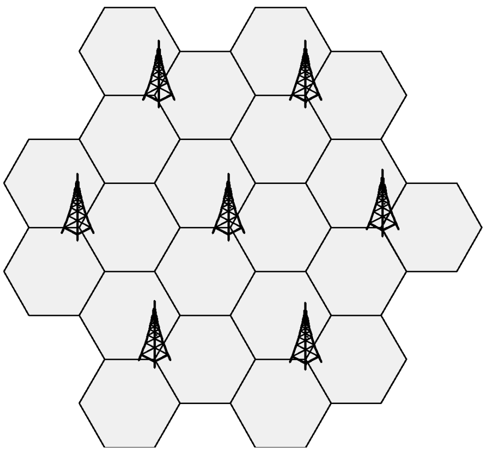
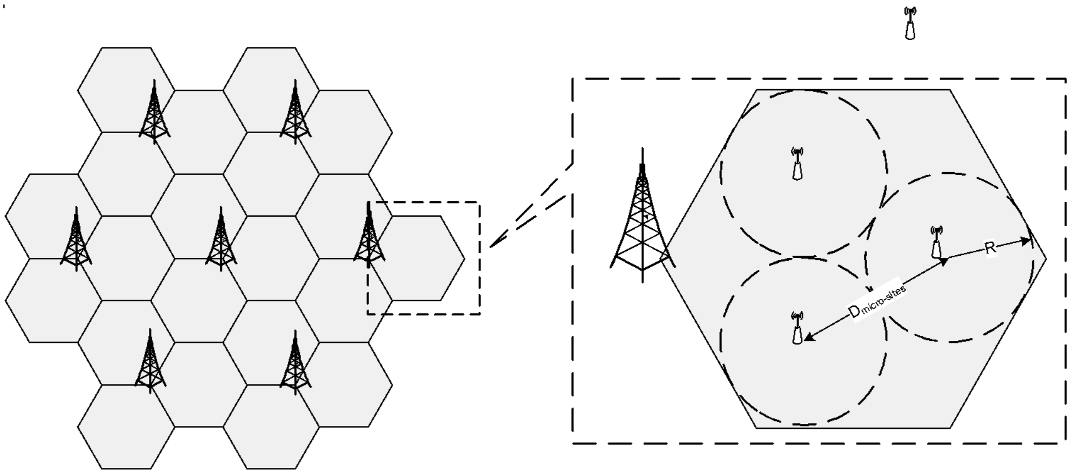


FIGURE X

Example sketch of dense urban-IC layout



8.3.3 Rural-IC

In Rural-IC 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–IC test environment, as shown in Fig. x. 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 xx of this Report.

8.3.4 Urban Macro-MC and Urban Macro-HRLLC

In the Urban Macro-MC and Urban Macro-HRLLC test environments, the BSs/sites are placed in a regular grid, following hexagonal layout with three TRxPs each, as in the Dense Urban-IC macro layer and Rural-IC test environment; this is shown in Fig. x.

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-IC test environment, the average spectral efficiency value should meet the threshold values for the LMLC evaluation configuration with ISD of 6 000 m and either evaluation configuration with ISD of 1 732 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 of this Report) 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 is not necessarily associated with the lowest/highest value in the range.

TABLE x

a) Evaluation configurations for Indoor Hotspot-IC test environment

Parameters	**Indoor Hotspot-IC**	
	Spectral Efficiency, Mobility, and Area Traffic Capacity Evaluations	
	Configuration A	**Configuration …**
Baseline evaluation configuration parameters		
Carrier frequency for evaluation		
BS antenna height		
Total transmit power per TRxP		
UE power class		
Additional parameters for system-level simulation		
Inter-site distance		
Number of antenna elements per TRxP		
Number of UE antenna elements		
Device deployment		
UE mobility model		
UE speeds of interest		
Inter-site interference modeling		
BS noise figure		
UE noise figure		
BS antenna element gain		
UE antenna element gain		
Thermal noise level		
Traffic model		
Simulation bandwidth		
UE density		
UE antenna height		

TABLE x (*CONTINUED*)

b) Evaluation configurations for Dense Urban-IC test environment

Parameters	Dense Urban-IC	
	Spectral Efficiency and Mobility Evaluations	
	Configuration A	**Configuration …**
Baseline evaluation configuration parameters		
Carrier frequency for evaluation		
BS antenna height		
Total transmit power per TRxP		
UE power class		
Percentage of high loss and low loss building type		
Additional parameters for system-level simulation		
Inter-site distance		
Number of antenna elements per TRxP		
Number of UE antenna elements		
Device deployment		
UE mobility model		
UE speeds of interest		
Inter-site interference modeling		
BS noise figure		
UE noise figure		
BS antenna element gain		
UE antenna element gain		
Thermal noise level		
Traffic model		
Simulation bandwidth		
UE density		
UE antenna height		

