3GPP TSG-RAN WG1 Meeting #104-e R1-21xxxxx

e-Meeting, April 12th – 20th, 2021

Source: Moderator (Qualcomm)

Title: Email discussion on Initial Evaluation Results for XR over NR

Agenda Item: 8.14.1

Document for: Information

# Introduction

This contribution is a summary on the email discussion on agenda item 8.14.3. Initial Performance Evaluation Results.

[104b-e-NR-XR-03] Email discussion/approval on initial performance evaluation results with checkpoints for agreements on Apr-15, Apr-20 – Eddy (Qualcomm)

Please note that this document is not for approval but for information as there are still some open issues for traffic models and evaluation methodology, and the initial evaluation results from companies that have been submitted to RAN1#104bis-e may not be consistent with final RAN1 agreements on traffic models and evaluation methodologies.

# Observations from Initial Evaluation Results

## Capacity: DL

**Baseline results**

Table 1 captures initial evaluation results from companies. Please note that the numbers in the table from different companies are under different assumptions, e.g., SU-MIMO vs. MU-MIMO, TDD configuration, gNB/UE antenna configuration, etc.

Table 1. Initial results: AR/VR/CG capacity in DL (#UEs/Cell)

|  |  |  |  |
| --- | --- | --- | --- |
| Scenarios | Dense Urban | Urban Macro | Indoor Hotspot |
| **FR1** | | | |
| CG, 8Mbps, 15ms PDB | 9 ~ 54 | 7 ~ 46 | 9 ~ 38 |
| CG, 30Mbps, 15ms PDB | 7.4 ~ 24 | 6.8 ~ 16 | 2~13 |
| AR/VR, 30Mbps, 10ms PDB | 5.7 ~ 12 | 4.9 ~ 8.4 | 2~10 |
| AR/VR, 45Mbps, 10ms PDB | 2.3 ~ 9 | 1.5 ~ 6 | 4~7 |
| **FR2** | | | |
| CG, 8Mbps, 15ms PDB | 27 | N/A | 17 ~ 32 |
| CG, 30Mbps, 15ms PDB | 6~20 | N/A | 4~10 |
| AR/VR, 30Mbps, 10ms PDB | 6 | N/A | 3 ~ 5 |
| AR/VR, 45Mbps, 10ms PDB | 3-9 | N/A | 2~5 |

Observations from initial evaluation results from companies on DL capacity for XR/CG are summarized as follows (please note that some observations are only from a limited number of companies).

* XR/CG capacity for Dense Urban is generally larger than that for Indoor Hotspot.
* XR/CG capacity for Indoor Hotspot is generally larger than that for Macro Urban.
* XR/CG capacity is increasing with increasing air interface PDB.
* XR/CG capacity is increasing with decreasing application bit rates.
* XR/CG capacity is increasing with decreasing packet success rate requirement.
* DL capacity for AR/VR is poorer than that for CG due to larger data rates and more stringent latency requirement.
* XR/CG capacity can be substantially increased by MU-MIMO compared to SU-MIMO, especially for high rate applications, e.g., equal to or larger than 30Mbps.

**Potential enhancements and proposals**

Some companies observed XR/CG capacity improvements over baseline via different schemes. The observations are summarized as follows (please note that some observations are only from a limited number of companies).

* XR/CG capacity can be improved by delay-aware scheduling.
* XR/CG capacity in a multi-stream model can be improved by prioritizing the transmission of the more important stream, e.g., I-frame against P-frame.
* Appropriate staggering across UEs in terms of packet arrival time within one cell can increase XR/CG capacity.
* Inter-cell interference coordination among different gNBs can increase XR/CG capacity.
* Reducing the tail of the distribution of the HARQ retransmission may be beneficial to improve performance.
* CA can provide capacity gain and the system capacity with CA is the larger than the sum of the capacity of its component carriers.
* Capture in the TR results for TDD with and without Cooperative MIMO via DL interference probing based on SRS enhancements to improve XR system capacity.
* Study enhancements to MU-MIMO with a large number of antennas in order to increase the system capacity of XR.

### Additional results

Apple [15] evaluated 3 traffic models for DL:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Video stream | Audio/data stream | Note |
| Model 1 | Yes | Yes | Packets with the video stream and packet with the audio/data stream arrive independently, and they can be transmitted independently. |
| Model 2 | Yes | Yes | Packets with the video stream and packet with the audio/data stream arrive independently, and any packet with the data/audio stream is transmitted always with a packet with the video stream |
| Model 3 | Yes | No | Only the video stream is modelled. |

For both Model 1 and Model 2, there are two data flows with DL:

Video stream and audio/data stream. With Model 1, those two flows are modelled separately, and a packet with the audio/data stream can be scheduled right at its arrival at the gNB. With Model 1, even though there are 2 separate data flows, the transmission of a packet with the audio/data stream always piggybacks on the transmission of a packet of the video stream. By comparing the simulation results, we would like to see whether merging the audio/data stream and the video stream is feasible or not for DL traffic modeling.



**Observation: modeling of the data/audio stream reveals complex interaction between different flows.**

**Question 1. Please share your comment on the above observations, if any, from initial evaluation results for DL capacity for AR/VR/CG.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| MTK | We think the observations are good and contain some useful information. |
| ZTE | We are OK with the potential enhancements and proposals.  Moreover, according to Table 1, it is obvious to observe that the simulation results among companies under the same traffic and the same scenario are quite different. For example, the maximum satisfied UE for AR/VR 30Mbps traffic in InH scenario is five times the minimum results. Therefore, we suggest to calibrate the simulation results among companies. To this end, it’s suggested to select two of the four typical traffic to reduce the workload. For example, (30Mbps, 15ms) for CG and (45Mbps, 10ms) for AR/VR are selected for calibration. Then, unified simulation assumptions for DL, e.g., parameters of packet size distribution, FPS, scheduler, gNB/UE antenna configuration, TDD configuration and etc, should be developed. |
| FUTUREWEI | Given the wide variations in the results we tend to agree with ZTE that some type of calibration is needed with unified simulation assumptions for DL. Preferably the Dense Urban deployment with 30 Mbps with PDB 10 msec. As presented above its very difficult to draw any conclusions from Table1.  Second comment, is that it would be useful to add reference to each of the bullets in **Potential enhancements and proposals** so it is easier to look up details of the enhancements as proposed from each company. Adding references to the results in the table is useful also.  Third comments, it may be useful to further categorize the enhancements above into subcategories for example scheduling, precoding (interference avoidance), resource coordination, etc. This may help in the process of making conclusions.  Additionally, reporting the assumptions such as equal or unequal number of UEs per cell, assumption of staggered or aligned UEs, etc are useful in general to categorize results and in future draw conclusions. |
| QC | We see that the large variance in results comes from different simulation assumptions. Companies should provide all required simulation parameters in an easily processing form. The results submission template could be used to reduce overhead of comparison and analysis. We think companies should actively propose new parameter (column) in the template if it can make difference in capacity/power results so that FL can improve it and companies can use an updated template. This will make the comparison across companies easy and potentially helpful in reducing variance. |
| Nokia, NSB | We appreciate the effort to collect the results together but cannot support with the summary of the observations/conclusions presented after Table 1 (especially, the part on “Potential enhancements and proposals”).  **The only meaningful conclusion we see from Table 1 is that the results reported by companies differ too much (by up to an order of magnitude in some cases).** Hence, the assumptions/methodologies used by different companies are still very far from each other. In such a case, it is not appropriate (and not even possible) to judge any observation, proposal, or enhancement until the results for the baseline setup (state-of-the-art NR) are made comparable among the companies.  The priority to progress in this SI should be to strive to continue resolving possible ambiguities and interpretations in the discussed traffic models and evaluations methodology. When these are resolved, the results reported by companies should become comparable and that would be the right time to start discussing observations and/or possible enhancements to be eventually captured in the TR. |
| OPPO | * + - 1. As the results suffer lager variance, it seems better to do some calibration among companies. Converged results will facilitate the identification of bottleneck.       2. It is too premature to formulize the potential enhancements since solid evaluation results are waiting for the traffic models and simulation assumption. |
| vivo | We appreciate FL’s great effort to collect the initial evaluation results from companies and prepare the draft observations. Given the fact of large variance among companies, we think we can focus on finalizing the traffic model and evaluation methodologies, and collect more simulation results from companies. After that, we believe we can make more concrete observations accordingly.  We suggest companies to use the new proposed template with simulation assumptions with additional modification if necessary to submit the simulation results. It will be very helpful for FL to summarize the evaluation results with the same/similar assumptions/configurations. Then we can formally collect simulation results, perform comparison and make conclusion from the next RAN1 meeting. Since there may be different simulation algorithms and capabilities among companies, even we can try to agree a single common baseline simulation assumption, it is not easy to calibrate among companies formally. Still, it is helpful for companies to calibrate their simulation results if possible. |
| Ericsson | We appreciate the efforts of the FL to collect and summarize the results – it makes the situation (painfully) clear.  We share Nokia’s view that it is not meaningful to draw conclusions based on the reported results and is definitely premature to summarize potential enhancements. Companies are free to contribute, of course.  We should focus on understanding what causes the large difference between companies. Performing a full calibration is beyond the scope of this SI. |
| LG | We also appreciate the effort of summarizing all the results into a tabular format. We also agree with all of the summarized observations. Regarding the diversity of the results, we somehow agree that trying to align evaluation assumptions to calibrate the results would be helpful. If that is not easy, then providing as much as information would be also helpful even if it may require some post-processing phase to sort out the results based on different assumptions. It seems the latter may be more realistic.  For the observations on the potential enhancements, we also think tagging reference later on would be helpful to look into the details.  One minor typo found in 2.1.1.  Video stream and audio/data stream. With Model 1, those two flows are modelled separately, and a packet with the audio/data stream can be scheduled right at its arrival at the gNB. With Model ~~1~~2, even though there are 2 separate data flows, the transmission of a packet with the audio/data stream always piggybacks on the transmission of a packet of the video stream. By comparing the simulation results, we would like to see whether merging the audio/data stream and the video stream is feasible or not for DL traffic modeling. |

## Capacity: UL – pose/control traffic

Table 2 captures initial evaluation results from companies for UL CG/VR capacity, where traffic model is pose/control stream with 4ms periodicity, constant 100bytes packet size, and 10ms PDB. Please note that the numbers in the table from different companies are under different assumptions, e.g., TDD configuration, gNB/UE antenna configuration, CG vs. DG, etc.

