**3****GPP TSG RAN WG1 #106b-e R1-xxxxxxx**

**e-Meeting, October 11th – 19th**

**Agenda item:** **8.14**

**Title: TR for Study on XR Evaluations for NR**

**Source: Rapporteur (Qualcomm)**

**Document for: Discussion**

This version of TR intends to capture RAN1 agreements that had been made until RAN1#106-e. Please note that editorial fixes, e.g., coherent text fonts, table numbers, etc., will be made later. Please focus on the content. Also note that RAN1 agreements on sections for evaluation results that are being separately discussed will be incorporated later depending on the progress/agreements.

Note: Throughout the TR, baseline vs. optional will be explicitly indicated per RAN1 agreements.

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| --- |
| 3GPP TR 38.838 V0.1 (2021-10) |
| Technical Report |
| 3rd Generation Partnership Project;Technical Specification Group Radio Access Network;Study on XR (Extended Reality) Evaluations for NR(Release 17) |
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# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# Scope

The present document captures the results and findings from the study item "Study on XR Evaluation for NR "[2].

The purpose of this TR is to document the evaluation methodology for XR evaluation including XR applications, simulation scenarios, traffic models, KPIs, simulation parameters, etc,

to document the performance evaluation results of XR applications in NR for both FR1 and FR2 considering the scenarios and services of interest,

to document the identified problems/challenges in supporting XR applications of interest in various scenarios.

This activity involves the Radio Access work area of the 3GPP studies and has potential impacts both on the Mobile Equipment and Access Network of the 3GPP systems.

# References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

1. 3GPP TR 21.905: "Vocabulary for 3GPP Specifications"
2. 3GPP RP-201145: "Revised SI on XR Evaluations for XR"
3. 3GPP R1-2104023: “LS on Status Update on XR Traffic”
4. 3GPP S4-210614: “FS\_XRTRaffic: Permanent document, v0.6.0”
5. 3GPP TR 23.501: “System architecture for the 5G System (5GS)”
6. 3GPP TR 38.840: “Study on User Equipment (UE) power saving in NR”
7. 3GPP R1-2101765, “LS on XR-Traffic Models”

# Definitions of terms, symbols and abbreviations

## Terms

For the purposes of the present document, the terms given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

**example:** text used to clarify abstract rules by applying them literally.

## Symbols

For the purposes of the present document, the following symbols apply:

<symbol> <Explanation>

## Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

ACK Acknowledgement

BWP Bandwidth Part

CSI Channel State Information

DL Downlink

DMRS Dedicated Demodulation Reference Signals

FDD Frequency Division Duplex

gNB NR Node B

fps Frames per second

HARQ Hybrid Automatic Repeat reQuest

iBLER initial BLock Error Rate

MCS Modulation and Coding Scheme

NACK Negative Acknowledgement

PDCCH Physical Downlink Control Channel

PDB Packet Delay Budget

PSG Power Saving Gain

PSR Packet Success Rate

PUCCH Physical Uplink Control Channel

PUSCH Physical Uplink Shared Channel

PDSCH Physical Downlink Shared Channel

SR Scheduling Request

STD STandard Deviation

TDD Time Division Duplex

UE User Equipment

UL Uplink

XR Extended Reality

# Introduction

**XR Applications**

eXtended Reality(XR) is a term for different types of realities and refers to all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables. It includes following representative forms and the areas interpolated among them. [to add a few sentences explaining CG]

* Augmented Reality (AR)
* Mixed Reality (MR)
* Virtual Reality (VR)

XR and Cloud Gaming (CG) are currently one of the most important 5G media applications under consideration in the industry[2].

**[System Architecture**

One specific aspect to be considered is the role of Edge Computing as a network architecture to enable XR and Cloud Gaming. Edge Computing is a concept that enables cloud computing capabilities and service environments to be deployed close to the cellular network. It promises several benefits such as lower latency, higher bandwidth, reduced backhaul traffic and prospects for several new services as indicated in the SA6 Study on application architecture for enabling Edge Applications (TR 23.758). Edge Applications are expected to take advantage of the low latencies enabled by 5G and the Edge network architecture to reduce the end-to-end Application-level latencies. Edge Computing is a valuable enabler which should be considered to help 5G systems achieve the required performance to enable XR and Cloud Gaming[2].] This part may be softened/removed per further discussion.

**Traffic Characteristics**

5G NR is designed to support applications demanding high throughput and low latency in line with the requirements posed by the support of XR and Edge Computing applications in NR networks. XR and Edge Computing are services enabled by Rel-15 NR networks[2].

**Objective**

The objectives of this study are as follows.

* Confirm XR and Cloud Gaming applications of interest
* Identify the traffic model for each application of interest taking outcome of SA WG4 work as input, including considering different upper layer assumptions, e.g. rendering latency, codec compression capability etc.
* Identify evaluation methodology to assess XR and CG performance along with identification of KPIs of interest for relevant deployment scenarios
* Once traffic model and evaluation methodologies are agreed, carry out performance evaluations towards characterization of identified KPIs

# Traffic Models

In this section, we provide the DL and UL traffic models for VR, CG, and AR applications. Since DL/UL traffic models for these applications share similar characteristics, we first define a generic and parameterized DL / UL traffic model, which could be later used in defining VR, CG, AR applications.

The traffic model defined in this section is statistical traffic model, where packet size and packet arrival process are characterized by certain random variables. The described model is based on the input XR traffic study from SA4[7][3][4].

## Generic DL Traffic Model

### Single Stream DL Traffic Model

This section provides a parameterized generic single stream DL traffic model. In this model, as shown in Figure 1, the XR DL traffic is modelled as a sequence of video frames arriving at gNB according to the considered video frame rates and random jitter. The size of each frame is also random according to a certain distribution.



