**3GPP TSG RAN WG1 #103-e R1-20xxxxx**

**e-Meeting, October 26th – November 13th, 2020**

**Agenda item:** 8.14.1

**Source:** Moderator (Qualcomm)

**Title:** Email discussion approval for applications, traffic model and evaluation methodology: Other than capacity evaluation

**Document for:** Discussion and Decision

# XR Applications

Table 1 captured the views on XR applications of interest from different sources.

Table 1 Views on XR Applications

|  |  |
| --- | --- |
| Source | View |
| [1] | Proposal 1: FS\_NR\_XR\_eval considers selecting one application (e.g., VR2: “Split Rendering: Viewport rendering with Time Warp in device”, or CG: Cloud Gaming) as the focus of study, at least in the initial stage of the study item. |
| [2] | Proposal 1: For VR1, VR2 and CG applications, downlink traffic is studied and evaluated with higher priority. |
| [3] | Proposal 1: RAN1 studies VR2, AR1 and CG applications as high priority. |
| [5] | Proposal 1: The applications of interest of the study item include at least the following listed in RP-193241.   |  | | --- | | * VR1: Viewport dependent streaming * VR2: Split Rendering: Viewport rendering with Time Warp in device * AR1: XR Distributed Computing * AR2: XR Conversational * CG: Cloud Gaming |  * Up to one single (Rate, PDB, PER) requirement is evaluated for each application of interest * For delivery of CG applications, generalized split rendering architecture and its relevant traffic characteristics are considered. |
| [7] | Proposal 1: Prioritize the AR applications/use cases from [1] for the XR SI. Also consider cloud gaming. |
| [8] | Proposal 1: Confirm the XR and cloud gaming applications in the SI for XR evaluations |
| [12] | Proposal: Classify AR1 and AR2 as essential applications in the RAN1 Rel-17 study item for evaluation of XR for NR. |
| [13] | Proposal 1: Prioritize the evaluation of CG over AR/VR considering the highest business value of CG among VR/AR/CG.  Proposal 2: Prioritize the evaluation of AR over VR considering the higher popularity of AR service. If VR is considered, prioritize indoor deployment scenario, e.g. Indoor Hotspot (InH).  Proposal 3: Adopt the following study priorities on applications and deployment scenarios for R17 XR/CG: |
| [16] | Proposal 1 RAN1 to confirm that the VR1/VR2/AR1/AR2/Cloud gaming applications are of interest for Rel-17 study on XR evaluation for 5G NR and determine which of the use cases would need to be prioritized for the evaluation study.  Proposal 2 In the XR evaluation SI, RAN1 to treat cloud gaming with first priority, AR use cases with second priority, and VR use cases with third priority. |
| [17] | Proposal 1:   * CG and VR can be discussed in the RAN1#103-e meeting considering the availability of traffic models in SA4 TR. As for AR, it needs to wait for SA4 progress. |
| [18] | Proposal 1: RAN1 considers all the XR applications described in the RAN XR SID for evaluation (i.e., VR, AR, and CG). More details, e.g., prioritization and/or down-selection of them can be further discussed once the outcome of SA4 study on XR traffic model becomes available. |

**Summary**

Companies have shown their views on application of interests. Following table captures the indicated priorities of applications of interest from sources. “1” = highest priority, “2”=second highest priority, etc.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | VR1 | VR2 | AR1 | AR2 | CG |
| [3] | 2 | 1 | 1 | 2 | 1 |
| [13] |  |  | 3 | 2 | 1 |
| [1] |  | 1 |  |  | 1 |
| [16] | 3 | 3 | 2 | 2 | 1 |
| [17] | 1 | 1 | 2 | 2 | 1 |
| [7] |  |  | 1 | 1 | 1 |
| [12] |  |  | 1 | 1 |  |

**FL Proposal 1**: RAN1 confirms that diverse applications of VR1/2, AR1/2 (including low rate AR), CG [TR26.928] are of interest for evaluation. Prioritization/down selection of these applications for evaluation, if needed, is to be discussed after detailed traffic model and evaluation assumptions are determined.

**Question 1**. Please share your comments on Proposal 1 if any.

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| --- | --- |
| Company | View |
| QC | All VR1/VR2/AR1/AR2(including low rate AR)/CG are interesting to us. In particular, low rate AR is interesting application to study because it may be one of the most relevant applications in the near term market. Any decision related to the prioritization or down-selection of applications for evaluation should be made after we have a good understanding, in particular on traffic model. |
| MTK | We are fine with the FL proposal. However, given that CG is marked as “1” for the most companies, we prefer to further prioritize CG, and choose 1 or 2 applications from AR1/2, VR1/2 later. |
| ZTE, Sanechips | We don't think low rate AR should be explicitly captured here given the traffic related discussion is still pending at this moment. Moreover, given the prioritization is still open in the proposal, it's suggested changing evaluation to study to avoid confusion. The preferred change to the proposal would be:  **FL Proposal 1**: RAN1 confirms that diverse applications of VR1/2, AR1/2 ~~(including low rate AR)~~, CG [TR26.928] are of interest for ~~evaluation~~ study. Prioritization/down selection of these applications for evaluation, if needed, is to be discussed after detailed traffic model and evaluation assumptions are determined. |
| Nokia, NSB | We agree that the selection of the applications should be done after the understanding of the appropriate traffic models. |
|  |  |

# Traffic Model

DL Traffic Model

Table 2 captures the views from different sources on DL traffic model.