Table 2. Initial results: VR/CG capacity in UL (#UEs/Cell)

|  |  |  |  |
| --- | --- | --- | --- |
| Scenarios | Dense Urban | Urban Macro | Indoor Hotspot |
| **FR1** | | | |
| CG/VR | Source 1: 10.5  Source 2: >15  Source 3: >5  Source 5: 55 | Source 1: 3.2  Source 2: >15  Source 4: <1  Source 5: 50 | Source 1: 8.9  Source 2: >15  Source 5: 40 |
| **FR2** | | | |
| CG/VR | Source 2: >30 (400MHz) | N/A | Source 2: >30 (400MHz) |

### Additional results

Apple [15] considered 3 traffic models for UL:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Video stream | Audio/data stream | Control/pose stream | Note |
| Model 1 | Yes | Yes | Yes | Packets with the video stream and packet with the audio/data stream arrive independently, and they can be transmitted independently. |
| Model 2 | Yes | Yes | Yes | Packets with the video stream and packet with the audio/data stream arrive independently, and any packet with the data/audio stream is transmitted always with a packet with the video stream |
| Model 3 | Yes | No | Yes |  |

For both Model 1 and Model 2, there are three data flows with UL:

Video stream, audio/data stream and control/pose stream. With Model 1, the video stream and the audio/data stream are modelled separately, and a packet with the audio/data stream can be transmitted right away at its arrival at the UE. With Model 2, the transmission of a packet with the audio/data stream always piggybacks on the transmission of a packet of the video stream. By comparing the simulation results, we would like to see whether merging the audio/data stream and the video stream is feasible or not for UL traffic modeling.

For all the streams, X=95% is used, e.g. for a UE with 3 streams in UL, then the error rate for each from video, audio/data, pose/control streams should be less than 5% to designate the UE as “satisfied”.

For uplink, the same observation on the video stream and data/audio stream as for downlink can be made. Due to a smaller portion of resource is dedicated to uplink from the DL/UL split with “DDDUU”, also lower spectral efficiency for UL than for DL, and stringent latency requirement, etc., none of the UEs is satisfied.

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**Question 2. Please share your comment on the above observations, if any, from initial evaluation results for UL capacity for VR/CG (pose/control traffic).**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| MTK | We think the table format is good. One thing to be noted is that “Source 2” in the table seems to be vivo but not OPPO, while in the Reference section (Section 3) citation 2 is OPPO.  For the moderator question to our UL capacity result, we checked internally and found that the 25kbps UL data rate in our contribution is a typo. We actually use 25kBps UL data rate for simulation, which is aligned with previous RAN1 agreement (100Bytes per 4ms). We also checked vivo’s result (R1-2102548) as shown below and it can be seen that the UL capacity (Satisfied UE ratio = 90%) is a lot more than 15. Besides, after further checking our simulation results, our RU and Satisfied UE ratio is aligned with vivo’s value in Table 14 when UE number = 15. Hence, we would keep our current reported values for now. Thanks moderator for the careful check.  R1-2102548 Table 14. FR1 UL capacity simulation results for Pose information   |  |  |  |  |  | | --- | --- | --- | --- | --- | | **Scenarios** | **#UEs per cell** | **UE%** | **RU** | **Latency** | | **Indoor Hotspot** | >15 | 100% | 20.47% | 2.86ms | | **Dense Urban** | >15 | 100% | 20.76% | 2.94ms | | **Urban Macro** | >15 | 95.99% | 22.46% | 3.82ms |  |  |  | | --- | --- | |  |  | | 1. UE% | 1. Latency |   R1-2102548 Figure 1. UL simulation results for Pose information in FR1 |
| ZTE | Similar with DL capacity results, obvious differences among companies exist in Table 2. For UL capacity evaluation, we think that the uplink simulations also need to be calibrated. To this end, unified simulation assumptions for UL, e.g., TDD configuration, gNB/UE antenna configuration and etc, should be developed. |
| FUTUREWEI | Similar comment to the Question1. Results vary widely among companies making it difficult to draw conclusions. Suggest to focus on one scenario for calibration with unified simulation assumptions before making any conclusions. |
| QC | As commented by companies during the online meeting, there is large variance in results. Since this is the initial results based on evaluation method which is not completed yet, one can expect such a large variance.  We hope RAN1 strives to reduce the variance of results by following agreed assumptions and providing detailed assumptions/parameters for submitted results. |
| Nokia, NSB | Same as above, the major outcome is that the results reported by companies differ too much to make any real observations and conclusions.  From our own experience, UL pose/control update is not a limiting factor in capacity evaluations for VR and CG, as the results are always higher than the corresponding values for DL video traffic in VR/CG. This is somehow reflected in Table 2 as well. But again, since different companies report values ranging from 3.2 to 50 for the same deployment, it is hard and inappropriate to do any meaningful judgement. |
| OPPO | Similar to DL results, some calibration seems needed. |
| vivo | It seems uplink capacity results are more diverse. We suggest companies can further align the simulation assumptions and results informally, then we can make conclusions in the next meeting. |
| Ericsson | Same comment as for DL, the summary makes it painfully clear that results are diverging. Similar to Nokia, we have noticed that the impact of increasing load is marginal for pose/control: coverage and access latency dominate. |
| LG | Similar comment as above. Also agree with the necessity of further aligning evaluation assumptions such as TDD configuration, antenna configuration, etc. |

## UE Power Consumption

Table 3 summarizes initial evaluation results from companies for power saving (PS) gain from evaluated power saving schemes. Please note that the numbers in the table from different companies are under different assumptions, e.g., SU-MIMO vs. MU-MIMO, TDD configuration, gNB/UE antenna configuration, DL only, UL only, DL + UL (joint vs. separate simulations), etc.

Table 3. Initial results: UE power saving gain from evaluated power saving schemes

|  |  |  |  |
| --- | --- | --- | --- |
| Scenarios | Mean PSG (%) | % of UE satisfied (baseline, AlwaysON) | % of UE satisfied |
| **FR1** | | | |
| CDRX(17,10,2) | 10 | 90 | 70 |
| CDRX(10,5,5) | 10.2 | 96.1 | 94.8 |
| R15+16+17 | 64 | 97 | 96.7 |
| CDRX (10,3,1) | 25 |  | 96 |
| CDRX (10,5,1) | 15 |  | 80 |
| CDRX (10,5,5) | 11 |  | 88 |
| CDRX (10,8,1) | 5.0 |  | 96 |
| CDRX(8,4,4) | 7 | 82 | 81 |
| CDRX(8,4,2) | 13 | 82 | 66 |
| Genie | 33 | 95 | 95 |
| eCDRX(16,4,2) | 36 | 98 | 81.6 |
| **FR2** | | | |
| PDCCH skipping + cross slot scheduling | 36 | No data | No data |

Note 1: CDRX (X,Y,Z) [ms]: X=cycle, Y=On duration, Z=inactivity timer

Note 2: red font – cases where %satisfied UEs is less than 90%.

Observations from initial evaluation results from companies on UE power consumption for XR/CG are summarized as follows (please note that some observations are only from a limited number of companies).

* In general, UE power consumption for XR/CG is proportional to average packet transfer time.
  + UEs with larger pathloss generally have higher power consumption than UEs with lower pathloss.
  + UE power consumption tends to increase with increasing system load (i.e., # UEs per cell).
* In a baseline scenario where UE is always on (i.e., with no PS scheme being applied), UE power consumption for PDCCH decoding only (i.e., no grant for DL/UL in the slot) is substantial for XR/CG (e.g., up to 50-70% of the total UE power consumption).
* There is a trade-off relation between power saving gain from a power saving scheme (e.g., CDRX, PDCCH skipping, etc.) and ratio of satisfied UEs per cell. The ratio of satisfied UEs per cell can decrease if parameters for the applied power saving technique are not properly chosen.
* Power saving gain from a power saving technique while the ratio of satisfied UEs per cell maintains tends to be larger in a lower load scenario (i.e., smaller number of UEs per cell).
* Power saving gain from a power saving technique while the ratio of satisfied UEs per cell maintains tends to be larger for UEs with smaller pathloss (i.e., power saving gain tends to be is larger for cell-center UEs than that for cell-edge UEs)
* Current R15/16 CDRX scheme can provide limited/some power saving gain for XR/CG if parameters are chosen such that the ratio of satisfied UEs does not much decrease compared to the baseline (i.e., UE always ON).
* An enhanced CDRX (eCDRX) that provides more flexible CDRX configurations to fix the mismatch between the CDRX cycles configurable by R15/16 and typical video frame periodicity (e.g., 60/120 fps) can provide more power saving gain than R15/16 CDRX.
* When both DL and UL PUSCH XR traffic is considered
  + PUSCH transmissions contribute a larger fraction to overall UE power consumption.
  + Even with relatively low XR DL data rate of 8Mbps, the achievable power savings is reduced.
* The retransmission-aware DCI-based power saving adaptation can increase power saving gain.
* With jitter (e.g., STD of 2ms and range of [-4ms, 4ms]), power saving gain from CDRX/eCDRX/PDCCH skipping while the ratio of satisfied UEs per cell maintains tends to decrease.
  + CDRX/eCDRX need longer timer duration to have the ratio of satisfied UEs not much affected, which washes out their power saving gain.
  + PDCCH skipping cannot accurately tell how long UE can sleep until next packet arrival.
  + There is a larger gap from Genie scheme in power saving gain.
  + Fast wake up signal can help to recover the loss in power saving gain.
* Larger pose/control periodicity than 4ms (e.g., 16.7ms) can substantially reduce UE power consumption.