**Figure 1 Single stream DL Traffic Model**

#### Packet Size

In this model, a packet models the set of IP packets belong to the same video frame. The video frame includes both left and right eye frame sharing the same buffer, which is referred to as ‘single stream for dual eye buffer’ or ‘single eye buffer’ throughout this document.

The size of a packet is determined by the given data rates and frame rates, which is modelled as a random variable following truncated Gaussian distribution with following statistical parameters.

**Table 1 Statistical parameters for packet size following truncated Gaussian distribution**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | unit | Baseline values for evaluation | Optional values for evaluation for single eye buffer |
| Mean: M  | byte | R×1e6 / F / 8 | R×1e6 / F / 8 |
| STD | byte | 10.5% of M | 3 % of M |
| Max | byte | 150% of M | 109% of M |
| Min | byte | 50% of M | 91% of M |
| R: data rate of the flow in Mbps. F: frame generation rate of the flow in fps.Note that the mean and STD are for **before** truncation applies.Note that the value of R, F depend on application. |

Exploration to other distributions for packet size are left up to each company and could be reported with the modelling details.

#### Packet Arrival

In this model, the **packet arrival rate** is determined by the frame generation rate, e.g., 60fps. Accordingly, the average **packet arrival periodicity** is given by the inverse of the frame rate, e.g., 16.6667ms = 1/60fps. The periodic arrival without jitter gives the arrival time at gNB for packet with index k (=1,2,3….) as

*k/F\*1000 [ms]*,

where F is the given frame generation rates (per second).

Note that this periodic packet arrival implicitly assumes fixed delay contributed from network side including fixed video encoding time, fixed network transfer delay, etc.

However, in a real system, the varying frame encoding delay and network transfer time introduces **jitter** in packet arrival time at gNB which. In this model, the jitter is modelled as a random variable added on top of periodic arrivals. The jitter follows truncated Gaussian distribution with following statistical parameters shown in Table 1.

**Table 2 Statistical parameters for jitter**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | unit | Baseline value for evaluation | Optional value for evaluation |
| Mean | ms | 0 |  |
| STD | ms | 2 |  |
| Truncation range | ms | [-4, 4] | [-5, 5] |

Note that the given parameter values and considered frame generation rates (60 or 120 in this model) ensure that packet arrivals are in order (i.e., arrival time of a next packet is always larger than that of the previous packet).

Thus, the periodic arrival with jitter gives the arrival time for packet with index k (=1,2,3….) as

*offset + k/F\*1000 + J [ms]*,

where F is the given frame generation rates (per second) and J is a random variable capturing jitter. Note that actual traffic arrival timing of traffic for each UE could be shifted by the UE specific arbitrary *offset*.

#### PDB

The latency requirement of XR traffic in RAN side (i.e., air interface) is modelled as packet delay budget (PDB[[1]](#footnote-2)). The PDB is a limited time budget for a packet to be transmitted over the air from a gNB to a UE.

For a given packet, the delay of the packet incurred in air interface is measured from the time that the packet arrives at the gNB to the time that it is successfully transferred to the UE. If the delay is larger than a given PDB for the packet, then, the packet is said to violate PDB, otherwise the packet is said to be successfully delivered.

The value of PDB may vary for different applications and traffic types.

#### Packet Success Rate Requirement

The performance requirement in terms of packet success rate is given as X (%). If packet delivery delay exceed a given PDB, then, the packet is counted as failure. Following values for packet success rate X are considered.

**Table 3 Packet Success Rate Requirement**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | unit | Baseline values for evaluation  | Optional values for evaluation |
| Packet success rate requirement X for DL single stream | % | 99 | 95, 99.99, etc |

Note that the Packet error rate (PER[[2]](#footnote-3)) in percentage is given as PER = 100 – X.

#### Dual Eye Buffer Model

This section describes optional modification of packet size and frame rates for separate packet arrival for dual-eye buffer.

In single eye buffer model, the frame for both eyes arrive at the same time as a single packet. Thus, mean packet size M is given as R×1e6 / F, where R is frame generation rate in Mbps and F is frame generation rate.

Whereas, in dual eye buffer model of data rate R, the left and right eye frame arrive separately with a time offset, which makes the arrival process effectively equivalent to have two times of frame rates and half mean packet size of that of single eye buffer model. Accordingly, we have mean packet size M of dual eye buffer model is given as R×1e6 / (2×F) for dual eye buffer model.

**Table 4 Statistical parameter values for dual eye buffer packet size**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | unit | values for evaluation | Optional values for evaluation  |
| Mean: M | byte | R×1e6 / (2×F) /8 |  R×1e6 / (2×F) / 8 |
| STD | byte | 10.5% of M | 4% of M |
| Max | byte | 150% of M | 112% of M |
| Min | byte | 50% of M | 88% of M |
| R: data rate of the flow in MbpsF: frame generation rate of the flow in fps |

### Multi-Streams DL Traffic Model

This section provides optional multi-streams model for XR DL traffic.

* Option 1: I-frame + P-frame
	+ Option 1A: slice-based traffic model
	+ Option 1B: Group-Of-Picture (GOP) based traffic model
* Option 2: video + audio/data
* Option 3: FOV + omnidirectional stream

#### Option 1 (I+P)

For Option 1, two streams (I-stream and P-stream) are modelled according to following table.

* Stream 1: I stream
* Stream 2: P stream

Depending on the video encoding scheme, two additional sub models – slice based, and Group of Picture (GOP)-based models are defined.