Table 2 View on DL Traffic Model

|  |  |
| --- | --- |
| Source | View |
| [1] | Proposal 2: RAN1 notifies SA4 that RAN1 prefers a statistical XR traffic model in FS\_NR\_XR\_eval studies and kindly asks SA4 to confirm that such a statistical XR traffic model can be provided as an outcome of SA4’s related study item on XR. |
| [2] | Proposal 3: For VR and CG performance evaluation, periodic traffic with frame arrival interval 1/F seconds is considered as a starting point, where F is frame rate in FPS. |
| [4] | Proposal 9: The XR traffic model could consider the packet size, including fixed value and random distribution, and the packet arrival time, including periodic and non- periodic. |
| [5] | Proposal 2: The following 2 categorizations of XR representative services for DL services as the starting point   * , 300, fixed periodicity, fixed packet size * 100Mbps,, [5-30] fixed periodicity and fixed packet size/statistical model for fluctuating traffic * FFS periodicity values and the modeling of variant inter arrival rate * FFS statistical model for fluctuating traffic, target to down-select in RAN1#103-e between Gaussian distribution and Pareto distribution   Proposal 3: Adopt the three-step methodology to derive the traffic models for Gaussian/Pareto distribution of file size.  Step 1: Generate the mean packet size according to the packet arrival rate and the data rate requirement.  Step 2: Determine the minimum file size or the standard derivation parameter based on the relationship between the mean data rate and the minimum/maximum (i.e. truncated) data rate.  Step 3: Determine the remaining parameter, if any, by jointly considering the mean file size and the parameter obtained from step 2. |
| [6] | Proposal 1: The frame size of DL follows a random distribution, while the frame size of UL can be assumed as two different values, one is for pose and control information, and the other is for scene update information. |
| [7] | Proposal 2: Down-select between the Gaussian and Pareto distributions for modelling packet arrivals and jitter and select a small set of packet sizes, jitter values, and packet arrival rates for evaluation. |
| [9] | Proposal 1:   * In the traffic model for XR, multiple data streams (e.g. for audio and video) for each direction (DL or UL) are generated for a UE; * Each data stream can be configured separately with * Periodicity * Packet size distribution (e.g. fixed or following a distribution)   Data flow specific latency and reliability requirements |
| [10] | Proposal 1: For evaluations, RAN1 to use a generalized/parametric XR traffic model with configurable parameters that can represent any of the XR traffic. The configurable parameters in the generalized XR traffic model are:   * UL:   + Traffic arrival distribution: [Quasi-periodic with configurable inter-packet arrival rate] (e.g. 60 to 500Hz)   + Traffic file distribution: [Uniform distribution with configurable packet size] (e.g. 30 to 250B)   + Number of data streams: [Configurable number of streams, configurable traffic parameters common to all streams] (e.g. single/multiple streams with bounded latency)   + Traffic parameters of each data stream: [Configurable data rate, latency and reliability]   (e.g. 500kbps, 10ms, 10E-04 PER)   * DL:   + Traffic arrival distribution: [Quasi-periodic with configurable inter-packet arrival time duration] (e.g. FTP3, inter-packet arrival proportional to 1/frame-rate)   + Traffic file size distribution: [Truncated Gaussian distribution or Parero distribution with configurable mean, σ, min, max] (e.g. mean: 1200B)   + Number of data streams: [Configurable number of streams, configurable traffic parameters common to all streams] (e.g. isochronous multi-stream with bounded latency)   + Traffic parameters of each data stream: [Configurable data rate, latency and reliability]   (e.g. 100Mbps, 10ms, 10E-04 PER) |
| [11] | VR1   |  |  |  | | --- | --- | --- | |  | DL Traffic Model | UL Traffic Model | | Traffic model | FTP Model 3 | Periodic traffic | | Rate | HEVC @ 60 fps:   * 4K: 43 Mbit/s | Period = 1/X, X=100-200ms | | PDB | 10ms | 10ms | | PER | 1e-4 | 1e-4 | | Packet size | 1500 byte | 100 bytes | | Packet size distribution | Constant | Constant | | Transport protocol | TCP (DASH/HTTP) | TCP (DASH/HTTP) |   VR2   |  |  |  | | --- | --- | --- | |  | DL Traffic Model | UL Traffic Model | | Traffic model | FTP Model 3 | CBR | | Rate | 50-100 Mbps | Several 100 kbps | | PDB | 20 ms | < 10 ms | | PER | 1e-4 | 1e-4 | | Packet size | 1500 byte | 100 bytes | | Packet size distribution | Constant | Constant |   AR1   |  |  |  | | --- | --- | --- | |  | DL Traffic Model | UL Traffic Model | | Traffic model | FTP Model 3 (option 2), CBR (option 3) | FTP Model 3 (option 2,3) | | Rate | Option 2:  HEVC @ 60 fps:   * 4K: 43 Mbit/s   Option 3:   * 10 kbit (small object) every 5s * 10 Mbit (large object) every 5s | Option 2,3:  HEVC @ 60 fps:   * 720p: 10 Mbit/s * 1080p: 29 Mbit/s * 4K: 43 Mbit/s | | PDB | 10ms | 10ms | | PER | 1e-6 | 1e-6 | | Packet size | 1500 byte | 1500 byte | | Packet size distribution | Constant | Constant | | Transport protocol | UDP (RTP) | UDP (RTP) |   CG   |  |  |  | | --- | --- | --- | |  | DL Traffic Model | UL Traffic Model | | Traffic model | FTP Model 3 | CBR | | Rate | HEVC @ 60 fps:   * 720p: 10 Mbit/s * 1080p: 29 Mbit/s * 4K: 43-45 Mbit/s | 0.2-0.7 Mbit/s | | PDB | 10ms | 10ms | | PER | 1e-4 | 1e-4 | | Packet size (interval) | 1200 byte | 100 byte | | Packet size distribution | Constant | Constant | | Transport protocol | UDP (GQUIC) | UDP (GQUIC) | |
| [12] | Proposal: RAN1 should develop relevant over-the-air traffic model for AR1 and AR2 applications as well as VR1, VR2 and CG applications based on the output of SA4 study item during the RAN1 Rel-17 study item for evaluation of XR for NR. |
| [13] | Proposal 4: Adopt the proposed traffic model for cloud gaming traffic.    Proposal 5: The jitter should be modelled as a parameter in the traffic model.  Proposal 6: For the XR traffic, the Cloud Gaming traffic model could be used as a baseline and extended as needed. |
| [14] | Proposal-1: A simplified baseline DL model (media) is to consider periodic traffic (arriving at framerate) together with a truncated distribution for packet size. The addition of randomness to this periodic traffic burst due to jitter might be required. |
| [15] | Proposal 3: Periodic traffic can be assumed for the DL and UL traffic of the VR service |
| [16] | Proposal 3 The frame size for the video traffic may include a variance, e.g., Gaussian distribution, in time to be more realistic.  Proposal 4 The frame arrival time to RAN for the video traffic may be approximated to be periodic and equal to the inverse of a frame refresh rate.  Proposal 5 RAN1 should decide the exact video traffic parameters further when SA WG4 XR study is finalized [3]. The parameters can include a frame size in terms of mean, variance, the maximum and the minimum value at least for the minimal acceptable encoding rate and the frame generation interval.  Proposal 6 Both DL and UL should be studied to understand the impact of a wide-spread deployment of XR services in a cellular network. |
| [18] | **Proposal 2:** RAN1 defers its conclusion on XR traffic model to be used for performance evaluations until the outcome of SA4 study on XR traffic model is available. |

**Summary**

Companies have shown their initial view on following aspect of DL traffic model.