**Question 3. Please share your comment on the above observations, if any, from initial evaluation results for UE power consumption to support AR/VR/CG.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| MTK | We think the observations part is good. For Table 3, we are not sure it’s good to capture so many DRX results with different configurations while R15/R16/R17 mechanisms other than DRX are merged into one row. We also suggest to list the source (tdoc) which generated the result for each row to give easier reference and check for the listed values. |
| ZTE | We are fine with the Observation from initial evaluation results for Power saving except the seventh bullet:   * An enhanced CDRX (eCDRX) that provides more flexible CDRX configurations to fix the mismatch between the CDRX cycles configurable by R15/16 and typical video frame periodicity (e.g., 60/120 fps) can provide more power saving gain than R15/16 CDRX.   To our observation, when the ratio of satisfied UE for eCDRX is approximately equal to that for R15/16 CDRX, we may conclude that eCDRX provides more power saving gain than R15/16 CDRX.  Therefore, we suggest to modify as:   * An enhanced CDRX (eCDRX) that provides more flexible CDRX configurations to fix the mismatch between the CDRX cycles configurable by R15/16 and typical video frame periodicity (e.g., 60/120 fps) can provide more power saving gain than R15/16 CDRX, under the same capacity degradation   Moreover, as we mentioned in Q1 and Q2, capacity evaluation for DL and UL should be calibrated at the first of stage. With the unified capacity evaluation results, we suggest to develop a unified set of N (the number of UE per cell) for specific scenarios to observe the power saving gain. At least low overloading and high overloading scenarios should be reflected. |
| FUTUREWEI | In our views, at this point the focus is on capturing and categorizing the results clearly and comprehensively rather than attempting to agreeing/commenting on observations.  At this point it is not easy to compare the results in the table since they represent different simulation assumptions and are not calibrated. For example, the scheme R15+16+17 in row three seem to provide the largest gain but it is not clear what the scheme is doing, and which company proposed it. A reference to contribution may help to further look up the details.  Therefore its still early at this point to comment on observations given that the focus should be on clearly capturing / categorizing results. |
| QC | As mentioned by ZTE, using the same number of N would be very helpful reducing variance of results across companies. We observed that the number of UEs / cell affects power saving gain of power saving schemes. Thus, in order to reduce the variance coming from different N numbers, companies could use limited set of N values: e.g., one equal to capacity number (high load) and the other for lightly loaded N=[3]. |
| Nokia, NSB | We think it is important to start collecting the results for UE power saving as well, but suggest that we clearly separate the two categories of schemes:   1. Existing UE power saving features (e.g., DRX configurations already supported in the NR, etc.) 2. New/adjusted UE power saving features proposed by different companies.   This may be implemented by e.g., separating Table 3 into two parts (the first set of rows – existing schemes, while the second set of rows – new proposals different from the existing NR specs).  Priority should be given to the first bullet and to ensure that the results reported by different companies for the existing schemes are comparable to each other. Until then, we don’t see much benefit in making any observations, proposals, or conclusions regarding possible enhanced schemes. |
| OPPO | The proposal from ZTE/QC is helpful: Use the same number of UE per cell to reduce the variance between different companies.  Similar to the capacity results, we think it seems premature to discussion observation since the initial results are not stable. |
| vivo | It seems the power evaluation results in our Tdoc (R1-2102548) are not captured in the table…  On different power saving techniques, we may need to further categorize into CDRX configurations supported by R15/R16, eCDRX, PDCCH skipping and etc, and make conclusion accordingly. Power saving gain in high load (70% RU), medium load (50% RU) and low load (30% RU) scenarios can be provided separately for each power saving technique. In the meanwhile, we can focus on the simulation cases (e.g. AR/CG + Dense urban) and the potential power saving techniques, since these use cases have high demand for power saving. |
| Ericsson | Collecting UE power savings results are also relevant. However, it seems the evaluation conditions are even more disparate for UE power savings.  Since we are evaluating baseline, it is questionable if novel power schemes should be included in summaries. If they are included, they should be clearly separated, as Nokia proposes. We also realize that it becomes critical to state the fraction of satisfied UEs for the baseline. |
| LG | We support the proposal from Nokia seconded by Ericsson. We should focus on the evaluation results with existing NR scheme. The results based on the schemes not directly supported by the current spec are secondary and should be clearly separated to avoid any misinterpretation. |

# List of contributions in RAN1 #104b-e

1. [R1-2102322](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102322.zip) Initial evaluation results for XR and Cloud Gaming Huawei, HiSilicon
2. [R1-2102420](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102420.zip) Initial performance results for XR evaluation OPPO
3. [R1-2102548](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102548.zip) Initial performance evaluation results of XR vivo
4. [R1-2102614](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102614.zip) Evaluation results of XR performance CATT
5. [R1-2102707](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102707.zip) 8.14.3 Initial Performance and Evaluation Results for XR and CG MediaTek Inc.
6. [R1-2102771](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102771.zip) XR initial evaluations FUTUREWEI
7. [R1-2102829](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102829.zip) Performance results in indoor hotspot and dense urban deployments of CG and VR/AR applications Nokia, Nokia Shanghai Bell
8. [R1-2102904](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102904.zip) Initial XR Evaluation Results CMCC
9. [R1-2102957](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102957.zip) Initial XR performance evaluation results Ericsson
10. [R1-2103130](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103130.zip) Initial performance evaluation on XR Apple
11. [R1-2103194](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103194.zip) Initial Evaluation Results for XR Capacity and UE Power Consumption Qualcomm Incorporated
12. [R1-2103280](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103280.zip) Initial Performance Evaluation Results for XR ZTE, Sanechips
13. [R1-2103431](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103431.zip) Performance Evaluation Results on XR applications InterDigital, Inc.
14. [R1-2103439](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103439.zip) XR Initial Performance Results AT&T
15. R1-2103833 Initial performance evaluation on XR Apple

# Appendix-A (observations in RAN1#104bis-e tdocs)

**Huawei, HiSilicon**

In this contribution, initial system level evaluation results of the scenario of FR1 Dense Urban and the scenario of FR1 Urban Macro for XR and CG service are discussed with the following observations:

*Observation 1: As shown in Table 3, the network capacity depends on XQI score. Higher XQI score refers to better user experience and results in less network capacity.*

*Table 4. Network capacity of the single-stream model with different XQI scores in FR1 Dense Urban*

|  |  |  |
| --- | --- | --- |
| ***XQI score*** | ***Description*** | ***Average number of supported users per cell*** |
| ***XQI=5*** | ***Excellent*** | ***3.3*** |
| ***XQI***≥***4*** | ≥***Good*** | ***5.7*** |
| ***XQI***≥***3*** | ≥***Fair*** | ***7.7*** |

*Observation 2: In FR1 Dense Urban, the network capacity of the single-stream model with XQI≥4 is summarized in Table 4.*

*Table 5. Network capacity of the single-stream model with XQI≥4 in FR1 Dense Urban*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Average number of supported users per cell*** | ***VR/AR (30Mbps)*** | ***VR/AR (45Mbps)*** | ***CG (8Mbps)*** | ***CG (30Mbps)*** |
| ***SU-MIMO*** | ***5.7*** | ***2.3*** | ***>15*** | ***7.4*** |
| ***MU-MIMO*** | ***12*** | ***5.6*** | ***>15*** | ***>15*** |

***Observation 3: In FR1 Urban Macro, the network capacity of the single-stream model with XQI≥4 is summarized in Table 5.***

*Table 6. Network capacity of the single-stream model with XQI≥4 in FR1 Urban Macro*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Average number of supported users per cell*** | ***VR/AR (30Mbps)*** | ***VR/AR (45Mbps)*** | ***CG (8Mbps)*** | ***CG (30Mbps)*** |
| ***SU-MIMO*** | ***4.9*** | ***1.5*** | ***>15*** | ***6.8*** |
| ***MU-MIMO*** | ***8.4*** | ***4*** | ***>15*** | ***11.1*** |

*Observation 4: The network capacity of the multi-stream model can be improved by prioritizing the transmission of the more important stream as shown in Table 6.*

*Table 7. Network capacity of the multi-stream model with XQI≥3 in FR1 Dense Urban*

|  |  |  |
| --- | --- | --- |
| ***Scheduling scheme*** | ***S1***  ***(no prioritization between I/P streams)*** | ***S2***  ***(prioritize I-stream)*** |
| ***Average number of supported users per cell*** | ***1.6*** | ***1.8*** |
| ***Capacity improvement of S2 over S1*** | ***12.5%*** | |

* ***Observation 5: For baseline of XR traffic, power consumption of PDCCH-only is about 50%~70% over the total power consumption****.*

**OPPO**

Observation 1: In FR1, for XR/VR DL video stream with 60Mbps @60 fps and PDB=10ms in dense urban scenarios

* + If 90% of UEs are satisfied (baseline), the capacity is about 3 user pers cell
* If 95% of UEs are satisfied (optional), the capacity is 2 user pers cell

**vivo**

Observation 1: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR1 Indoor Hotspot, system capacity is 16 UEs per cell.
* For DL CG with 30Mbps and 120FPS in FR1 Indoor Hotspot, system capacity is 20 UEs per cell.
* For DL VR/AR with 45Mbps and 60FPS in FR1 Indoor Hotspot, system capacity is 6 UEs per cell.
* For DL VR/AR with 45Mbps and 120FPS in FR1 Indoor Hotspot, system capacity is 10 UEs per cell.
* For DL VR/AR with 60Mbps and 60FPS in FR1 Indoor Hotspot, system capacity is 3 UEs per cell.
* For DL VR/AR with 60Mbps and 120FPS in FR1 Indoor Hotspot, system capacity is 7 UEs per cell.

Observation 2: When the capacity requirement per UE is more than 95% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR1 Indoor Hotspot, system capacity is 18 UEs per cell.
* For DL CG with 30Mbps and 120FPS in FR1 Indoor Hotspot, system capacity is 22 UEs per cell.
* For DL VR/AR with 45Mbps and 60FPS in FR1 Indoor Hotspot, system capacity is 7 UEs per cell.
* For DL VR/AR with 45Mbps and 120FPS in FR1 Indoor Hotspot, system capacity is 10 UEs per cell.
* For DL VR/AR with 60Mbps and 60FPS in FR1 Indoor Hotspot, system capacity is 4 UEs per cell.
* For DL VR/AR with 60Mbps and 120FPS in FR1 Indoor Hotspot, system capacity is 8 UEs per cell.

Observation 3: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR1 Dense Urban, system capacity is 24 UEs per cell.
* For DL CG with 30Mbps and 120FPS in FR1 Dense Urban, system capacity is 30 UEs per cell.
* For DL VR/AR with 45Mbps and 60FPS in FR1 Dense Urban, system capacity is 9 UEs per cell.
* For DL VR/AR with 45Mbps and 120FPS in FR1 Dense Urban, system capacity is 14 UEs per cell.
* For DL VR/AR with 60Mbps and 60FPS in FR1 Dense Urban, system capacity is 5 UEs per cell.
* For DL VR/AR with 60Mbps and 120FPS in FR1 Dense Urban, system capacity is 9 UEs per cell.