TABLE x (*CONTINUED*)

c) Evaluation configurations for Rural-IC test environment

Parameters	Rural-IC	
	Spectral Efficiency and Mobility Evaluations	
	Configuration A	**Configuration …**
Baseline evaluation configuration parameters		

Parameters	Rural-IC	
	Spectral Efficiency and Mobility Evaluations	
	Configuration A	Configuration …
Carrier frequency for evaluation		
BS antenna height		
Total transmit power per TRxP		
UE power class		
Percentage of high loss and low loss building type		
Additional parameters for system-level simulation		
Inter-site distance		
Number of antenna elements per TRxP		
Number of UE antenna elements		
Device deployment		
UE mobility model		
UE speeds of interest		
Inter-site interference modeling		
BS noise figure		
UE noise figure		
BS antenna element gain		
UE antenna element gain		
Thermal noise level		
Traffic model		
Simulation bandwidth		
UE density		
UE antenna height		

TABLE x (*CONTINUED*)

d) Evaluation configurations for Urban Macro-MC test environments

Parameters	Urban Macro–MC	
	Connection Density Evaluation	
	Configuration A	Configuration …
Baseline evaluation configuration parameters		
Carrier frequency for evaluation		

Parameters	Urban Macro–MC	
	Connection Density Evaluation	
	Configuration A	**Configuration …**
BS antenna height		
Total transmit power per TRxP[4]		
UE power class		
Percentage of high loss and low loss building type		
Additional parameters for system-level simulation		
Inter-site distance		
Number of antenna elements per TRxP		
Number of UE antenna elements		
Device deployment		
UE mobility model		
UE speeds of interest		
Inter-site interference modelling		
BS noise figure		
UE noise figure		
BS antenna element gain		
UE antenna element gain		
Thermal noise level		
Traffic model		
Simulation bandwidth		
UE density		
UE antenna height		

TABLE x (*CONTINUED*)

e) Evaluation configurations for Urban Macro-HRLLC test environments

Parameters	Urban Macro–HRLLC	
	Reliability Evaluation	
	Configuration A	**Configuration …**
Baseline evaluation configuration parameters		
Carrier frequency for evaluation		
BS antenna height		
Total transmit power per TRxP		

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

Parameters	Urban Macro–HRLLC	
	Reliability Evaluation	
	Configuration A	Configuration …
UE power class		
Percentage of high loss and low loss building type		
Additional parameters for system-level simulation		
Inter-site distance		
Number of antenna elements per TRxP[1]		
Number of UE antenna elements		
Device deployment		
UE mobility model		
UE speeds of interest		
Inter-site interference modelling		
BS noise figure		
UE noise figure		
BS antenna element gain		
UE antenna element gain		
Thermal noise level		
Traffic model		
Simulation bandwidth		
UE density		
UE antenna height		

TABLE x

Additional parameters for link-level simulation (for mobility, reliability, connection density requirements)

Parameters	Indoor hotspot-IC	Dense Urban-IC	Rural-IC	Urban Macro–MC	Urban Macro–HRLLC
Evaluated service profiles					
Simulation bandwidth					
Number of users in simulation					
Packet size					
Inter-packet arrival time					

TABLE x

Evaluation configuration parameters for analytical assessment of peak data rate, peak spectral efficiency

Parameters	Values
Number of BS antenna elements	
Number of UE antenna elements	

TABLE x

Additional channel model parameters for link-level simulation

Parameters	Indoor Hotspot-IC (for Mobility)	Dense Urban-IC (for Mobility)	Rural-IC (for Mobility)	Urban Macro-IC (for Connection density)	Urban Macro-IC (for Reliability)
Link-level Channel model					
Delay spread scaling parameter $DS_{desired}$ (s)					
AoA, AoD, ZoA angular spreads scaling parameter $AS_{desired}$ (degree)					
ZoD angular spreads scaling parameter $AS_{desired}$ (degree)					

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 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.