* DL file inter arrival: this could be roughly inverse of frame rate (Fps). Depending on jitter modeling, it could be periodic (i.e., w/o jitter) or random w/ jitter
  + Periodic (w/o jitter): [2] [4] [5] [9] [14] [15] [16]
  + Random (w/ jitter): [4] [7] [10] [11] [13] [14]
* File size distribution: this is also related to whether to model each file as IP packet or frame.
  + Fixed: [4] [5] [11]
  + Random: [4] [6] [7] [9] [10] [13] [16]
    - Ex : truncated Gaussian, Pareto, etc
* Multiple data streams to model e.g., video, audio, etc.
  + [9] [10]
* Views to take into account SA4 outcome in traffic model discussion given that SA4 is working on traffic model
  + [1][12][16][18]

UL Traffic Model

Table 3 captures the views on UL traffic model from different sources. Some of views commented with DL are already captured in Table 2 are not captured here.

Table 3 Views on UL Traffic Model

|  |  |
| --- | --- |
| Source | View |
| [5] | Proposal 4: The following 2 categorizations of XR representative services for UL services as the starting point.   * , 300, fixed periodicity, fixed packet size * 2.7-50Mbps,, [5-30] fixed periodicity and fixed packet size/statistical model for fluctuating traffic * FFS periodicity values and the modeling of variant inter arrival rate * FFS statistical model for fluctuating traffic, target to down-select in RAN1#103-e between Gaussian distribution and Pareto distribution |

**Summary**

Companies have provided views on UL traffic model in following aspects.

* UL file inter arrival
  + Periodic: [5] [15] [11] [10]
  + Random: [11] [10]
* UL file size
  + Fixed: [5] [10] [6] [11]
  + Random: [5] [10]
* Multiple streams: [9] [10]
* Views to take into account SA4 outcome in traffic model discussion given that SA4 is working on traffic model
  + [1][12][16][18]

**FL Proposal 2**: Traffic model for DL and UL should reflect various bit rates, variable frame/slice/file/packet size, and periodicity with jitter, where statistical model is preferred. Conclusion on detailed traffic model is deferred to the next RAN1 meeting (RAN1 104-e) where SA4 outcome on traffic model is expected to be available.

**Question 2**. Please share your comments on Proposal 2 if any.

|  |  |
| --- | --- |
| Company | View |
| QC | Decisions on traffic model should be made after SA4 provides its outcome to RAN1. |
| MTK | We can accept to defer the conclusion on detailed traffic model to the next RAN1 meeting (RAN1 104-e) where SA4 outcome on traffic model is expected to be available. |
| ZTE, Sanechips | It would be better to clarify that it's not mandatory to consider the variable frame frame/slice/file/packet size or periodicity with jitter for all the applications of interest as confirmed in Q1 given at least for VR case, it seems jitter-free periodic traffic with fixed packet size for both UL/DL is sufficient per SA4 TR26.928. Alternatively, we are also fine to initiate the traffic model related discussion in RAN1#104-e  A modified proposal would be,  Traffic model for DL and UL ***for certain application(s) of interest*** should reflect various bit rates, variable frame/slice/file/packet size, and periodicity with jitter, where statistical model is preferred. Conclusion on detailed traffic model is deferred to the next RAN1 meeting (RAN1 104-e) where SA4 outcome on traffic model is expected to be available. |
| Nokia, NSB | We agree that the RAN1 study conclusions should be in line with the SA4 outcome. At the same time, we believe it is important to start discussing (at least discussing, not mandatory concluding) this topic straightaway, as it holds many other important discussions. We can at least start collecting the companies’ view on how many traffic models do we need in RAN1 (e.g., 5 as the use cases, less models, where one model is representative to several use cases, more than one model per use case), etc.  Note that reference [11] was missing from UL traffic size inputs (added with highlight) |
|  |  |

# Evaluation of UE Power Consumption for XR

Evaluation Methodology for UE power consumption for XR

Companies’ view on evaluation of UE power consumption for XR is collected in Table 4.