Observation 4: When the capacity requirement per UE is more than 95% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR1 Dense Urban, system capacity is 25 UEs per cell.
* For DL CG with 30Mbps and 120FPS in FR1 Dense Urban, system capacity is 32 UEs per cell.
* For DL VR/AR with 45Mbps and 60FPS in FR1 Dense Urban, system capacity is 9 UEs per cell.
* For DL VR/AR with 45Mbps and 120FPS in FR1 Dense Urban, system capacity is 15 UEs per cell.
* For DL VR/AR with 60Mbps and 60FPS in FR1 Dense Urban, system capacity is 6 UEs per cell.
* For DL VR/AR with 60Mbps and 120FPS in FR1 Dense Urban, system capacity is 10 UEs per cell.

Observation 5: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR1 Urban Macro, system capacity is 16 UEs per cell.
* For DL CG with 30Mbps and 120FPS in FR1 Urban Macro, system capacity is 20 UEs per cell.
* For DL VR/AR with 45Mbps and 60FPS in FR1 Urban Macro, system capacity is 6 UEs per cell.
* For DL VR/AR with 45Mbps and 120FPS in FR1 Urban Macro, system capacity is 9 UEs per cell.
* For DL VR/AR with 60Mbps and 60FPS in FR1 Urban Macro, system capacity is 3 UEs per cell.
* For DL VR/AR with 60Mbps and 120FPS in FR1 Urban Macro, system capacity is 6 UEs per cell.

Observation 6: When the capacity requirement per UE is more than 95% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR1 Urban Macro, system capacity is 18 UEs per cell.
* For DL CG with 30Mbps and 120FPS in FR1 Urban Macro, system capacity is 22 UEs per cell.
* For DL VR/AR with 45Mbps and 60FPS in FR1 Urban Macro, system capacity is 6 UEs per cell.
* For DL VR/AR with 45Mbps and 120FPS in FR1 Urban Macro, system capacity is 10 UEs per cell.
* For DL VR/AR with 60Mbps and 60FPS in FR1 Urban Macro, system capacity is 4 UEs per cell.
* For DL VR/AR with 60Mbps and 120FPS in FR1 Urban Macro, system capacity is 7 UEs per cell.

Observation 7: When the reliability requirement is relaxed from 99% to 95%, the system capacity could increase by 0 to 2 UE per cell for FR1 DL traffics.

Observation 8: When increasing the frame rate from 60FPS to 120FPS, the system capacity could increase by 3 to 7 UEs per cell for FR1 DL traffics.

Observation 9: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 9 UEs per cell with 100MHz bandwidth.
* For DL CG with 30Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 10 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 45Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 5 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 45Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 6 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 60Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 3 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 60Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 4 UEs per cell with 100MHz bandwidth.

Observation 10: When the capacity requirement per UE is more than 95% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 10 UEs per cell with 100MHz bandwidth.
* For DL CG with 30Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 12 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 45Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 6 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 45Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 7 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 60Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 4 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 60Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 5 UEs per cell with 100MHz bandwidth.

Observation 11: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 46 UEs per cell with 400MHz bandwidth.
* For DL CG with 30Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 50 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 45Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 27 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 45Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 31 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 60Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 20 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 60Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 23 UEs per cell with 400MHz bandwidth.

Observation 12: When the capacity requirement per UE is more than 95% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 50 UEs per cell with 400MHz bandwidth.
* For DL CG with 30Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 53 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 45Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 30 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 45Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 33 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 60Mbps and 60FPS in FR2 Indoor Hotspot, system capacity is 22 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 60Mbps and 120FPS in FR2 Indoor Hotspot, system capacity is 25 UEs per cell with 400MHz bandwidth.

Observation 13: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR2 Dense Urban, system capacity is 20 UEs per cell with 100MHz bandwidth.
* For DL CG with 30Mbps and 120FPS in FR2 Dense Urban, system capacity is 24 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 45Mbps and 60FPS in FR2 Dense Urban, system capacity is 9 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 45Mbps and 120FPS in FR2 Dense Urban, system capacity is 12 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 60Mbps and 60FPS in FR2 Dense Urban, system capacity is 6 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 60Mbps and 120FPS in FR2 Dense Urban, system capacity is 8 UEs per cell with 100MHz bandwidth.

Observation 14: When the capacity requirement per UE is more than 95% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR2 Dense Urban, system capacity is 22 UEs per cell with 100MHz bandwidth.
* For DL CG with 30Mbps and 120FPS in FR2 Dense Urban, system capacity is 26 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 45Mbps and 60FPS in FR2 Dense Urban, system capacity is 10 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 45Mbps and 120FPS in FR2 Dense Urban, system capacity is 13 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 60Mbps and 60FPS in FR2 Dense Urban, system capacity is 7 UEs per cell with 100MHz bandwidth.
* For DL VR/AR with 60Mbps and 120FPS in FR2 Dense Urban, system capacity is 9 UEs per cell with 100MHz bandwidth.

Observation 15: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR2 Dense Urban, system capacity is greater than 35 UEs per cell with 400MHz bandwidth.
* For DL CG with 30Mbps and 120FPS in FR2 Dense Urban, system capacity is greater than 35 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 45Mbps and 60FPS in FR2 Dense Urban, system capacity is greater than 35 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 45Mbps and 120FPS in FR2 Dense Urban, system capacity is greater than 35 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 60Mbps and 60FPS in FR2 Dense Urban, system capacity is greater than 25 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 60Mbps and 120FPS in FR2 Dense Urban, system capacity is greater than 25 UEs per cell with 400MHz bandwidth.

Observation 16: When the capacity requirement per UE is more than 95% of packets are successfully delivered within a given air interface PDB,

* For DL CG with 30Mbps and 60FPS in FR2 Dense Urban, system capacity is greater than 35 UEs per cell with 400MHz bandwidth.
* For DL CG with 30Mbps and 120FPS in FR2 Dense Urban, system capacity is greater than 35 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 45Mbps and 60FPS in FR2 Dense Urban, system capacity is greater than 35 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 45Mbps and 120FPS in FR2 Dense Urban, system capacity is greater than 35 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 60Mbps and 60FPS in FR2 Dense Urban, system capacity is greater than 25 UEs per cell with 400MHz bandwidth.
* For DL VR/AR with 60Mbps and 120FPS in FR2 Dense Urban, system capacity is greater than 25 UEs per cell with 400MHz bandwidth.

Observation 17: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For UL Scene information in FR1 Indoor Hotspot, system capacity is 6 UEs per cell.
* For UL Scene information in FR1 Dense Urban, system capacity is 3 UEs per cell.
* For UL Scene information in FR1 Urban Macro with 1 UE per cell, there is less than 90% of UEs that can satisfy system capacity requirement.

Observation 18: When the capacity requirement per UE is more than 95% of packets are successfully delivered within a given air interface PDB,

* For UL Scene information in FR1 Indoor Hotspot, system capacity is 6 UEs per cell.
* For UL Scene information in FR1 Dense Urban, system capacity is 3 UEs per cell.
* For UL Scene information in FR1 Urban Macro with 1 UE per cell, there is less than 90% of UEs that can satisfy system capacity requirement.

Observation 19: For Scene information in FR1 UL, system capacity cannot be improved by relaxing reliability requirement from 99% to 95%.

Observation 20: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For UL Pose information in FR1 Indoor Hotspot, system capacity is greater than 15 UEs per cell.
* For UL Pose information in FR1 Dense Urban, system capacity is greater than 15 UEs per cell.
* For UL Pose information in FR1 Urban Macro, system capacity is greater than 15 UEs per cell.

Observation 21: For Pose information in FR1 for UL, 95th percentile user interaction delay is far below 10ms with the number of UEs per cell up to 15.

Observation 22: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For UL Scene information in FR2 Indoor Hotspot, system capacity is greater than 30 UEs per cell with 400MHz bandwidth.
* For UL Scene information in FR2 Dense Urban, system capacity is greater than 30 UEs per cell with 400MHz bandwidth.

Observation 23: When the capacity requirement per UE is more than 95% of packets are successfully delivered within a given air interface PDB,

* For UL Scene information in FR2 Indoor Hotspot, system capacity is greater than 30 UEs per cell with 400MHz bandwidth.
* For UL Scene information in FR2 Dense Urban, system capacity is greater than 30 UEs per cell with 400MHz bandwidth.

Observation 24: When the capacity requirement per UE is more than 99% of packets are successfully delivered within a given air interface PDB,

* For UL Pose information in FR2 Indoor Hotspot, system capacity is greater than 30 UEs per cell with 400MHz bandwidth.
* For UL Pose information in FR2 Dense Urban, system capacity is greater than 30 UEs per cell with 400MHz bandwidth.

Observation 25: For DL CG with 30Mbps and 60FPS in FR1 Indoor Hotspot,

* 3.22% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 5.10% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 24.76% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 29.73% mean PSG can be achieved without capacity loss by using PDCCH skipping with jitter handling scheme.

Observation 26: For DL CG with 30Mbps and 60FPS in FR1 Dense Urban,

* 2.07% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 3.62% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 19.63% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 25.79% mean PSG can be achieved without capacity loss by using PDCCH skipping with jitter handling scheme.

Observation 27: For DL CG with 30Mbps and 60FPS in FR1 Urban Macro,

* 2.42% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 3.69% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 22.09% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 27.27% mean PSG can be achieved without capacity loss by using PDCCH skipping with jitter handling scheme.

Observation 28: For DL VR/AR with 45Mbps and 60FPS in FR1 Indoor Hotspot,

* 4.06% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 5.97% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 28.40% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 32.23% mean PSG can be achieved without capacity loss by using PDCCH skipping with jitter handling scheme.

Observation 29: For DL VR/AR with 45Mbps and 60FPS in FR1 Dense Urban,

* 3.86% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 5.70% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 26.77% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 31.24% mean PSG can be achieved without capacity loss by using PDCCH skipping with jitter handling scheme.

Observation 30: For DL VR/AR with 45Mbps and 60FPS in FR1 Urban Macro,

* 3.75% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 5.61% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 27.15% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 31.10% mean PSG can be achieved without capacity loss by using PDCCH skipping with jitter handling scheme.

Observation 31: For DL VR/AR with 60Mbps and 60FPS in FR1 Indoor Hotspot,

* 4.29% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 6.17% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 29.07% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 32.70% mean PSG can be achieved without capacity loss by using PDCCH skipping with jitter handling scheme.

Observation 32: For DL VR/AR with 60Mbps and 60FPS in FR1 Dense Urban,

* 4.01% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 5.86% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 26.68% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 31.18% mean PSG can be achieved without capacity loss by using PDCCH skipping with jitter handling scheme.