* Slice-based: In this encoding scheme, a single video frame is divided into N slices. Out of N, one slice is I slice and remaining N-1 slices are P slices. N packets (one I and N-1 P) packets corresponds to one video frame arriving at the same time.
* GOP-based: In this encoding scheme, a single video frame is either I frame or P frame. I frame is transmitted every K frames, where K is the GOP size, i.e., every group of picture. One video frame arrives at a time as a packet.

 **Table 5 Statistical parameters for Option 1 multi streams DL traffic model**

|  |  |  |
| --- | --- | --- |
| **Two data streams** | **Option 1A: slice-based** | **Option 1B: GOP-based** |
| I-stream | P-stream | I-stream | P-stream |
| **Packet modelling** | Slice-level | Frame-level |
| **Traffic pattern** | Both streams are periodic at 60 fps with the same jitter model as for single stream.  | Follow the GOP structure, where GOP size K = 8 with the same jitter model as for single stream. |
| **Number of packets per stream at a time** | 1 | N-1 | I-frame: 1 or 0P-frame: 0 or 1At each time instant, there is either only one I-stream packet or only one P-stream packet |
| N = 8: the number of slices per frame. |
| **Average data rate per stream** | $$R\_{I}=R\*\frac{α}{N-1+α}$$ | $$R\_{P}=R\*\frac{N-1}{N-1+α}$$ | $R\_{I}=R\*\frac{α}{K-1+α}$  | $R\_{P}=R\*\frac{K-1}{K-1+α}$  |
| * R: average data rate of a single stream video
* $α$: average size ratio between one I-frame/slice and one P-frame/slice
	+ $α$ = 1.5, 2 (baseline)
	+ $α$ = 3 (optional)
 |
| **Packet size distribution** | Truncated Gaussian distribution |
| Mean = $\frac{R\_{I}}{FPS}$ | Mean = $\frac{R\_{P}}{FPS\*(N-1)}$ | Mean = $R\_{I}\*\frac{K}{FPS}$ | Mean = $R\_{P}\*\frac{K}{FPS\*(K-1)}$ |
| * [STD, Max, Min]: [10.5, 150, 50]% of Mean packet size
* FPS is the frame rate of the single stream video
 |
| **Packet Success Rate X** | Depends on application, see 6.3.1, 6.4.1, 6.5.1 for VR, CG, AR respectively. |
| **PDB** | Depends on application, see 6.3.1, 6.4.1, 6.5.1 for VR, CG, AR respectively. |

#### Option 2 (video+audio/data)

For Option 2, two streams (video + audio/data) are modelled.

* Stream 1: video
* Stream 2: audio/data

The stream 1 - video stream follows the generic single stream model given in section 7.1.1. The stream 2 - audio/data a periodic traffic with following parameters.

**Table 6 Statistical parameter values for Option 2 multi streams model**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | unit | Baseline values for evaluation | Optional values for evaluation |
| Periodicity P | ms | 10 |  |
| Data rate: R | Mbps | 0.756, 1.12 |  |
| Packet size | byte | R×1e6 × P /1000 / 8 |  |
| PDB | ms | 30 | Other values can be optionally evaluated |
| Packet Success Rate | % | 99 | 99.9 |

#### Option 3 (FOV + omnidirectional view)

For Option 3, following two streams are modelled.

* Stream 1: FOV
* Stream 2: omnidirectional view stream

The detailed modelling of the two streams is left to company with the report of evaluation results.

## Generic UL Pose/Control Traffic

In this section, we provide the generic UL pose/control stream traffic model. A packet for UL pose/control arrives at UE periodically with following parameters.

**Table 7 Statistical parameters for the UL pose/control traffic**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | unit | Baseline values for evaluation | Optional value for evaluation |
| Periodicity | ms | 4 | Other values can be optionally evaluated. |
| Jitter | ms | No jitter |  |
| Packet size  | byte | 100 |  |
| PDB | ms | 10 |  |
| Packet Success Rate X | % | 99 | 90, 95 |

## VR Traffic Model

### VR DL Stream

**Single Stream Model**

The VR DL single stream follows generic single stream DL video traffic model in section 7.1.1 with following parameters.

**Table 8 Statistical Parameters for single stream DL VR Traffic Model**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | unit | Baseline values for evaluation | Optional values for evaluation |
| data rate: R | Mbps | 30, 45 | 60 |
| frame generation rate: F | fps or Hz | 60 |  |
| PDB | ms | 10 | 5, 20 |

Optionally, following combination of packet success rate X and PDB could be also considered for evaluation.

**Table 9 Optional (X, PDB) for single stream DL VR Traffic Model**

|  |  |  |
| --- | --- | --- |
| Parameter | unit | Optional values for evaluation |
| Packet success rate requirement X and PDB pair (X, PDB) for DL single stream  | (%, ms) | (99, 7), (95, 13) for VR/AR |

**Multi-streams Model**

The VR DL multi-streams follows generic multi-streams DL traffic model given in section 7.1.2 with following parameters.

**Table 10 Statistical Parameters for multi streams DL VR Traffic Model**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | unit | Baseline values for evaluation | Optional values for evaluation |
| Packet Success rate X for I stream | % | 99 | Other values can be optionally evaluated. |
| Packet Success rate X for P stream | % | 99 | Other values can be optionally evaluated. |
| PDB for I stream | ms | 10 | Other values can be optionally evaluated. |
| PDB for P stream | ms | 10 | Other values can be optionally evaluated. |

For Option 2, two streams (video + audio/data) are modelled as given in Section 7.1.2.

* Stream 1: video
* Stream 2: audio/data

The stream 1 - video stream follows the generic single stream model given in section 7.1.1. The stream 2 - audio/data a periodic traffic with following parameters.