Table 4 Companies’ Views on evaluation of UE power consumption for XR

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| --- | --- |
| Source | View |
| [3] | Both the power saving gain and the capacity performance loss need to be considered.  For power consumption evaluation, both the power saving gain and the capacity performance loss need to be considered.  During the evaluation, power consumptions for different cases can be collected for subsequent comparisons as depicted in Figure 3, including:   * Case 1: No power saving mechanism is introduced. It is the performance baseline to show the consumed power and corresponding capacity performance. * Case 2: The DRX mechanism for connected mode in NR is introduced which can be a starting point. Each UE may be configured with different DRX offset   For XR power consumption evaluation,   * Power consumption performance is evaluated by using power consumption model in TR 38.840. * Capacity performance is evaluated by considering different DRX configurations.   + Details of DRX configuration are reported by companies |
| [4] | For XR service evaluation, the power consumption evaluation methodology and metric in TR38.840 could be reused. |
| [6] | Besides, the trade-off between power consumption and other performance should be considered, e.g. 60fps with lower power consumption or up to 90fps performance boost with higher power consumption, can be chosen in the game settings.  The power consumption model in TR 38.840 can be reused to evaluate the power consumption performance of XR and Cloud Gaming |
| [7] | Rel-16/17 UE power savings mechanisms and potential enhancements are considered subject to minimal/no additional scheduling latency and minimal/no increase in PDCCH blocking probability.  The power consumption models developed in TR 38.840 and Rel-16 and Rel-17 mechanisms for power savings can be a starting point subject to considerations for minimal/no additional scheduling latency and minimal/no increase in PDCCH blocking probability. |
| [13] | Coverage evaluation should be done in the agenda of R17 coverage enhancement considering that coverage is a trade-off with capacity.  Reuse the evaluation assumption agreed in R17 power saving as baseline with necessary modifications   * R1-2007419: LS on evaluation for connected mode UE power saving |
| [15] | The power consumption model and performance metrics in TR 38.840 can be reused for the evaluation of power consumption. |
| [16] | Evaluations for existing connected mode UE power savings techniques so far have shown that achieving power savings generally comes with a throughput/latency trade-off.  Baseline XR performance should be evaluated assuming that the UE is always available for scheduling (i.e., DRX or other power saving techniques are not considered) and any studies on power savings techniques should consider latency/throughput impact compared to the baseline. |
| [17] | The followings can be considered for KPIs for XR evaluations:   * Capacity: TR38.824 can be baseline for both URLLC independent case and eMBB/URLLC coexistence case * Mobility: up to 300 km/h or 500 km/h should be taken into account * Power: TR38.840 can be starting point * Coverage: Rel-17 coverage enhancement study can be starting point |
| [18] | Power and capacity has trade-off relation.  RAN1 performs system level simulation method for power evaluation, especially to accurately evaluate the capacity-power tradeoff.  In case power saving gain of power saving techniques is quantified, the gain is evaluated, compared, and captured subject to a given capacity constraint.  The grey point is the baseline scheme w/o power saving scheme: UE in always ON state (i.e., no DRX enabled).  For XR power evaluation, RAN1 consider various power saving schemes including R15/R16/R17 power saving techniques and various assumptions having high impact on UE power consumption. |

**System level evaluation**

It is discussed in [18] that UE power consumption for XR in reality is affected by various aspects including UE geometry, link adaptation, user selection by gNB scheduler in case of multi-UEs in the network, parameter configuration of applied power saving techniques (e.g., CDRX parameters), etc. It is therefore proposed in [18] that system level simulations should be conducted to accurately evaluate effect of those aspects since link level simulations have limitations to capture those aspects in evaluation for UE power consumption.

**Question 3.** Please share your view on whether system level simulation should be the baseline for evaluation of UE power consumption for XR.

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| --- | --- |
| Company | View |
| QC | We support the system level simulation study for power evaluation. The operations of dynamic power saving schemes highly depend on PS (power saving) control signal reception (via DCI), and DRX timer values (determining Active Time/non Active Time), and/or scheduling decision across multiple UEs. Thus, we think that system level study should be used to accurately capture the impact of these aspects on UE power consumption. |
| MTK | We support to use system level simulator, while RAN1 should choose a reasonable amount of parameter combinations to avoid a too large simulation effort. |
| ZTE, Sanechips | As expressed in our response to the email thread under 8.14 TR skeleton, it would be good to have a discussion on prioritization among the potential evaluations related to XR given the TU allocated and the work load. We believe power saving related evaluations could be deferred a bit (e.g., to 2021 Q2) compared to capacity and coverage. |
| Nokia, NSB | We should first establish whether we will engage in power consumption evaluation in the first place. It is premature to have this level of detail at this stage. The questionnaire already assumes, not just that a power consumption evaluation is to be made but also has a very specific split of work built into it. What we need to discuss is whether we do power evaluation, and then what is the appropriate level of work. It is also important to avoid work duplication over what is done in the power saving enhancements WID.  Notably power consumption evaluation is not part of the SID objectives and we should first start by agreeing if UE power consumption is a relevant KPI to measure the performance.  *3. Identify evaluation methodology to assess XR and CG performance along with identification of KPIs of interest for relevant deployment scenarios* |
|  |  |

**Baseline UE power consumption: UE power consumption w/ no power saving scheme**

Multiple companies emphasize the importance of evaluation of UE power consumption for XR, including evaluation of power saving gain from various power saving techniques that have been developed since Rel-15. The power saving gain can be evaluated compared to a baseline UE consumption result. Multiple companies propose to define the baseline UE power consumption to be the power consumption for the case when the UE is always available for scheduling, i.e., the UE never goes into a sleep state (in others words, no power saving technique is applied).

**Question 4.** Please share your view on the above definition of baseline UE power consumption to be used for evaluation of the gain of a UE power saving technique.

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| --- | --- |
| Company | View |
| QC | The baseline power consumption scheme is always ON scheme (w/o any power saving scheme, e.g., no CDRX, no BWP switching, no WUS, etc). The power saving gain of other power saving schemes can be compared w.r.t this baseline. This will allow the comparison of different schemes with the same reference point. |
| MTK | Considering the power-capacity trade-off, we can accept to use the FL proposed baseline for first wave evaluation. If RAN1 found that some existing power saving techniques introduce negligible capacity loss, a new baseline can be applied. |
| ZTE, Sanechips | We agree that no power saving scheme should be considered as the baseline. The impact of power saving schemes on the KPIs, such as capacity, coverage, mobility, should be evaluated. |
| Nokia, NSB | Should the UE power consumption be agreed as a relevant XR performance KPI, there is no reason to exclude DRX or other power saving techniques specified in Rel-15 – Rel-17 if they are applicable with a given traffic model. It is, however, premature to discuss how to evaluate the baseline before we have agreed to do the work at all. If the answer is yes, then at that point we should look at what power saving tools Rel-15 – Rel-17 that are applicable with the traffic models applicable for XR services. |
|  |  |

**Upper bound of UE power saving gain: Genie UE power consumption**

As another useful reference for evaluation of UE power consumption for XR, “Genie” UE power consumption is proposed in [18], defined as UE power consumption for the case when the UE is assumed to enter a sleep state in all the slots with neither DL reception nor UL transmission. Which sleep state (micro, light, or deep) the UE can enter is determined based on the duration of consecutive slots with no DL reception and no UL transmission. The Genie result can serve as the upper bound of the power saving gain of a power saving technique, which may potentially motivate development of new power saving techniques that can approach the Genie performance.