Observation 33: For DL VR/AR with 60Mbps and 60FPS in FR1 Urban Macro,

* 3.56% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 5.39% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 26.14% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 30.46% mean PSG can be achieved without capacity loss by using PDCCH skipping with jitter handling scheme.

Observation 34: By adopting the R15/R16 DRX configuration, only 2.07%~6.17% mean PSG can be obtained without the loss of the system capacity for FR1 DL.

Observation 35: 19.63%~32.7% mean PSG will be achieved by aligning the start time of DRX ON Duration with the arrival of XR traffic or PDCCH skipping scheme without capacity loss, which is five times as much as the power saving gain obtained by the R15/R16 DRX configuration.

Observation 36: For UL Scene information in FR1 Indoor Hotspot,

* 5.22% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 7.67% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 37.59% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 52.04% mean PSG can be achieved without capacity loss by using PDCCH skipping scheme.

Observation 37: For UL Scene information in FR1 Dense Urban,

* 6.01% mean PSG can be achieved without capacity loss by using DRX scheme with 10ms DRX cycle.
* 7.35% mean PSG can be achieved without capacity loss by using DRX scheme with 4ms DRX cycle.
* 31.13% mean PSG can be achieved without capacity loss by using aligning DRX ON Duration scheme.
* 40.88% mean PSG can be achieved without capacity loss by using PDCCH skipping scheme.

Observation 38: By adopting the R15/R16 DRX configuration, only 5.22%~7.67% mean PSG can be obtained without the loss of the system capacity for FR1 uplink Scene information.

Observation 39: For FR1 uplink Scene information, 31.13%~37.59% PSG and 40.88%~52.04% mean PSG can be obtained without capacity loss by aligning the start time of DRX ON Duration with the arrival of XR traffic and adopting PDCCH skipping scheme, respectively.

Observation 40: For UL Pose information in FR1 Indoor Hotspot,

* 22.83% mean PSG can be achieved without capacity loss by using DRX without considering packets bundling.
* 36.20% mean PSG can be achieved without capacity loss by using packets bundled transmission.

Observation 41: For UL Pose information in FR1 Dense Urban,

* 22.93% mean PSG can be achieved without capacity loss by using DRX without considering packets bundling.
* 36.34% mean PSG can be achieved without capacity loss by using packets bundled transmission.

Observation 42: Compared with the DRX configuration without packets bundling, the packets bundled transmission scheme can obtain additional 13.37% and 13.41% PSG for Indoor Hotspot scenario and Dense Urban scenario, respectively.

Observation 43: For both Dense Urban and Urban Macro scenarios in FR1, for VR/AR/CG traffic with 100MHz bandwidth, PUSCH is the bottleneck channel with frame structure DDDSU in terms of MIL.

Observation 44: For Dense Urban scenario in FR2, for VR/AR/CG traffic with 400MHz and 100MHz bandwidth, PUSCH is the bottleneck channel with frame structure DDDSU in terms of MIL.

Observation 45: For Indoor Hotspot scenario in FR2, for VR/CG traffic with 400MHz bandwidth, and VR/AR /CG traffic with 100MHz bandwidth, PDSCH is the bottleneck channel with frame structure DDDSU in terms of MIL.

Observation 46: For Indoor Hotspot scenario in FR2, for AR traffic with 400MHz bandwidth, PUSCH is the bottleneck channel with frame structure DDDSU in terms of MIL.

**CATT**

***Observation 1:*** ***For XR service in Indoor Hotspot scenario, the system capacity without any power saving scheme is 6 UEs per cell for XR service with 60 FPS frame rate and 30Mbps bit rate.***

***Observation 2: For CG service in Indoor Hotspot scenario, the system capacity without any power saving scheme is at least 12 UEs per cell for CG service with 60FPS and 8Mbps bit rate.***

***Observation 3: For XR service at Indoor Hotspot scenario, the system capacity of XR with the DRX configuration could be reduced by 18.1%~75% and even up to 100% compared to the system capacity of XR without any power saving scheme.***

***Observation 4: Compare to common DRX configuration parameter for R15 UE power saving, the DRX configuration matched the inter-arrival of XR traffic has less impact on capacity.***

***Observation 5: The performance of DRX for 30Mbps XR service in Indoor Hotspot and detailed DRX configurations are shown as follows,***

***Table 4: Detailed DRX configuration***

|  |  |  |  |
| --- | --- | --- | --- |
| DRX configuration | DRX Cycle | OnDurationTimer | InactivityTimer |
| C-DRX 1 | 160ms | 100ms | 8ms |
| C-DRX 2 | 17ms | 10ms | 2ms |

***Table 5: Evaluation of UE power saving schemes for Indoor Hotspot***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Power Saving Scheme | Power Saving Gain (PSG) compared to Case 1 | | | | #satisfied UEs per cell / #UEs per cell |
| Mean PS gain | PS gain of 5%-tile UE in PSG CDF | PS gain of 50%-tile UE in PSG CDF | PS gain of 95%-tile UE in PSG CDF |
| Case 1 | - | - | - | - | 5 / 6 |
| C-DRX 1 | 7.3 % | 7.13% | 4.68% | 20.5% | 0 / 6 |
| C-DRX 2 | 10.37% | 4.9 % | 9.87 % | 17.28% | 2 / 6 |

***Observation 6:*** ***For XR service in Dense Urban scenario, the system capacity without any power saving scheme is 10 UEs per cell with XR service of 60 FPS frame rate and 30Mbps bit rate.***

***Observation 7: For XR service in Dense Urban scenario, the system capacity with DRX configuration is reduced by 15.9%~52.4% compare to the system capacity without any power saving scheme.***

***Observation 8: The performance of DRX for 30Mbps XR service in Dense Urban and detailed DRX configurations are shown as follows,***

***Table 4: Detailed DRX configuration***

|  |  |  |  |
| --- | --- | --- | --- |
| DRX configuration | DRX Cycle | OnDurationTimer | InactivityTimer |
| C-DRX 2 | 17ms | 10ms | 2ms |

***Table 6: Evaluation of UE power saving schemes for Dense Urban***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Power Saving Scheme | Power Saving Gain (PSG) compared to baseline | | | | #satisfied UEs per cell / #UEs per cell |
| Mean PS gain | PS gain of 5%-tile UE in PSG CDF | PS gain of 50%-tile UE in PSG CDF | PS gain of 95%-tile UE in PSG CDF |
| baseline | - | - | - | - | 9 / 10 |
| C-DRX 2 | 10.3 % | 4.7% | 8.9 % | 19% | 7 / 10 |

**MTK**

Observation 1: The downlink capacity result for Cloud gaming in FR1 is 54, 46 and 38 with 8Mbps data rates and is 12, 9 and 7 with 30Mbps data rates for Dense Urban, UMa and Indoor Hotspot, respectively.

Observation 2: For the downlink traffic evaluation in FR1, the capacity number in Indoor Hotspot is smaller than the capacity number in Dense Urban and UMa due to inferior antenna setting.

Observation 3: The downlink capacity results for Cloud gaming in FR2 is 27 for Dense Urban and 32 for Indoor Hotspot with 8Mbps data rates and is 7 with 30Mbps data rates for both scenarios.

Observation 4: Since the downlink capacity results for Indoor Hotspot in FR1 and FR2 are comparable for Cloud gaming service, the service can be supported via FR2 spectrum for indoor scenarios.

Observation 5: The downlink capacity result for AR/VR is poorer than the downlink capacity results of CG due to larger data rates and more stringent latency requirement.

Observation 6: The downlink capacity result for AR/VR in FR1 is 9, 6 and 6 with 30Mbps data rates and is 5, 4 and 4 with 45Mbps data rates for Dense Urban, UMa and Indoor Hotspot, respectively.

Observation 7: The downlink capacity result for AR/VR in FR2 is 6 and 4 with 30Mbps data rates and is 3 and 2 with 45Mbps data rates for Dense Urban and Indoor Hotspot, respectively.

Observation 8: With only 100MHz transmission bandwidth, the downlink system capacity for AR/VR with 45Mbps data rates is poor in both FR1 and FR2. Enhancement like carrier aggregation can be utilized to increase the capacity.

Observation 9: CA can provide capacity gain and the system capacity with CA is the larger than the sum of the capacity of its component carriers.

Observation 10: With additional enhancements on CA, 66% capacity gain for Dense Urban and 33% capacity gain for Indoor Hotspot can be observed compared to the CA without enhancements.

Observation 11: The adopted TDD patterns in supporting latency-sensitive services like AR/VR should consider the trade-off between the uplink and downlink opportunities and the uniformity of uplink slots.

Observation 12: With CA of two carriers in FR2, the capacity increases from 3 to 12 users per cell for Dense Urban and from 2 to 12 for Indoor Hotspot.

Observation 13: With CA of two carriers in FR2, the system can achieve good capacity for AR/VR with 45Mbps data rates and the service can be supported via FR2 spectrum for indoor scenarios.

Observation 14: A UE is more likely to be configured with multiple carriers in FR2 than in FR1, the scheduler efficiency in terms of downlink control information to schedule large number of carriers can be an issue for further discussion.

Observation 15: Both XR and CG applications are supportable in both FR1 and FR2. Considering FR1 has the better coverage, it is more suitable to support XR/CG applications in Dense Urban via FR1.

Observation 16: The uplink capacity number for CG/VR with only pose/control traffic is larger than 55, 50 and 40 for Dense Urban, UMa and Indoor Hotspot, respectively.

Observation 17: The downlink capacity is the bottleneck of CG/VR services.

Observation 18: The uplink capacity number for AR traffic where 20Mbps data rates is considered for the video is smaller than the downlink capacity number and a lower data rates could be considered.

Observation 19: The uplink is not the bottleneck for AR traffic if the video data rates is 10Mbps.

Observation 20: The power saving gain for cDRX used in data-intensive services like AR/VR is limited and it can lead to larger increase of outage rate.

Observation 21: The retransmission-aware DCI-based power saving adaptation can provide considerable power saving gain with acceptable increase of the outage rate.

Proposal 1: For the video data rates for AR traffic, consider the value less than 20Mbps, e.g., 10Mbps.