**Table 6 Statistical parameter values for Option 2 multi streams model** **[“Option 2” to be clarified]**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | unit | Baseline values for evaluation | Optional values for evaluation |
| Periodicity P | ms | 10 |  |
| Data rate: R | Mbps | 0.756, 1.12 |  |
| Packet size | byte | R×1e6 × P /1000 / 8 |  |
| PDB | ms | 30 | Other values can be optionally evaluated |
| Packet Success Rate | % | 99 | 99.9 |

### VR UL Stream

VR UL Stream follows generic UL pose and control traffic model described in section 8.2.

## CG Traffic Model

### CG DL Stream

**Single-stream Model**

The CG DL stream follows generic single stream DL video traffic model in section 7.1.1 with following parameters.

**Table 11 Statistical Parameters for single stream CG Traffic Model**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | unit | Baseline values for evaluation | Optional values for evaluation |
| data rate: R  | Mbps | 30, 8 | 45 |
| frame generation rate: F  | fps or Hz | 60 |  |
| PDB | ms | 15 | 10, 30 |

Optionally, following combination of X and PDB could be also considered for evaluation.

**Table 12 Optional (X, PDB) pair for single stream CG Traffic Model**

|  |  |  |
| --- | --- | --- |
| Parameter | unit | Optional values for evaluation |
| Packet success rate requirement X and PDB pair (X, PDB) for DL single stream  | (%, ms) | (99, 12), (95, 18) for CG |

**Multi-streams Model**

The CG DL multi-streams follows generic multi-streams DL traffic model given in 7.1.2 with following parameters in.

**Table 13 Statistical Parameters for multi streams DL CG Traffic Model**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | unit | Baseline values for evaluation | Optional values for evaluation |
| Packet Success rate X for I stream | % | 99 | Other values can be optionally evaluated. |
| Packet Success rate X for P stream | % | 99 | Other values can be optionally evaluated. |
| PDB for I stream | ms | 15 | Other values can be optionally evaluated. |
| PDB for P stream | ms | 15 | Other values can be optionally evaluated. |

### CG UL Stream

CG UL Stream follows generic UL pose and control traffic model described in section 8.2.

## AR Traffic Model

### AR DL Stream(s)

The AR DL Stream(s) has/have the same models as VR DL stream model given in section 7.3.1.

### AR UL Stream(s)

In this section, we provide four different options for AR UL traffic model. Given that AR has multiple streams in UL, one can choose a model from various options depending on what/how to model the streams. Four options are as follows.

* Model 1: one stream model
* Model 2: Two streams model
* Model 3A: Three streams model A
* Model 3B: Three streams model B

The detail of each model is given in following sections.

#### Model 1 (one stream model)

In Model 1, all AR UL flows are modelled as a single stream with following parameters.

**Table 14 Statistical parameters for AR UL Model 1 (one stream model)**

|  |  |  |
| --- | --- | --- |
| Parameters | unit | value |
| Packet size | byte | Follows section 8.3.1 (i.e., mean packet size = R×1e6 / F / 8, STD/Min/Max=10.5/50/150%) |
| packet generation rate: F  | Hz | 60 |
| Jitter | ms | Optional, follows the description in 8.1.1.2 |
| Data rate: R | Mbps | 10 (baseline), 20 (optional) |
| PDB | ms | 30 (baseline), 10 or 15 or 60 (optional) |

Note that Model 1 is optional for power evaluation and baseline for capacity evaluation.

#### Model 2 (two streams model)

In Model 2, two streams are considered.

* Stream 1 for pose/control
	+ Traffic model/requirement for stream 1 follows section 8.2.
* Stream 2 aggregating scene, video, data, and audio
	+ Follows the statistical parameters shown in Table 7.

#### Model 3A (three streams model A)

In Model 3A, three steams are considered.

* Stream 1: pose/control
	+ Traffic model/requirement for stream 1 follows section 8.2.
* Stream 2: A stream aggregating streams of scene and video
	+ Follows the statistical parameters shown in Table 14.
* Stream 3: A stream aggregating streams of audio and data

**Table 15 Statistical parameters for stream 3 of AR UL Model 3A (three streams model)**

|  |  |  |
| --- | --- | --- |
| Parameters | unit | value |
| Data rate: R | Mbps | 0.756, 1.12 |
| Periodicity: P  | ms | 10 |
| Packet size | byte | mean packet size = R×1e6 × P/1000 / 8 |
| PDB | ms | 30 |

#### Model 3B (three streams model B)

In Model 3B, three streams are considered

* Stream 1: pose/control
	+ Traffic model/requirement for stream 1 follows section 8.2.
* Stream 2: I-stream for video
* Stream 3: P-stream for video
* **Table xx Statistical Parameters for stream 2 and 3 of AR UL Model 3B (three streams model)**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | unit | Baseline values for evaluation | Optional values for evaluation |
| Packet Success rate X for I stream | % | 99 | Other values can be optionally evaluated. |
| Packet Success rate X for P stream | % | 99 | Other values can be optionally evaluated. |
| PDB for I stream | ms | 30 | Other values can be optionally evaluated. |
| PDB for P stream | ms | 30 | Other values can be optionally evaluated. |

Note: For stream 2 and stream 3, the I/P-stream model for DL video can be reused for UL video.  Companies should report detailed assumptions in their simulations on packet size distribution for each stream, packet arrival interval (or fps) for each stream, PDB for each stream, PER requirement for each stream, criteria to be satisfied UE.

# Deployment Scenarios

We consider following three different deployment scenarios for XR.