**Question 5.** Please share your comment if any on evaluation of the “Genie” UE power consumption as a benchmark.

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| --- | --- |
| Company | View |
| QC | We support the evaluation of Genie scheme in XR power evaluation. Identifying gap between any considered scheme and upper bound could be an important outcome of XR power study in the sense that it can identify potential issues and solutions. |
| MTK | We can accept to include the evaluation of the “Genie” UE power consumption as a benchmark. However, it should be noted that the upper bound can not address the power saving schemes that applied BW scaling, MIMO layer adaptation, or UL/DL transmission timing relaxation. |
| ZTE, Sanechips | We think the “Genie” UE power saving consumption can be informative but not mandated. |
| Nokia, NSB | Premature to discuss, no agreement even on whether the UE power consumption is a KPI of interest for assessing the XR and CG performance |
|  |  |

**Evaluation of UE power saving gain of power saving schemes**

It is highly beneficial to study the power saving gain of various power saving schemes, e.g.,

* Rel-15/16/17 UE power saving techniques, e.g., CDRX, BWP switching, cross-slot scheduling, etc.
* Potential future enhancements (e.g., CDRX enhancements if needed, etc.).

In addition, it will be useful to explicitly study and better understand the impact of certain critical features/configurations on UE power consumption, e.g.,

* **DL rx and UL tx alignment**: In case DL and UL transmissions to/from a UE are consecutive, UE can stay longer in a deeper sleep state. It will be useful to see the power performance difference between DL/UL alignment vs. misalignment.
* **Impact of jitter in UE power consumption**: Effect of certain power saving techniques, e.g., CDRX can be substantially reduced by jitter (as packet arrival times at gNB vary over time which are not aligned with the beginning of the configured CDRX on duration). Although jitter may be part of traffic model, it would be highly beneficial to explicitly evaluate UE power consumption with and without jitter. The study outcome may potentially motivate development of a new power saving technique that is more effective with jitter.

**Question 6**. Please share your view on which power saving techniques among various candidates discussed above are to be evaluated with high priority in terms of power saving gain over the baseline discussed above.

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| --- | --- |
| Company | View |
| QC | It is very important to evaluate existing power saving schemes to understand power consumption aspect in XR support. However, due to the limited time, it would not be doable to evaluate all the combinations of the power saving schemes defined in R15/R16 as well as potentially in R17. To reduce workload without missing any potentially important study results, RAN1 should focus on PS schemes which have the highest impact on UE power consumption. We think at least following scheme should be evaluated in this SI.   * CDRX   In addition to the specific PS schemes, we could also consider evaluation of configurations/assumptions with high impact on power consumption. We agree that UL/DL alignment can reduce power consumption by reducing UE’s wake up and extend potential sleep duration. Jitter is another critical aspect to study especially when DRX is used. With jitter, the expected delay for packet transmission can increase which potentially have negative impact on power and capacity as well. |
| MTK | Since RAN1 has developed various power saving schemes in R15/R16/R17(on-going) power saving agenda, to avoid duplicated effort in RAN1 discussion, we prefer to first evaluate existing power schemes in R15/R16 power saving agenda, ex., “CDRX, BWP switching, cross-slot scheduling, SCell dormancy”, to observe the capacity-power trade-off for existing schemes. After this, if it is observed that a significant power saving gain gap exists, new power saving schemes in R17 power saving agenda or other new schemes can be evaluated. |
| ZTE, Sanechips | To have a better understanding of the impact and potential problems of the legacy power saving solutions, we think the schemes including C-DRX, BWP switch, and cross-slot scheduling specified in Rel-15/16, and Rel-17 candidate enhancements (e.g., dynamic PDCCH reduction) needs to be evaluated. |
| Nokia, NSB | Premature to discuss, no agreement even on whether the UE power consumption is a KPI of interest for assessing the XR and CG performance. Notably this SI is not a study of what power saving gains the already specified power saving features offer over no power saving features applied. These components should end up as part of the baseline if such evaluation is decided to be needed. |
|  |  |

**Power saving gain taking into account capacity-power tradeoff**

As captured in Table 4, multiple companies have observed and pointed out that there exist tradeoff relations among different performance aspects: capacity, power, coverage. For example, [3][6][16][18] have observed the tradeoff between capacity and power. [13] has observed the tradeoff between coverage and capacity. One good example is tradeoff between power saving gain and capacity. In network/UE operation, applying a power saving scheme may result in delayed packet scheduling (as the UE is supposed to be in a sleep state for a certain duration depending the applied power saving scheme), which can increase the chance of violating packet delay budget and consequently lead to lower capacity.

Understanding the tradeoff of the evaluated power saving technique is important, e.g., for fair comparison of schemes/assumptions since one scheme may have higher hit on one performance metric than other schemes (e.g., scheme A={CDRX with cycle=50ms} has higher power saving gain than scheme B={CDRX with cycle=5ms}, but A would have lower capacity than B). Thus, when the gain of a power saving technique is evaluated, the capacity loss compared to the baseline scheme (i.e., no power saving scheme) needs to be evaluated together.

**FL proposal**: The UE power saving gain of a power saving technique is defined to be the reduction (%) in UE power consumption compared to the baseline UE power consumption (i.e., UE power consumption with no power saving scheme), subject to at most Y% (e.g., Y=5) system capacity reduction induced by the applied power saving technique. When the power saving gain of a power saving technique is submitted, the following should be reported together: (i) the amount of capacity loss caused by the evaluated power saving technique and (ii) how far is from the “Genie” UE power consumption (i.e., additional power consumption in % compared to the Genie power consumption).

**Question 7**. Please share your view on the above proposal and appropriate Y value.

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| --- | --- |
| Company | View |
| QC | Putting a constraint on capacity loss in power number evaluation/comparison is required to make it as a fair evaluation/comparison across different power saving schemes. We think Y=5 would be a reasonable value. |
| MTK | We think the FL proposal is reasonable and Y=5 or 10 can be considered. We also think one value for Y is enough. |
| ZTE, Sanechips | The user experience is strongly relevant to the system capacity, we think Y=2.5% is reasonable. |
| Nokia, NSB | Premature to discuss, no agreement even on whether the UE power consumption is a KPI of interest for assessing the XR and CG performance. |
|  |  |

Other Evaluation Assumptions

Following sources captured in Table 5 have provided their views.