Table 8: Summary of the downlink system capacity results for baseline

|  |  |  |  |
| --- | --- | --- | --- |
| Scenarios | Dense Urban | UMa | Indoor Hotspot |
| FR1 1CC | | | |
| DL Capacity for CG, 8Mbps | 54 | 46 | 38 |
| DL Capacity for CG, 30Mbps | 12 | 9 | 7 |
| DL Capacity for XR, 30Mbps | 9 | 6 | 6 |
| DL Capacity for XR, 45Mbps | 5 | 4 | 4 |
| FR2 1CC | | | |
| DL Capacity for CG, 8Mbps | 27 | N/A | 32 |
| DL Capacity for CG, 30Mbps | 7 | N/A | 7 |
| DL Capacity for XR, 30Mbps | 6 | N/A | 4 |
| DL Capacity for XR, 45Mbps | 3 | N/A | 2 |

Table 9: Summary of the uplink system capacity results for baseline

|  |  |  |  |
| --- | --- | --- | --- |
| Scenarios | Dense Urban | UMa | Indoor Hotspot |
| FR1 1CC | | | |
| UL Capacity for CG/VR | >55 | >50 | >40 |
| UL Capacity for AR, 20Mbps video | 5 | <2 | <3 |
| UL Capacity for AR, 10Mbps video | 11 | 4 | 6 |

**Futurewei**

Proposal 1:  Study enhancements to MU-MIMO with a large number of antennas in order to increase the system capacity of XR

Proposal 2: Capture in the TR results for TDD with and without Cooperative MIMO via DL interference probing based on SRS enhancements to improve XR system capacity.

Observation 1: For the FR1 Dense Urban Scenario and with the assumption of zero forcing precoding, the capacity of the XR system is ~4 UEs/cell when users traffic packet arrival are aligned and ~7 UEs/cell when users traffic packet arrival are staggered.

Observation 2: The traffic packet arrival staggering could increase the XR capacity.

Observation 3: With BiT precoding, the gain is 50% for the XR system capacity with the assumption of having users aligned while the gain is 70% when the users are assumed to be staggered with respect to their traffic arrival

Observation 4: TDD ZF performance can be significantly improved by flexible A-SRS triggering with dynamically indicated partial frequency sounding

**Nokia**

***Observation 1:*** *When we consider CG traffic model at 30Mbps for an InH deployment, we can support the number of UEs per cell indicated in Table 5.*

***Observation 2:*** *When we consider VR/AR traffic model at 30Mbps for an InH deployment, we can support the number of UEs per cell indicated in Table 6.*

***Observation 3:*** *When we consider CG traffic model at 30Mbps for a Dense Urban deployment, we can support a number of UEs per cell indicated in Table 8.*

***Observation 4:*** *The method used for the random placement of UEs in the simulation area affects the system capacity. The even load random placement results in higher system capacity than uneven load placement by up to 2 UE/cell in Dense Urban deployments for CG applications at 30Mbps.*

***Observation 5:*** *When we consider AR/VR traffic model at 30Mbps for a Dense Urban deployment, we can support a number of UEs per cell indicated in Table 9.*

***Observation 6:*** *The method used for the random placement of UEs in the simulation area affects the system capacity. The even load random placement results in higher system capacity than uneven load placement by 1 UE/cell in Dense Urban deployments for AR/VR applications at 30Mbps.*

***Observation 7:*** *When we consider Pose/Control model for UL traffic with packet size equal to 100 bytes and constant inter-arrival time equal to 4ms, we can support at least 5 UEs per cell in UL. Further optimization of UL transmit power control settings is expected to result in additional improvements.*

All previous observations are captured and summarized by the following tables:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **InH deployment** | | | |
|  | **CG (30 Mbps)** | | **VR/AR (30 Mbps)** | |
|  | **X=95%** | **X=99%** | **X=95%** | **X=99%** |
| **FR1 (100 MHz)** | 2 | 2 | 2 | 2 |
| **FR2 (100 MHz)** | 5 | 5 | 5 | 4 |
| **FR2 (200 MHz)** | >10 | >10 | >10 | 10 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Dense Urban deployment** | | | | | | | |
|  | **CG (30 Mbps)** | | | | **VR/AR (30 Mbps)** | | | |
|  | **X=95%** | | **X=99%** | | **X=95%** | | **X=99%** | |
|  | **Uneven Load** | **Even Load** | **Uneven Load** | **Even Load** | **Uneven Load** | **Even Load** | **Uneven Load** | **Even Load** |
| **FR1** | 3 | 5 | 3 | 4 | 2 | 3 | 2 | 3 |
| **FR2** | 3 | 5 | 2 | 4 | 2 | 3 | 2 | 2-3 |

**CMCC**

Observation 1: In FR1 Indoor Hotspot scenario, the network capacity of XR service is 5 users per cell; the network capacity of CG service is 7 users per cell.

Observation 2: In FR1 Dense Urban scenario, the network capacity of XR service is 3 users per cell; the network capacity of CG service is 7 users per cell.

**Ericsson**

**DL capacity**

Observation 1: Already at moderate loads, it becomes difficult to fulfill the quality-of-experience targets.

Observation 2: Reducing the tail of the distribution of the HARQ retransmission may be beneficial to improve performance.

For Urban Macro, due to the increase ISD, the coverage is worse than for the Dense Urban scenario. Since the achievable bit rates are lower, so is the capacity. However, the difference is not dramatic: the capacities for 15ms PDB are 7 and 9 users per cell, for 99% and 95% quality thresholds. This illustrates that the potential for wide area XR deployment is good

**UL pose capacity**

The load has only a small impact on the performance on the quality-of-experience: the number of satisfied users is more or less independent of the load. On the other hand, there is a problem with coverage: some 20% of the users are unsatisfied, even at low load. This is clear when we compare the performance for only outdoor UEs: here more than 95% of the UEs are satisfied, irrespective of the load. If the packet delay budget is increased, more UEs become satisfied.

Note that we have run the UL pose traffic with dynamic scheduling: there is thus an inherent delay delivery of the packets: SR->BSR->UL data. Although configured grant may sound like a perfect use case for the pose traffic, dynamic scheduling may be the only realistic option for applications that are deployed at a wide scale.

**Power: DL CG**

**Table 2.3.1-1: XR capacity vs. UE power savings tradeoff (DL CG)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **DRX configuration  (DRX cycle, On duration, IAT)** | **Mean PS gain compared to baseline (%)** | **95%-tile PS gain**  **(highest Energy)** | **5%-tile PS gain**  **(lowest Energy)** | **%satisfied UEs (10UEs/cell)** |
| No DRX (baseline) | N/A | N/A | N/A | 96% |
| (10ms,3ms,1ms) | 25% | 22% | 32% | 80% |
| (10ms,5ms,1ms) | 15% | 13% | 16% | 88% |
| (10ms,5ms,5ms) | 11% | 9.0% | 12% | 96% |
| (10ms,8ms,1ms) | 5.0% | 3.8% | 5.9% | 95% |
| genie | 33% | 22% | 41% | N/A |

**Power: DL CG + UL pose**

**Table 2.3.2-1: XR UE power savings (DL CG + UL pose)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **DRX configuration** | **Mean PS gain compared to baseline (%)** | **95%-tile PS gain**  **(highest Energy)** | **5%-tile PS gain**  **(lowest Energy)** | **%satisfied UEs (10UEs/cell)** |
| No DRX baseline | N/A | N/A | N/A | 96% |
| genie | 18% | 12% | 23% | N/A |

We make the following preliminary observations from the initial evaluations.

* When DL XR traffic is considered without taking into account the PUSCH impact
  + contribution of “PDCCH monitoring” (i.e., PDCCH monitoring without scheduled data) to overall UE power consumption is larger (e.g. as shown in Figures 2.3.1-4a/4b)
  + Results show that at least for the evaluated cases, appropriate Rel15 long DRX settings can achieve some UE power savings gain without impacting XR user satisfaction (e.g ~9-12% as shown in Table 2.3.1-1)
* When both DL and UL PUSCH XR traffic is considered
  + PUSCH transmissions contribute a significant fraction to overall UE power consumption (e.g. as shown in Figures 2.3.2-3a/3b)

Even with relatively low XR DL data rate of 8Mbps, the achievable power savings is much reduced (e.g. idealistic genie assumptions show only 18% avg power savings potential compared to baseline as shown in Table 2.3.2-1)

**Qualcomm**

FR1:

Observation 1: Delay-aware scheduling could increase XR capacity.

Observation 2: Appropriate staggering across UEs within one cell could increase XR capacity.

Observation 3: Inter-cell interference coordination among different gNBs could increase XR capacity.

Observation 4: About 50% of UEs in UMa transmit with max tx power.

Observation 5: Tx power is saturated beyond 120dB of pathloss.

Observation 6: In general, UEs with higher pathloss have higher power consumption than that UEs with lower pathloss.

Observation 7: If a UE transmits with its max tx power, its UL power contribution could be larger than its DL power contribution.

Observation 8: Average DL spectral efficiency a good indicator for DL power consumption.

Observation 9: DL power contribution is proportional to average packet transfer time.

Observation 10: There is tradeoff relation between power saving gain and ratio of satisfied UEs per cell.

Observation 11: The enhanced CDRX (eCDRX) power saving scheme could provide better tradeoff relation than R15/16 CDRX.

Observation 12: Higher UE power consumption is expected for UMa scenario.

Observation 13: Current R15/16 CDRX scheme can provide limited power saving gain for XR.

Observation 14: The large room for further improvement in power saving is identified by Genie scheme.

Observation 15: Higher framerates requires higher UE power consumption for the same bit rate.

Observation 16: Higher bit rates requires higher power consumption.

Observation 17: Higher power saving gain is expected for cell center UEs than cell edge UEs.

Observation 18: There is large gap between Genie and R15/16 CDRX(8/4/4) for 30Mbps.

Observation 19: Shorter pose transmission periodicity require UE be awake longer and consumes high power.

Observation 20: eCDRX could provide good power saving gain w/ short On duration when there is no jitter.

Observation 21: When there is jitter, due to the lack of alignment caused by random jitter, satisfied UE ratio of eCDRX drops sharply.

Observation 22: Longer timer duration is needed to recover %UE for eCDRX, which washes out its power saving gain.

Observation 23: Fast wake up signal could be used to recover the PS gain loss of eCDRX due to jitter.

FR2:

Observation 1: For both InH and Dense Urban deployment scenarios, for a given PDB, the XR DL capacity increases as the bit rate of the application decreases.

Observation 2: For both InH and Dense Urban deployment scenarios, the XR DL capacity increases as the system bandwidth increases.