* Dense Urban: In this scenario, XR Ues are in urban area where gNBs are deployed densely with inter site distance (ISD) of 200m. User playing cloud gaming (CG), users experiencing VR/AR indoor and outdoor are considered. For FR1, 80/20% of Ues are assumed in indoor/outdoor. For FR2, 100% Ues are assumed to be outdoor.
* Indoor Hotspot: In this scenario, only indoor XR users are considered. VR or CG applications is more likely for indoor for work and gaming. Indoor AR application is also considered. This applies to both FR1 and FR2.
* Urban Macro: In this scenario, larger ISD of 500ms is considered, where XR users are distributed over larger area. Due to large ISD deployment, XR applications with lower rate would be more relevant to this scenario. Urban Macro scenario is evaluated for FR1 only.

# XR Capacity Evaluation

## Purpose of Study

In this section, we describe the KPI for capacity evaluations and provide evaluation results for capacity based on baseline parameters and optional parameters/modelling methods.

The purpose of capacity study is to understand the performance of NR systems for XR applications, and identify any issues and performance gaps, which could be useful for understanding the limitation of current NR systems in supporting XR applications and the potential directions for future necessary enhancements to better support XR.

## KPI

### UE Satisfaction

A UE is declared as a **satisfied UE** if **all** the considered streams meet their own PER and PDB requirements, i.e., more than a certain percentage of packets are successfully transmitted within a given air interface PDB. Specifically, we have followings depending on the evaluation directions considered.

* In DL-only evaluation, only DL streams are considered when identifying UE satisfaction**.**
* In UL-only evaluation, only UL streams are considered when identifying UE satisfaction**.**

### System Capacity

System capacity is identified as KPI for capacity study, which is defined as the maximum number of users per cell with at least Y % of UEs being satisfied.

* Y=90 (baseline) or 95 (optional)
* Other values of Y can also be evaluated optionally.

For details on how to evaluate capacity, see capacity evaluation section 14.

## Capacity Results

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# XR UE Power Consumption Evaluation

## Purpose of Study

The purpose of power study is to understand the NR UE power consumption performance for XR applications, and identify any issues and performance gaps, which could be useful for understanding i) the limitation of current NR systems in supporting XR applications and ii) the potential directions for future necessary enhancements to improve power efficiency.

## KPI

The KPI for power evaluation is the UE power consumption, which is UE specific metric. The detailed method for estimating UE power consumption is given in evaluation methodology section.

The power saving gain (PSG) is determined from A: the power consumption of a power saving scheme and B: the power consumption of baseline (AlwaysOn) case; PSG = (B-A)/B×100%.

Since UE power saving gain typically comes with the loss in capacity (i.e., more precisely, the loss in the satisfied UE ratio), it also needs to be considered jointly with power consumption/power saving gain.

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# XR Coverage Evaluation

## Purpose of Study

The coverage study is for understanding the DL and UL coverage performance of XR applications. Note that the coverage depends on the evaluation assumptions/setup such as considered link direction (DL vs UL), bit rate, PDB, PER requirement, gNB/UE tx power, etc. Thus, the metric should be understood as a conditional metric for the given assumption. Through this study, we can identify the coverage of XR applications in terms of coupling gain and bottleneck direction of the considered applications.

## KPI

The KPI of the coverage evaluation is *XR coverage* which is defined as the 5% point of CDF of coupling gains for the satisfied Ues.

In this study, we consider two slightly different evaluation methodologies. The details of the two coverage evaluation methodologies are found in Annex A.3.

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# XR Mobility evaluations

## Purpose of study

[As XR and Cloud Gaming see consumer adoption, the services are expected to be consumed by users on the move. Minimizing user experience degradation through mobility events is a key consideration in enabling mass adoption of such services. As such, mobility an important factor for XR and Cloud Gaming.]

## KPI

## Mobility evaluation results

# Conclusions

# Annex <A>: Evaluation Methodology

# A.1 Evaluation Methodology for Capacity

**System Level Simulation Parameters for Capacity Evaluation**

For Capacity evaluation, system level simulation (SLS) is carried out based on the simulation parameters presented in **Table *16*** (for FR1) and **Table *17*** (for FR2) should be used.

The gNB and UEs in the simulation are configured base on simulation parameters presented in **Table *16*** (for FR1) and **Table *17*** (for FR2) and the traffic model used for the simulation is selected from the XR/CG traffic models presented in Section 7.

**DL-only and UL-only Evaluation**

In capacity evaluation, the DL and UL evaluation is done separately and independently.

**UE Dropping**

For a given number of UEs per cell, *N*, the *N* UEs are randomly dropped in the network using the UE distribution specified in **Table *16*** (for FR1) and **Table *17*** (for FR2) for the chosen deployment scenario. Either exactly equal number of UEs per cell could be assumed or on average N Ues per cell could be assumed. Either approach is accepted, and companies are to report the method used for their evaluation.

**Packet Discarding**

Once communication commence between the UE and gNB, an XR/CG packet is deemed in error (i.e., lost) when it has exceeded the PDB, such that it will be added to the PER counting. It is up to company to report the details for the handling of packet which has exceeded the PDB, e.g.

* **Option 1:** The packet exceeding the delay is still delivered to the other side
* **Option 2:** The packet (including the non-transmitted part) is discarded at the transmitter (at the gNB for DL packets and at the UE for UL packets)
* Other options are not precluded

**Satisfied UE and Capacity**

For a given UE, the achieved PER for all packets communicated during the session is determined. Using the achieved PER per UE, the percentage of the satisfied UEs can be determined for this simulation.

Multiple runs of the SLS are required to sweep the number of UEs per cell, *N,* in order to determine, the capacity C (i.e., the maximum value of *N* satisfying at least 90% of the UEs are satisfied (see Section 9.1 for definition of capacity))

The system capacity for DL and UL are identified separately though independent evaluation.

**Additional Metrics**

In addition to the KPIs discussed in Section 9.1, following performance metrics can be optionally reported.