Table 5 Views on Evaluation Methodology on Power

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| --- | --- |
| Source | View |
| [3] | **Proposal 19**: For XR power consumption evaluation,  • power consumption performance is evaluated by using power consumption model in TR 38.840.  • capacity performance is evaluated by considering different DRX configurations.  - details of DRX configuration are reported by companies. |
| [4] | **Proposal 5**: For XR service evaluation, the power consumption evaluation methodology and metric in TR38.840 could be reused. . |
| [6] | **Proposal 2**: The power consumption model in TR 38.840 can be reused to evaluate the power consumption performance of XR and Cloud Gaming. |
| [7] | The power consumption models developed in TR 38.840 [4] and Rel-16 and Rel-17 mechanisms for power savings can be a starting point subject to considerations for minimal/no additional scheduling latency and minimal/no increase in PDCCH blocking probability. |
| [13] | **Proposal 9**: Reuse the evaluation assumption agreed in R17 power saving as baseline with necessary modifications   * R1-2007419: LS on evaluation for connected mode UE power saving |
| [15] | Power consumption  The power consumption model and performance metrics in TR 38.840 can be reused for the evaluation of power consumption. |
| [17] | Proposal 4:   * The followings can be considered for KPIs for XR evaluations: * Capacity: TR38.824 can be baseline for both URLLC independent case and eMBB/URLLC coexistence case * Mobility: up to 300 km/h or 500 km/h should be taken into account * Power: TR38.840 can be starting point * Coverage: Rel-17 coverage enhancement study can be starting point |

Given that R16 UE PS SI provides a good starting point power evaluation methodology, many companies have suggested it as a starting point. There was also a view [17] that R17 UE PS evaluation method should be the baseline with necessary modification.

**FL Proposal**. For XR UE power evaluation, use TR38.840 as baseline power evaluation methodology with necessary modifications if necessary.

**Question 8**. Please share your comments on the above proposal if any.

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| --- | --- |
| Company | View |
| QC | Agree to use 38.840 as the baseline power evaluation methodology. We think it need further enhancement in UL power modeling to better capture increased power contribution from UL activities of XR devices. Our view on such enhancements is presented below by answering relevant questions. |
| MTK | We think R17 UE PS evaluation method should be the baseline with necessary modification. However, we can accept to use 38.840 since it also includes various R16 power saving techniques for evaluation. |
| ZTE, Sanechips | We agree to take TR38.840 as the baseline. And further enhancements (see our reply to Q9, Q10, Q11, and Q14) are also needed. |
| Nokia, NSB | Premature to discuss, no agreement even on whether the UE power consumption is a KPI of interest for assessing the XR and CG performance. |
|  |  |

**Linear Interpolation based UL Power Consumption Estimate for different Tx Power**

In some XR applications, UL data transmissions may include pose/control/scene upload. Their data rates range from e.g., 1Mbps ~ 10Mbps with short interval (2ms ~ 100ms) between two consecutive transmissions. This makes UL power consumption contribution to total power consumption increase significantly. Thus, it is critical to evaluate UE power consumption from UL transmissions. The power model defined in TR 38.840 is available only for two values of UE tx power: 0dBm and 23dBm, not available for other power levels. Thus, in order to effectively capture different tx power contributions from UEs with different tx power in various locations in the cell (also depending on various interference levels), UE power consumption model for power levels other than 0dBm and 23dBm is needed. For instance, linear interpolation model (that is already used in TR 38.840 to estimate the power consumption for different number of blind decoding) is proposed in [18].

**Question 9**. Please share your view on how to model UE power consumption for UE tx power other than 0dBm and 23dBm.

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| --- | --- |
| Company | View |
| QC | We think it is quite reasonable to use linear interpolation technique to estimate intermediate power consumption values for tx power other than 0dBm and 23dBm. Based on our study, the linear interpolation in linear power domain could provide quite a good estimate which is close to actual measurements. This is because the scaled power is mostly due to power consumed at power amplifier (PA) and its power consumption scaling w.r.t output tx power is close to linear in the regime of interest.  This should be applied to not only the UL slots in 38.840 but also other potential UL slots to be added if necessary. |
| MTK | We are open to model UE power consumption for UE tx power other than 0dBm and 23dBm. The exact method may need to be further discussed and aligned to provide consistent assumptions between companies. |
| ZTE, Sanechips | We think the UE power consumption model for other UE transmission power are necessary. The following issues need discussion/clarification towards linear interpolation,  1)PA output seems to be linear in real domain thus there could be need for a conversion from log domain to real domain  2) We are not quite sure whether linear alone would be sufficient for the whole range of interest including that larger than 23dBm  Furthermore, the UL transmission power for FR2 in38.840 (copied as below) is unclear and should be decided before the discussion of scaling rule for FR2 transmission power adaptation.   |  |  |  |  | | --- | --- | --- | --- | | Power State | Characteristics | Relative Power | | | FR1 | FR2 | | UL | Long PUCCH or PUSCH. | 250 (0 dBm)  700 (23 dBm) | 350  (FFS Tx power level) | |
| Nokia, NSB | Premature to discuss, no agreement even on whether the UE power consumption is a KPI of interest for assessing the XR and CG performance. |
|  |  |

**Additional UL Slots for Power Evaluation**

The UL power model in 38.840 needs to be further improved for UL power evaluation of XR applications. The power model in TR 38.840 has power state for UL (or PUSCH or long-PUCCH) or short-PUCCH (or SRS). However, these two states are not enough to capture different power consumption values generated from various UL activities such as pose/control, scene upload, ACK/NACK for PDSCH, SR, CSI, or SRS especially across different UEs in system level study. In system level study, since multiple UEs’ UL transmissions can be multiplexed in the same slot, additional UL slot modelling is required. For example, in a UL slot with PUSCH+PUCCH+SRS, two UEs could be scheduled: PUSCH for the first UE, and PUCCH+SRS for the second UE. Since the power model in TR 38.840 does not have power state for e.g., PUSCH + gap, or gap+PUCCH+SRS, etc, the current model needs to be improved to capture more diverse slots to more accurately evaluate power consumptions in such cases.