Observation 3: A bandwidth increase from 100 MHz to 400 MHz resulted in a higher capacity increase in the Dense Urban deployment use case compared to the InH deployment scenario.

Observation 4: Observation 4: We observe minimal improvement in capacity by doubling the frame rate in Dense Urban deployment.

Observation 5: Jitter has minimal impact on the XR system capacity for both InH and Dense Urban deployment scenarios.

Observation 6: Coordinated staggering of UE’s packet arrival at the gNB can increase XR capacity.

Observation 7: For both InH and Dense Urban deployments, the DDDSU achieves higher DL XR capacity than the DDDUU. This is capacity increase in larger when the configured bandwidth is 400 MHz compared to a bandwidth of 100MHz.

Observation 8: PDCCH Skipping and Cross-slot scheduling can provide power saving gains to UEs supporting XR traffic.

**ZTE**

[Observation 1: Up to 12 UEs could be supported in Indoor Hotspot scenario and up to 13 UEs could be supported in Dense Urban scenario when downlink date rate is 30Mbps.](#_Toc68612482)

[Observation 2: 6 UEs could be supported in Indoor Hotspot scenario and up to 8 UEs could be supported in Dense Urban scenario when downlink date rate is 45Mbps.](#_Toc68612483)

[Observation 3: Jitter using the values captured in the WA will cause slight performance loss in DL FR1.](#_Toc68612484)

[Observation 4: For uplink evaluation of interaction/pose information delivery, up to 24 UEs per cell could be supported in Indoor Hotspot scenario.](#_Toc68612485)

[Observation 5: Enhanced DRX has about 40% power saving gain with some capacity loss.](#_Toc68612486)

[Observation 6: For DL XR traffic in FR2, system capacity with 15 UEs per cell can be achieved in Indoor Hotspot scenario.](#_Toc68612487)

**InterDigital**

Observation-1: System Capacity, i.e., the maximum number of supported UEs out of which at least 90% of UEs are satisfied, is very limited in both Indoor hotspot and dense urban scenarios (up to 9 UEs @30Mbps and 10ms and up to 4 UEs @45Mbps and 10ms).

Observation-2: @45Mbps, system capacity increases by 50% when increasing PDB from 10ms to 15ms

**AT&T**

Observation 1: For a given traffic model and deployment scenario, FR1 and FR2 performance can vary significantly depending on the offered load and number of simultaneous users.

Observation 2: Optimizing XR performance for DL and UL jointly, especially in the context of multi-connectivity may be beneficial to support different tradeoffs for FR1 and FR2 deployments.

# Appendix-B (previous agreements)

## RAN1 #103-e

Agreement: **XR applications**

RAN1 confirms that diverse applications of VR1/2, AR1/2,~~(XR conference FFS),~~ CG are of interest for study. Potential prioritization/down selection of these applications for evaluation is to be discussed after detailed traffic models and relevant evaluation assumptions are stable.

* FFS: other applications, e.g., XR conferencing

Agreement: **Traffic model**

Traffic model for DL and UL should reflect various aspects, e.g., various bit rates, variable frame/packet (definition of frame/packet to be clarified with traffic model as necessary) size, and periodicity (how to model jitter is FFS).  RAN1 will strive to conclude on detailed traffic models in the next RAN1 meeting (104-e) where SA4 outcome on traffic model is expected to be available.

* Statistical model is preferred.
* It is preferred traffic model for both UL and DL have a certain degree of variability so that~~and~~ the total number of traffic models can be reduced.
* Note: Taking into account the fact that the decision on traffic models may hold many other crucial decisions, discussion on traffic model in the next RAN1 meeting is prioritized from the beginning.

Agreement:

Adopt the following deployment for XR/CG evaluations

* Indoor hotspot: FR1 and FR2
  + Detailed definition of Indoor hotspot refers to TR 38.913.
  + Channel model: InH. Detailed definition of InH refers to TR 38.901.
* Dense urban: FR1 and FR2
  + Detailed deployment refers to TR 38.913, where single layer with Marco layer is assumed.
  + Channel model: UMi. Detailed definition of UMi refers to TR 38.901.

FFS: Whether to prioritize FR1 for evaluation.

Note 1: When selecting the deployment and evaluation assumptions for XR/CG evaluations, it is up to company to evaluate FR1 or FR2 or both for the frequency range.

Note 2: It does not mean that all applications are evaluated for all the deployment scenarios.

Agreement:

Urban Macro can be ~~optionally~~ reported for XR/CG evaluations only for FR1.

* FFS: whether Uma is optional or not
* Following parameters can be assumed.

|  |  |
| --- | --- |
| **Parameter** | **Proposed value** |
| **Urban Macro (FR1)** |
| Layout | 21cells with wraparound ISD = 500 m |
| BS Tx power | FR1: 49 dBm/20 MHz |

Agreement:

It is to be further discussed how to prioritize the combinations of deployment scenarios and applications after traffic models for each application are stable.

Agreement:

System capacity is defined as the maximum number of users per cell with at least X % of UEs being satisfied.

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

Note: The exact ‘satisfied’ requirements will be discussed separately

FFS: how to calculate the percentage of satisfied users across multiple drops of simulations

Agreement:

* Adopt the simulation assumptions in table 1 as below

Table 1: Simulation assumptions for XR evaluation (Part 1) (updated)

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Proposed value** | |
| **Indoor hotspot FR1/FR2** | **Dense urban FR1/FR2** |
| Layout | 120m x 50m ISD: 20m TRP numbers: 12 | 21cells with wraparound ISD: 200m |
| Carrier frequency | FR1: 4 GHz  FR2: 30 GHz | |
| Subcarrier spacing | FR1: 30 kHz  FR2: 120 kHz | |
| BS height | 3m | 25m |
| UE height | hUT=1.5 m | |
| BS noise figure | FR1: 5 dB  FR2: 7 dB | |
| UE noise figure | FR1: 9 dB  FR2: 13 dB | |
| BS receiver | MMSE-IRC | |
| UE receiver | MMSE-IRC | |
| Channel estimation | Realistic  FFS:Ideal(optional) | |
| UE speed | 3 km/h | |
| MCS | Up to 256QAM | |
| BS antenna pattern | Ceiling-mount antenna radiation pattern, 5 dBi | 3-sector antenna radiation pattern, 8 dBi |
| UE antenna pattern | FR1: Omni-directional, 0 dBi,  FR2: UE antenna radiation pattern model 1, 5dBi | |

Agreement:

Adopt the following UE distribution for XR/CG evaluation for outdoor scenario

* For outdoor scenario:
  + FR1: 80% indoor, 20% outdoor
  + FR2: 100% outdoor

Other UE distribution can be evaluated optionally.

Agreement:

Adopt the following TDD configuration for XR/CG evaluation

* FR1:
  + Option 1: DDDSU
  + Option 2: DDDUU
* FR2:
  + Option 1: DDDSU

FFS detailed S slot format

Note: Other TDD configuration or FDD can be optionally evaluated.

Agreement:

Adopt the following BS antenna parameters for indoor scenario for XR/CG evaluation

* FR1:
  + 32 TxRU, (M, N, P, Mg, Ng; Mp, Np) = (4,4,2,1,1;4,4)
  + (dH, dV) = (0.5, 0.5)λ
* FR2:
  + Option 2: 2 TxRU, (M, N, P, Mg, Ng; Mp, Np) = (16, 8, 2,1,1;1,1)
  + (dH, dV) = (0.5, 0.5)λ

Other BS antenna parameters can be optionally evaluated

Agreement:

For XR/CG evaluation, adopt the following assumptions for downtilt

* Dense Urban
  + FFS: 6 or 12 degree
  + ~~Other downtilt can be optionally evaluated.~~
* Indoor hotspot
  + 90° (pointing to the ground)

Other downtilt can be optionally evaluated

Agreement:

* Adopt the simulation assumptions in table 3 as below

Table 3: Simulation assumptions for XR evaluation (Part 3)

|  |  |
| --- | --- |
| **Power control parameter** | Companies should report |
| **Transmission scheme** | Companies should report~~, such as Type I/II codebook, rank assumption~~ |
| **Scheduler** | SU/MU-MIMO PF scheduler (company to report SU or MU),  other scheduler (e.g., delay aware scheduler) is up to companies report |
| **CSI acquisition** | Realistic  Both CSI feedback and SRS are considered  Companies 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, etc  and etc. |
| **PHY processing delay** | Baseline: UE PDSCH processing Capability #1  Optional: UE PDSCH processing Capability #2  Companies 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 |

Agreement:

The following aspects are to be discussed after traffic model is stable.

* For the system capacity definition, how to determine whether a UE is satisfied or not is to be deferred until the exact traffic model along with how to measure E2E user experience is available. Additional metrics to be collected will be further discussed after traffic model is stable.
* Various options for traffic arrival offset among UEs per cell were proposed by companies, e.g., even offset, random offset, no offset. It will be discussed after traffic model is determined.

Agreement:

System bandwidth for XR/CG evaluations are as follows.

* For FR1,
  + Baseline: 100 MHz
  + Optional: 20/40 MHz (FFS: 200 MHz)
* FFS FR2

Agreement:

For outdoor scenarios, the ~~baseline~~ BS antenna parameters are as follows.

* FFS FR1,
  + 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)
  + Option 3: 32TxRUs (M, N, P, Mg, Ng; Mp, Np) = (4,4,2,1,1,4,4)

(dH, dV) = (0.5λ, 0.~~8~~5λ)

* FR2:
  + TxRU, (M, N, P, Mg, Ng; Mp, Np) = (4,8,2,2,2;1,1)

(dH, dV) = (0.5λ, 0.5λ)

Other configurations can be optionally evaluated.

Agreement:

UE antenna parameters for XR/CG evaluations are as follows

* FR1:
  + 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
* FFS FR2: down-selection between the next two options. Please indicate if you have preference.
  + Option 1 (Follow Rel-17 evaluation methodology for FeMIMO in [R1-2007151](file:///E:\Workspace\3GPP%20related\3GPP%20meeting\2021\2021.Q2\RAN1%23104b-e\Summary\Docs\R1-2007151.zip))
    - (M, N, P)=(1, 4, 2), 3 panels (left, right, top)
    - (Mp, Np) is up to company. Need to be reported with simulation result.
  + 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°

Agreement:

BS Tx power for XR/CG evaluations are as follows

* For Indoor hotspot:
  + FR1:
    - 24 dBm per 20 MHz
  + FR2:
    - 23 dBm per 80 MHz. EIRP should not exceed 58 dBm
* For Dense urban:
  + FR1:
    - 44 dBm per 20 MHz
  + FR2:
    - 40 dBm per 80 MHz. EIRP should not exceed 73 dBm

For system BW larger than above, Tx power scales up accordingly.