* Percentage of satisfied UEs
* CDF of packet error ratio
* CDF of packet latency
* CDF of user-perceived throughput
* Resource utilization

**Table 22: System Simulation Parameters for FR1**

|  |  |
| --- | --- |
| **Parameter** | **Deployment scenarios** |
| **Dense Urban (**38.913 w/ following parameters) | **Urban Macro (**38.913 w/ following parameters) | **Indoor Hotspot (**38.913 w/ following parameters) |
| Layout | 21cells with wraparoundISD: 200m | 21cells with wraparoundISD = 500 m | 120m x 50mISD: 20mTRP numbers: 12 |
| Channel model | UMa (38.901) | UMa (38.901) | InH(38.901) |
| UE Distribution | 80% indoor, 20% outdoor**Note:** Other UE distribution can be evaluated optionally. | 100% indoor |
| Carrier frequency | 4 GHz |
| Subcarrier spacing | 30 kHz |
| BS height | 25m | 25m | 3m |
| UE height | For Dense urban and Urban Macro, the UE height for indoor UEs is updated as following based on Table 6-1 in TR 36.873.

|  |  |  |
| --- | --- | --- |
| UE height (*hUT*) in meters | general equation for UE height | *hUT*=3(*nfl* – 1) + 1.5 |
| *nfl* for outdoor UEs | 1 |
| *nfl* for indoor UEs | *nfl* ~ uniform(1,*Nfl*) where*Nfl* ~ uniform(4,8) |

 | 1.5 m |
| BS noise figure | 5 dB |
| UE noise figure | 9 dB |
| BS receiver | MMSE-IRC |
| UE receiver | MMSE-IRC |
| Channel estimation | RealisticIdeal(optional) |
| UE speed | 3 km/hr |
| MCS | Up to 256QAM |
| BS Antenna Pattern | 3-sector antenna radiation pattern, 8 dBi | Ceiling-mount antenna radiation pattern, 5 dBi |
| BS Antenna Configuration  | **Option 1:** 64 TxRU, (M, N, P, Mg, Ng; Mp, Np) = (8,8,2,1,1;4,8)**Option 2:** 32 TxRU, (M, N, P, Mg, Ng; Mp, Np) = (8,2,2,1,1,8,2)(dH, dV) = (0.5λ, 0.5λ)**Note:** Other BS antenna parameters can also be optionally evaluated. | 32 TxRU, (M, N, P, Mg, Ng; Mp, Np) = (4,4,2,1,1;4,4)(dH, dV) = (0.5λ, 0.5λ)**Note:** Other BS antenna parameters can also be optionally evaluated. |
| UE Antenna Pattern | Omni-directional, 0 dBi, |
| UE Antenna Configuration  | **Baseline:** 2T/4R, (M, N, P, Mg, Ng; Mp, Np) = (1,2,2,1,1;1,2), (dH, dV) = (0.5, N/A)λ**Optional:** 4T/4R, 1T/2R, 2T2R |
| Down Tilt  | 12 degrees**Note:** Other downtilt values can also be optionally evaluated | Up to company report |  90° (pointing to the ground)**Note:** Other downtilt values can also be optionally evaluated |
| BS Transmit Power | 44 dBm per 20 MHz**Note:** For system BW larger than above, Tx power scales up accordingly. | 49 dBm/20 MHz | 24 dBm per 20 MHz**Note:** For system BW larger than above, Tx power scales up accordingly. |
| UE max tx power | 23dBm |
| System Bandwidth | Single Carrier (SC) evaluations, * Baseline: 100 MHz
* Optional: 20/40 MHz,

 CA evaluations, * Optional: 2\*100 MHz with CA

**Note:** Other system bandwidths can also be optionally evaluated |

**Table 23: System Simulation Parameters for FR2**

|  |  |
| --- | --- |
| **Parameter** | **Deployment scenarios** |
| **Dense Urban****(**38.913 w/ following parameters) | **Indoor Hotspot****(**38.913 w/ following parameters) |
| Layout | 21cells with wraparoundISD: 200m | 120m x 50mISD: 20mTRP numbers: 12 |
| Channel Model | UMa(38.901) | InH(38.901) |
| UE Distribution  | For indoor scenario: 100% indoorFor outdoor scenario: 100% outdoor**Note:** Other UE distribution can be evaluated optionally. |
| Carrier frequency | 30 GHz |
| Subcarrier spacing | 120 KHz |
| BS height | 25m | 3m |
| UE height | The UE height for indoor UEs is updated as following based on Table 6-1 in TR 36.873.

|  |  |  |
| --- | --- | --- |
| UE height (*hUT*) in meters | general equation for UE height | *hUT*=3(*nfl* – 1) + 1.5 |
| *nfl* for outdoor UEs | 1 |
| *nfl* for indoor UEs | *nfl* ~ uniform(1,*Nfl*) where*Nfl* ~ uniform(4,8) |