**Question 10**. Please provide your view on additional UL slot power modeling discussed above.

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| --- | --- |
| Company | View |
| QC | The R16 UE PS study was mostly focused on DL side, and UL modelling got less attention than DL. In order to better study UE power consumption for XR, additional UL power modelling is required.  We think a new slot of PUSCH(12)+PUCCH(1)+SRS(1) can be considered which supports multi-UE simulation in system level to support PUSCH, PUCCH, and SRS in the same slot. Note that the number inside parenthesis is the # of OFDM symbols for the corresponding channel/signal. Depending on the UL activity of UEs, there are various UL transmissions in a UL slot, e.g., PUSCH only, PUCCH and SRS, etc.  The derivatives of the slot (which are generated depending on UE’s activity) are captured in the following table. The basic power numbers for 0dBm and 23dBm are based on existing UL slots in TR 38.840.  The baseline slots #1 and #5 are based on TR 38.840. Other slots #2~#4 are estimated based on linear interpolation based on # of active UL symbols considered in each case.   |  |  |  |  | | --- | --- | --- | --- | | # | Power state | Power number | Note | | 1 | PUSCH(12)+PUCCH(1)+SRS(1) | [250] (0dBm)  [700] (23dBm) | Same as UL power state | | 2 | PUSCH(12) + PUCCH(1) + Gap(1)  PUSCH(12) + Gap(1) + SRS(1) | [235] (0dBm)  [660] (23dBm) | Applied linear interpolation method to get power number for 13 UL symbols case with two end points A and B where A=power number for PUSCH(14) slot, B= power number short-PUCCH(1) | | 3 | PUSCH(12) + Gap(2) | [225] (0dBm)  [625] (23dBm) | Applied linear interpolation method to get power number for 12 UL symbols case with two end points A and B where A=power number for PUSCH(14) slot, B= power number short-PUCCH(1) | | 4 | MS(12) + PUCCH(1) + SRS(1) | [90] (0dBm)  [248] (23dBm) | Applied linear interpolation method to get power number for 2 UL symbols case with two end points A and B where A=power number for PUSCH(14) slot, B= power number short-PUCCH(1) .  Assumed that PUCCH and SRS power are the same. | | 5 | MS(13) + SRS(1) | [75] (0dBm)  [210] (23dBm) | As defined in 38.840, same as short-PUCCH | |  | \* PUSCH(X): X symbols of PUSCH  \* PUCCH(Y): Y symbols of PUCCH  \* SRS(Z): Z symbols of SRS  \* MS(N): N symbols of Micro Sleep  \* Gap(M): M symbols of gap  \* This is the case for UE’s number of Tx antenna = 1 | | | |
| MTK | We do not really feel the necessity of introducing additional UL slot power modelling since the power value of #1, #2, #3 and #4, #5 are actually close in QC’s suggested table. (#1 is close to #2, #3, and #4 is close to #5) |
| ZTE, Sanechips | We also observe that the UL states in TR38.840 are limited to PUSCH, Long PUCCH, short PUCCH and SRS. We agree to consider more UL power states to precisely simulate the UL UE behavior. And the combinations of UL transmission could be further discussed. |
| Nokia, NSB | Premature to discuss, no agreement even on whether the UE power consumption is a KPI of interest for assessing the XR and CG performance. |
|  |  |

**Special (S) Slot Power Consumption**

The power model in TR 38.840 for special(S) slots is available only for one specific configuration, “PDCCH+PDSCH+PUCCH” assumed to have the same power number as PDCCH+PDSCH state, which may hold only for 0dBm case. The reasoning based on this approximation is that PUCCH tx power at 0dBm is not significantly different from power consumption required for DL reception. For other tx power level, e.g., 23dBm tx power, this reasoning may not hold any more. Once S slot’s 23dBm power number is available, then power number for other tx power levels may be estimated by linear interpolation between power number for 0dBm and power number for 23dBm.

**Question 11**. Please share your view on power consumption model for S slot for XR power evaluation.

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| --- | --- |
| Company | View |
| QC | The modelling of S slot is useful in case the TDD frame structure to be evaluated includes S slot. The first step is to define power number for 0dBm and 23dBm.  PDCCH+PDSCH+PUCCH+SRS = [300] for 0dBm  PDCCH+PDSCH+PUCCH+SRS = [450] for 23dBm  Power for 0dBm case is based on PDCCH+PDSCH. Power for 23dBm is based on estimation and PA power measurement data points.  Power consumption for different tx power could be computed based on linear interpolation in linear power domain. |
| MTK | We are open to discuss S slot’s 23dBm power number. At the same time, we are curious how to model the SRS periodicity since this depends on NW implementation. |
| ZTE, Sanechips | To reduce the transmission delay, the special slot can be considered in the simulation to enable UE to feedback the HAQR-ACK/pose/position,etc. as soon as possible. We think it is necessary to discuss the power consumption of the special slot. And the combinations of different number of DL and UL symbols should be further discussed. We also agree the power consumption of special slot with different UL transmission power is needed. |
| Nokia, NSB | Premature to discuss, no agreement even on whether the UE power consumption is a KPI of interest for assessing the XR and CG performance. |
|  |  |

# Evaluation Methodology for Coverage

Table 8 captures the views from different sources on evaluation methodology for coverage evaluation.