8.5.1 BS antenna

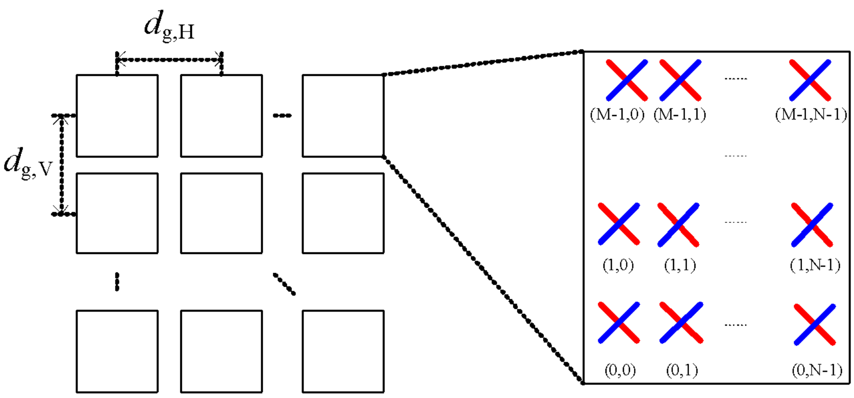
– BS antennas are modelled having one or multiple antenna panels, where an antenna panel has one or multiple antenna elements placed vertically, horizontally or in a two-dimensional array within each panel.

– 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 Fig. 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:

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

where $-180° \leq \varphi'' \leq 180°$, 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:

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

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

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

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 – IC (macro TRxP), Rural – IC, Urban Macro – MC and Urban Macro – HRLLC test environments are provided in Table x.

For Indoor Hotspot-IC test environment, the BS side antenna element pattern is provided in Table x.

TABLE x

3-TRxP BS antenna radiation pattern

Parameters	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)	$A''(\theta'',\varphi'') = -min\{-\lfloor A_{E,V}(\theta'') + A_{E,H}(\varphi'')\rfloor, A_m\}$
Maximum directional gain of an antenna element $G_{E,max}$	8 dBi

TABLE x

Indoor BS antenna radiation pattern – Ceiling-mount antenna pattern

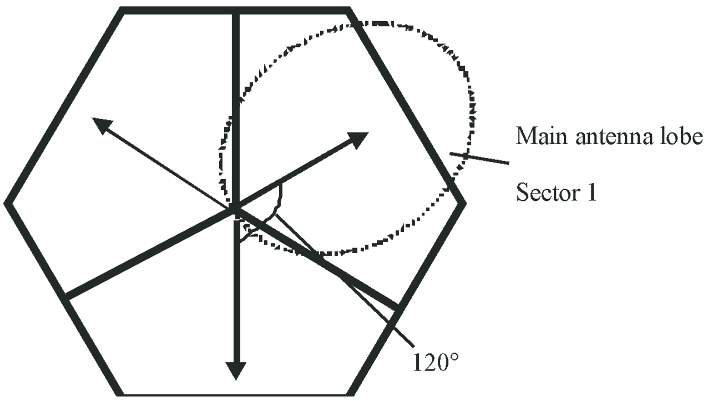
Parameters	Values
Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 90^0, SLA_V = 25$
Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 90^0, A_m = 25$
Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -min\{-\lfloor A_{E,V}(\theta'') + A_{E,H}(\varphi'')\rfloor, A_m\}$
Maximum directional gain of an antenna element $G_{E,max}$	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 x shows the hexagonal cell and its three TRxPs with the antenna bearing orientation proposed for the simulations with three-TRxP sites. The centre directions of the main antenna lobe in each TRxP point to the corresponding side of the hexagon.

FIGURE x

Antenna bearing orientation diagram



8.5.2 UE antenna

There are two options for UE side antenna element pattern. For xxx(carrier frequency) evaluation, Omni-directional antenna element is assumed.

For xx GHz and xx GHz evaluation, the directional antenna panel is assumed. In this case, the antenna pattern is defined in Table x, and the $M_g N_g$ antenna panels may have different orientations. Introduce $(\Omega_{m_g,n_g}, \Theta_{m_g,n_g})$ as the orientation angles of the panel (m_g, n_g) $0 \le m_g < M_g, 0 \le n_g < N_g$, where the orientation of the first panel $(\Omega_{0,0}, \Theta_{0,0})$ 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 xx, § xx (coordinate system).

TABLE x

UE antenna radiation pattern model for xxx GHz

Parameters	Values
Antenna element radiation pattern in θ'' dim (dB)	
Antenna element radiation pattern in φ'' dim (dB)	
Combining method for 3D antenna element pattern (dB)	
Maximum directional gain of an antenna element $G_{E,max}$	

9 Evaluation model approach

Editor note: Wait till June 2025

10 List of acronyms and abbreviations