 | 1.5m |
| BS noise figure |  7 dB |
| UE noise figure | 13 dB |
| BS receiver | MMSE-IRC |
| UE receiver | MMSE-IRC |
| UE speed | 3 km/hr |
| MCS | Up to 256QAM |
| BS antenna pattern | 3-sector antenna radiation pattern, 8 dBi | Ceiling-mount antenna radiation pattern, 5 dBi |
| BS Antenna Configuration | 2 TxRU, (M, N, P, Mg, Ng; Mp, Np) = (4,8,2,2,2;1,1)(dH, dV) = (0.5λ, 0.5λ)**Note:** Other BS antenna parameters can also be optionally evaluated. | 2 TxRU, (M, N, P, Mg, Ng; Mp, Np) = (16, 8, 2,1,1;1,1)(dH, dV) = (0.5, 0.5)λ**Note:** Other BS antenna parameters can also be optionally evaluated. |
| UE Antenna Pattern | UE antenna radiation pattern model 1, 5dBi |
| UE Antenna Configuration  | **Option 1**: (Follow Rel-17 evaluation methodology for FeMIMO in R1-2007151)(M, N, P)=(1, 4, 2), 3 panels (left, right, top)**Option 2:** (from TR 38.802 – developed in Rel-14)4Tx/4Rx: (M, N, P, Mg, Ng; Mp, Np) = (2,4,2,1,2;1,2), (dH,dV) = (0.5, 0.5)λ, the polarization angles are 0° and 90°**Note:** Other UE antenna parameters can also be optionally evaluated. |
| Downtilt | Not specified | 90° (pointing to the ground)**Note:** Other downtilt values can also be optionally evaluated |
| BS Transmit Power | 40 dBm per 80 MHz. EIRP should not exceed 73 dBm**Note:** For system BW larger than above, Tx power scales up accordingly. | 23 dBm per 80 MHz. EIRP should not exceed 58 dBm**Note:** For system BW larger than above, Tx power scales up accordingly. |
| UE max tx power | 23dBm, maximum EIRP 43 dBm |
| System Bandwidth | Single Carrier Evaluations:* Option 1: 100 MHz
* Option 2: 400 MHz

CA Evaluations: * Companies should report the CA system bandwidth if CA is configured.

**Note:** Other system bandwidths can also be optionally evaluated |

Table 18 includes common assumptions applied to both FR1 and FR2.

**Table 24 Common Assumptions for FR1 and FR2**

|  |  |
| --- | --- |
| TDD Configuration  | Option 1: DDDSUOption 2: DDDUUNote: Detailed S slot format is 10D:2F:2U.Note: For option 2, there is a 2-symbol gap at the end to third “D” slot of DDDUU |
| Scheduler | SU/MU-MIMO PF scheduler (company to report SU or MU),other scheduler (e.g., delay aware scheduler) is up to companies report |
| Channel Estimation /CSI acquisition | RealisticBoth CSI feedback and SRS are consideredCompanies should report •          CSI feedback delay, CSI report periodicity, whether using CSI quantization, CSI error model or not,•          Assumptions on SRS: periodicity, processing gain, processing delay, etcNote: Companies may optionally use ideal channel estimation  |
| PHY processing delay | Baseline: UE PDSCH processing Capability #1Optional: UE PDSCH processing Capability #2Companies should report gNB processing delay, e.g. DL NACK to retransmission delay, UL previous transmission to current transmission delay and etc. |
| PDCCH overhead | Companies should report |
| DMRS overhead | Companies should report |
| Target BLER | Companies should report |
| Max HARQ transmission | Companies should report |
| Power control parameter | Companies should report |
| Transmission scheme | Companies should report  |

# A.2 Evaluation Methodology for Power

**Baseline UE Power Model**

For XR UE power evaluation, the power model presented in [6] is used with additional modifications presented in this section.

**System Level Power Evaluation**

In this study, UE power consumption evaluation system is done in *system level* setup; UE are distributed across multiple cells are their dynamic DL rx and UL tx activities are considered in each UE’s power consumption evaluation including time varying channel conditions, and dynamic scheduling for DL and UL with HARQ operations, power control, etc. With system level setup, the study allows to capture distribution of UE power consumptions across different locations in the cell showing different power consumption distributions across different rx/tx physical channel activities (e.g., PDCCH, PDSCH, PUSCH, PUCCH, …).

More importantly, the system level power evaluation allows the joint evaluation of capacity and power – allowing to capture the interaction between scheduler and power saving mechanism (e.g., CDRX) revealing capacity and power tradeoff. Due to the power of system level power evaluation framework, one can compare different power saving mechanisms with capacity in consideration, i.e., making the comparison fair by making it subject to limited capacity loss.

**Power Saving Schemes**

To evaluate the power saving impact of different power saving schemes for XR/CG, companies are encouraged to evaluate UE power consumption as described below:

As a baseline, UE is always ON, i.e., UE is always available for gNB scheduling of XR/CG traffic, is considered. The power consumption of AlwaysOn could be reference for power saving gain calculation.

Optionally following power saving mechanisms can be further considered.

* **R15/16 CDRX** mechanism can be optionally evaluated. The CDRX configuration can be reported with the evaluation results.
* **Release 15/16/17 Connected mode** **power saving techniques** such as BWP switching, PDCCH skipping and search space switching can also be evaluated.
* **Genie** scheme can be studied. The Genie power saving scheme works such that UE is in a sleep state (e.g., micro/light/deep sleep as defined in TR38.840) whenever there is neither DL data reception nor UL transmission. From the gNB scheduling perspective, it is assumed that UE is always available for scheduling, i.e., there is no difference from Baseline in gNB scheduling and corresponding UE transmission/reception availability. Note that the Genie approach is expected to provide an *upper bound of power savings* gain since the UE is able to take advantage of all the unscheduled slot duration by entering sleep state whenever possible.
* [Other schemes not listed here could be also evaluated.]

**DL and UL Power Saving Evaluation**

For XR/CG power consumption evaluation, DL and UL power consumption can be evaluated based on following methods.

* **DL-only Evaluation, UL-only Evaluation:** DL and UL power are evaluated separately and independently, and the DL and UL power consumption results are collected separately.
* **DL+UL Joint Evaluation:** DL and UL performances are evaluated together, and DL and UL power consumption are counted to obtain the total power consumption.

Note that adding DL-only power number and UL-only power will not give the equal power number as DL+UL joint power number due to duplicate power cost counted in DL / UL-only method such as PDCCH monitoring.