Table 8 Views on Evaluation Methodology for Coverage

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| --- | --- |
| Source | View |
| [2] | Proposal 6: The CDF of XQI is used to evaluate the coverage performance of the network. |
| [3] | Proposal 15: For XR coverage evaluation, link budget can be adopted as the evaluation methodology, and max isotropic loss (MIL) can be used as the performance metrics. |
| [5] | Proposal 5: Consider the capacity metric and coverage enhancement metric in XR evaluation.  - Capacity metric should include both the number/percentage of UEs satisfying the PDB/PER/Rate requirement and the statistical metrics regarding the CDF of UPT.  - Coverage metric should use the service based metric i.e. calculate MPL and compare it with the ISD. For the link level simulations used to generate the MPL, the following discussion points should be settled.   * For DL, the number of PRBs should be generated by considering the full bandwidth dedicated. TBS should be determined by an agreed MCS. * For UL, the PRBs/TBS/MCS should be set in accordance with the UL traffic. * Target BLER should be set in accordance with the traffic, e.g. or . |
| [6] | Proposal 3: The capacity and coverage can be evaluated by the number of UEs and X% UEs that meet the requirement. |

To better manage RAN1 workload for XR evaluations for NR, it is proposed by the rapporteur in [19] to defer detailed discussion on evaluation methodology for XR mobility to 2021 Q2. The delayed start will also benefit from stable evaluation methodology and assumptions available for capacity and power evaluations.

**Question 12**. Please share your view on delay of discussion on evaluation methodology for XR mobility to 2021 Q2. Also please feel free to comment on any other aspects w.r.t. XR mobility evaluation.

|  |  |
| --- | --- |
| Company | View |
| QC | Defer mobility discussion to 2021 Q2. |
| MTK | Defer mobility discussion to 2021 Q1 or Q2 seems fine. |
| ZTE, Sanechips | There seems to be a typo in the question. We think coverage related discussion should be prioritized and we prefer to re-use the coverage related metrics/methodologies in the NR coverage enhancement study item such as MPL and ISD comparison. This is of interest of XR services given a large number of companies expressed interest towards scenarios such as Umi and Uma. Considering the high data rate requirement of typical XR services, coverage aspect is quite challenging and vital for the smooth delivery. |
| Nokia, NSB | Should the question be about coverage as the text above seems to belong to section 5 on mobility?  **Mobility evaluation** need and methodology discussion can be deferred to a later meeting.  **Coverage evaluation** may not necessitate its own evaluation, as the capacity evaluation can produce a percentage of the users served in a given deployment scenario that is indicative of the service coverage. Anyway, we can defer discussion on whether a specific coverage evaluation is needed to a later meeting (after we have established the capacity evaluation methodology)  Notably neither mobility nor coverage are mentioned in the SID objectives and we should first start by agreeing if one of the two or both quality as a relevant KPI to measure the XR and CG performance.  *3. Identify evaluation methodology to assess XR and CG performance along with identification of KPIs of interest for relevant deployment scenarios* |
|  |  |

# Evaluation Methodology for Mobility

Table 9 shows the captured views from different sources on evaluation methodology on mobility evaluation.

Table 9 Views on Evaluation Methodology for Mobility

|  |  |
| --- | --- |
| Source | View |
| [3] | Proposal 16: For XR mobility evaluation, performance metrics should be identified considering impacts on XR performance due to mobility, such as interruption delay, handover failure rate and cell-edge transmission performance. |
| [6] | Proposal 4: Different UE speeds for VR, AR and Cloud Gaming users can be assumed when evaluate the mobility. |

To better manage RAN1 workload for XR evaluations for NR, it is proposed by the rapporteur in [19] to defer detailed discussion on evaluation methodology for XR coverage to 2021 Q1. The delayed start will also benefit from stable evaluation methodology and assumptions available for capacity and power evaluations as well as available outcome of Rel-17 coverage enhancement study.

**Question 13**. Please share your view on delay of discussion on evaluation methodology for XR coverage to 2021 Q1. Also please feel free to comment on any other aspects w.r.t. XR coverage evaluation.

|  |  |
| --- | --- |
| Company | View |
| QC | Defer coverage discussion to 2021 Q1. |
| MTK | Since there are related discussion of coverage enhancement in R17 RedCap UE and R17 coverage enhancement, we think coverage can be further deferred after the discussion of mobility. |
| ZTE, Sanechips | There seems to be a typo in the question. We think mobility related discussion should be prioritized and we prefer to initiate the study by considering different UE speeds in the system level simulation. The capacity metrics could be re-used to reflect the impact in terms of mobility. |
| Nokia, NSB | Should the question be about mobility as the text above seems to belong to section 4 on coverage?  **Mobility evaluation** need and methodology discussion can be deferred to a later meeting.  **Coverage evaluation** may not necessitate its own evaluation, as the capacity evaluation can produce a percentage of the users served in a given deployment scenario that is indicative of the service coverage. Anyway, we can defer discussion on whether a specific coverage evaluation is needed to a later meeting (after we have established the capacity evaluation methodology)  Notably neither mobility nor coverage are mentioned in the SID objectives and we should first start by agreeing if one of the two or both quality as a relevant KPI to measure the XR and CG performance.  *3. Identify evaluation methodology to assess XR and CG performance along with identification of KPIs of interest for relevant deployment scenarios* |
|  |  |

**Question 14**. Please feel free to comment on any other aspects w.r.t. XR evaluations for NR that are not addressed above.

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| --- | --- |
| Company | View |
| MTK | There could be intensive simulation effort for XR agenda due to the various user number, performance requirement, and system aspects. RAN1 should strive to limit the simulation efforts to a reasonable level. |
| ZTE, Sanechips | In addition to the power consumption methodology discussed in section 3, the following aspects should also be considered.   1. For FR2, the system bandwidth is 100MHz for both DL and UL in 38.840, while in the XR simulation, the bandwidth for FR2 is assumed to be 400MHz. Since there is no scaling rule for FR2 BWP adaptation, we need to discuss it as well. 2. The number of transmission antenna is 1 in 38.840, while in XR simulation assumption, the Tx configuration is 2Tx or 4Tx. The scaling factor for Tx adaptation in TR38.840 is not sufficient and should be discussed.  |  | | --- | | Reference Configuration for FR1(in 38.840):  Uplink: TDD  - Tx antenna configuration: 1TX,  - Power levels: 0dBm and 23dBm  Reference **configuration** for FR2 (in 38.840):  Downlink: TDD, FR2  -....  - System Bandwidth: 100 MHz  ....  - Uplink: TDD, FR2  - ....  - Number of carrier = 1CC  - System Bandwidth = 100MHz  - Tx antenna configuration: 1TX chain | |
|  |  |
|  |  |

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