**System-level Simulation Flow**

For XR UE power consumption evaluation, SLS is carried out using the capacity evaluation methodology for the baseline and power saving scheme under investigation. The details are presented below:

* Step 1) Determine a scenario/application/configurations/power saving schemes for evaluation.
* Step 2) Determination of the number of Ues per cell N for power evaluation.
	+ N is set to floor(C), where C is the XR capacity for the given scenario/application/configuration and floor() is flooring operation.
	+ Note that N=floor(C) corresponds to the high system load case.
	+ Optionally, N could be set to smaller than C (N<< C) for low load case.
* Step 3) Perform system level power evaluation for the given scenario/application/configuration and N determined in Step 2)
* Step 4) Following metrics are reported.
	+ satisfied UE rate in capacity evaluation
	+ satisfied UE rate in power evaluation
	+ PSG CDF 5, 50, 95% points
		- Power saving gain is computed w.r.t to AlwaysOn case.
		- [PSG could be computed w.r.t either all UE or satisfied Ues. Companies to report method used with their results.]

**Additional UL Power Modelling**

One of necessary enhancements of power model for system level power evaluation is the UL power consumption model. The UL power model in TR 38.840 is incomplete for the case of UE transmit power other than 0 and 23dBm. The power consumption values corresponding to UE transmit powers other than 0 dBm and 23 dBm (cell middle UEs) are not defined. Therefore, to determine the power consumption for such scenarios, companies are encouraged to use the following methods to estimate UE power consumptions when transmitting with tx power other than 0 and 23dBm:

Linear interpolation method in linear scale for Tx power values other than 0 dBm and 23 dBm. Companies are to indicate how they do linear interpolation method in linear scale considering step-wise linear average of UE power model.

As another method that can be used for evaluation, consider only two Tx power values as defined in TR 38.840. Power number is given as *A* for *X= [0, M]*dBm and B for X =[M, 23]dBm, where A and B (defined in 38.840) correspond to power consumption numbers for a given uplink slot for 0dBm and 23dBm respectively with M = [20] or other value(s).

The power consumption of the UE transmitting with power less than 0 dBm[[3]](#footnote-4) could be set to the power number of 0 dBm. Alternatively, companies could choose to adopt the extrapolation of the power numbers from on 0 and 23dBm power numbers.

For other missing UL power modelling, companies to use their own model and report with their results.

# A.3 Evaluation Methodology for Coverage

For XR/CG Coverage Evaluation, there are two options for evaluating the coverage based on the coupling gain metric. The coupling gain is defined as the ratio of received and transmitted power measured in dB, and includes antenna gains, path loss, shadowing, indoor- or body loss, etc. For more information about coupling gain, readers are referred to TR 37.910.

Below are the two methodologies:

**Coverage Evaluation Methodology 1**

For a given XR application (AR/VR/CG) in a given deployment scenario (DU/InH/UMa), the XR/CG in DL or UL coverage is determined as follows:

* Run SLS with #UEs per cell = 1 as shown in Figure 2 and/or XR/CG capacity using the XR system capacity evaluation methodology presented in A.1.
* Determine the “satisfied UE” and evaluate coupling gain for those UEs.
* The coverage is defined to be the 5-percentile point in CDF of coupling gain for the “satisfied” Ues.

**Note:** For this methodology, the evaluation of coupling gain will be impacted by e.g., interference and scheduler mechanism, etc.



**Figure 2 Layout and UE distribution in Methodology 1 (1 UE per cell)**

**Coverage Evaluation Methodology 2**

For a given XR application (AR/VR/CG) for a given deployment scenario (DU/InH/UMa), the XR/CG in DL or UL coverage is determined as follows:

* Run SLS with #UEs per cell = 1 as shown in Figure 3. The UE is randomly dropped in the entire network (or in all the cells) that is associated with one of the three center cells (or gNBs), i.e., only one of the center gNBs is activated.
* Run SLS according to capacity evaluation methodology and determine whether the UE is satisfied or not.
* The coverage is defined to be the 5-percentile point in the CDF curve of coupling gain for all the satisfied Ues.



**Figure 3 Layout and UE distribution in Methodology 2 (1 UE / network)**

# Annex <B> Source Specific Capacity Performance Evaluation Results

Table 25 Capacity Evaluation results for FR1, DL, VR/AR, Single Stream

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (example) | tdoc number | Perf. Metric 1 | Perf. Metric 2 | Perf. Metric 3 | .. | .. | .. |  |
| Source 1 |  |  |  |  |  |  |  |  |
| Note |
| Source 2 |  |  |  |  |  |  |  |  |
| Note |
| … |  |  |  |  |  |  |  |  |
|  |

# Annex <C> Source Specific Power Performance Evaluation Results

Table 26 Power consumption results of CG (30Mbps) application in FR1 DL VR/CG scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Source** | **Power Saving scheme** | **avg # UEs/ cell = N1** | **C1=floor(Capacity)** | **Average PS gain (%)** | **% of satisfied Ues w/ PS when #UEs/cell = N1** | **% of satisfied Ues w/o PS when #UEs/cell = N1** |
| X | -  |   |  |  |  |  |
|  |   |  |   |  |  |
|  |   |  |   |  |  |
| Y |  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Note 1

# Annex <D> (informative):

# Change history

|  |
| --- |
| **Change history** |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2020-10 | RAN1#103e | R1-2009818 |  |  |  | Skeleton TR | 0.0.1 |
| 2021-10 |  | R1-xxxxxx |  |  |  | Update TR structure | 0.0.2 |

1. Note that the PDB defined in this section for XR evaluation purpose only. Its exact definition is different from that of the PDB in 5G system [↑](#footnote-ref-2)
2. Note that the exact definition of PER defined for this section is different from that defined in [5]. [↑](#footnote-ref-3)
3. Note that this is not intended to introduce new power class. [↑](#footnote-ref-4)