Agreement:

UE max Tx power for XR/CG evaluations are as follows

* FR1: 23 dBm
* FR2: 23 dBm, maximum EIRP 43 dBm

Agreement: **Baseline power evaluation methodology**

~~If UE power consumption is agreed as a KPI for evaluation of XR performance over NR,~~TR38.840 is the baseline methodology potentially with some modifications if necessary.  RAN1 aim to minimize modeling effort. ~~For example, the following aspects can be considered for further discussion but not limited to.~~

* ~~FFS whether/how to model UE power consumption for UE tx power other than 0dBm and 23dBm,~~
* ~~FFS whether/how to model UE power consumption for UL slots that are not defined in TR38.840~~
* ~~FFS whether/how to model UE power consumption for ‘S’ slot~~
* ~~FFS whether/how to model UE power consumption for 400MHz in FR2 including scaling rule for FR2 BWP adaption.~~
* ~~FFS whether/how to model UE consumption for the corresponding number of Tx antennas~~
* ~~FFS whether/how to model the UE power consumption for UE tx power under FR2~~

Agreement:

* RAN1 continues to discuss evaluation methodologies for UE power consumption and system capacity.
* RAN1 is to discuss whether/how to study/evaluate mobility and coverage at a later stage, e.g., starting from Q1 2021.

## RAN1 #104-e

Agreements**:** RAN1 adopts a parameterized statistical traffic model for evaluation of XR and CG, and KPI with details as shown below (RAN1 strives to agree on the remaining details during RAN1 #104e, based on SA4 input):

* There are M1 and M2 streams in DL and UL respectively
  + At least adopt the case where M1=1 & M2=1
  + FFS the values of M1 and M2, including the possibility of being application-dependent
* DL
  + Air interface Packet Delay budget (PDB)
    - Air interface delay is measured from the point when a packet arrives at gNB to the point when it is successfully delivered to UE
    - Air interface PDB for video streaming
      * VR/AR: [10ms (mandatory), 20ms (optional)]
      * CG: [15ms (mandatory), 30ms (optional)]
        + FFS: other optional values
* Per UE KPI
  + Baseline: A UE is declared a satisfied UE if more than X (%) of packets are successfully transmitted within a given air interface PDB. The exact value of X is FFS.
  + FFS: In addition to the baseline, the following additional method is FFS
    - When determining a XR/CG user is satisfied or not, the following factors are considered. FFS how to use those factors.
      * Packet loss information
      * Packet delay information
      * Some XR/CG source related information if they can be available within RAN, e.g. the mapping between packet and slices or frames and the packet importance
      * Multiple data streams traffic model
  + FFS if there are multiple streams (if adopted)
* FFS additional aspects not addressed above.
* Note 1: Companies are encouraged to provide details such as parameters (e.g., mean, STD, etc.), distributions, etc., by analyzing SA4 input, e.g., V/S/P traces
* Note 2: All FFS points above are to be further discussed in RAN1 #104e

Agreements

* Statistical traffic model for a single DL video stream for a single UE
  + The statistical traffic model for a single UE for a single DL video stream in Figure 1 is adopted, where a packet is assumed to represent multiple IP packets corresponding to a single video frame for modelling/evaluation purposes, e.g., traffic arrival, packet size, evaluation of latency and reliability.



* Frame per second (fps) for DL video stream for a single UE
  + 60 fps (baseline)
  + 120 fps (optional)
  + Other values, e.g., 30, 90 fps can be also optionally evaluated.
* Average data rate for DL video stream:
  + VR/AR: 30, 45 Mbps @60fps (baseline)
    - ~~30,~~ 60 Mbps @60fps (optional)
    - Note: this is the aggregated data rate when applicable
  + CG: 8, 30 Mbps @60fps (baseline)
    - ~~8,~~ 45 Mbps @60fps (optional)
  + Other values (in combination with fps) can be also optionally evaluated.
* Truncated Gaussian distribution is used for the packet size distribution of video stream for AR/VR/CG.
  + Other distribution is not precluded.
* (Working assumption) Parameters of Truncated Gaussian distribution for Packet size (note: these parameter values are those before the truncation)
  + Mean: Derived from average data rate and fps as follows.
    - (average data rate) / (fps for video stream, i.e., # packets per second in our statistical model) / 8 [bytes]
  + STD
    - TBD
  + Max packet size
    - TBD
  + Min packet size
    - TBD
    - FFS whether or not to use this parameter
* Per UE KPI
  + Baseline: A UE is declared a satisfied UE if more than X (%) of packets are successfully transmitted within a given air interface PDB.
    - The exact value of X is FFS, e.g., 99, 95
      * FFS different values for I-frame and P-frame if evaluation of them is agreed.
      * Other values can be optionally evaluated
* DL traffic model: video stream
* (Working assumption) Parameters of Truncated Gaussian distribution for Packet size (note: these parameter values are those before the truncation)
  + Mean: Derived from average data rate and fps as follows.
    - (average data rate) / (fps for video stream, i.e., # packets per second in our statistical model) / 8 [bytes]
  + STD
    - [15% of Mean packet size derived above]
    - Note: The above value is an example for further investigation, and is to be revisited potentially with more inputs from companies in RAN1#104-bis-e
  + Max packet size
    - [1.5 x Mean packet size derived above]
    - Note: The above value is an example for further investigation, and is to be revisited potentially with more inputs from companies in RAN1#104-bis-e
  + Min packet size
    - TBD
    - FFS whether or not to use this parameter
    - Note: This is to be revisited potentially with more inputs from companies in RAN1#104-bis-e.
* Jitter for DL video stream for a single UE
  + (Already agreed) Per the agreed statistical traffic model, arrival time of packet k is k/X1000 [ms] + J [ms], where X is the given fps value and J is a random variable.



* + (Newly proposed agreement) J is drawn from a truncated Gaussian distribution:
    - Mean: [0]
    - STD: [2 ms]
    - Range: [[-4, 4]ms]
      * Note: The values ensure that packet arrivals are in order (i.e., arrival time of a next packet is always larger than that of the previous packet)
    - Note: The above values for mean, STD and Range are working assumption for initial simulations, and is to be revisited potentially with more inputs from companies in RAN1#104-bis-e
* Air interface PDB for DL video stream
  + VR/AR:
    - 10ms
    - Other values, e.g., 5ms, 20 ms can be optionally evaluated.
  + CG:
    - 15ms
    - Other values, e.g., 10ms, 30ms can be optionally evaluated.
  + FFS whether or not to have more than one mandatory value

Working assumption: On UL Traffic model and QoS parameters

* CG/VR: single stream (pose/control)
* Traffic model for Pose/control
  + Periodic: 4ms (no jitter)
    - Other values can be optionally evaluated.
  + Fixed: 100 bytes (SA4 input)
  + PDB: 10 ms
* AR
  + FFS

Agreements: On evaluation of multiple streams/flows:

* FFS the following in RAN1#104-bis-e
  + Whether/how to model and evaluate I-frame and P-frame for both DL and UL, e.g., separate definition of fps, packet size, QoS requirements (e.g., PER, PDB), etc.
  + Whether/how to separately model and evaluate two streams of video and audio/data for both DL and UL
  + Whether/how to model and evaluate FOV (high-resolution) and non-FOV (lower-resolution omnidirectional) streams, e.g., separate definition of fps, packet size, QoS requirements (e.g., PER, PDB), etc

Agreement: Adopt following update for TDD configuration for XR/CG evaluation

* FR1:
  + Option 1: DDDSU
  + Option 2: DDDUU
* FR2:
  + Option 1: DDDSU
  + Option 2: DDDUU

Detailed S slot format is 10D:2F:2U. Other S slot format(s) can also be optionally evaluated.

Further clarify that for option 2 for FR1/FR2, there is [2]-symbol gap at the end of third “D” slot of  DDDUU.

FFS whether or not to differentiate the two options (e.g., mandatory vs. optional)

Agreement**:** For XR evaluation, ideal channel estimation can be optionally evaluated.

Agreements**:** System bandwidth for XR/CG evaluations are as follows.

* For FR1,
  + Baseline: 100 MHz
  + Optional: 20/40 MHz, 2\*100 MHz with CA
* FR2
  + Option 1: 100 MHz
  + Option 2: 400 MHz

Companies should report the CA setting if CA is adopted.

Other system bandwidth can also be optionally evaluated.

Agreements**:**For outdoor scenarios, the BS antenna parameters are as

* 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)

Company to report the BS antenna parameters for XR/CG evaluation.

Other BS antenna parameters can also be optionally evaluated.

Agreements**:**For FR2, UE antenna parameters for XR/CG evaluations are as follows.

* 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°

Company to report the UE antenna parameters for XR/CG evaluation.

Other UE antenna parameters can also be optionally evaluated.

Agreements**:** For XR/CG evaluation, adopt following assumptions for BS height for Urban Macro

|  |  |
| --- | --- |
| **Parameter** | **Proposed value** |
| **Urban Macro (FR1)** |
| BS height | 25m |

Agreements**:** 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.

|  |  |  |
| --- | --- | --- |
|  |  | Urban Micro/Macro cell  with high UE density  (3D-UMi) /(3D-UMa) |
| UE height (*hUT*) in meters | general equation | *hUT*=3(*nfl* – 1) + 1.5 |
| *nfl* for outdoor UEs | 1 |
| *nfl* for indoor UEs | *nfl* ~ uniform(1,*Nfl*) where  *Nfl* ~ uniform(4,8) |

Agreements: At least for XR/CG capacity evaluation, for DL and UL

* Baseline: DL and UL performances are evaluated independently
* Optional: DL and UL performance are evaluated together
* FFS details both the baseline and the optional evaluations

Agreements: For Dense urban for XR/CG evaluation, update the agreement in RAN1 #103e for channel model as follows.

* Dense urban: FR1 and FR2
  + Channel model: ~~UMi~~ UMa. Detailed definition of ~~UMi~~ UMa refers to TR 38.901.

Agreements: For XR/CG evaluation, adopt 12 degree for downtilt for Dense Urban in FR1.

* Other downtilt value can also be optionally evaluated

Agreements: To facilitate further discussion on evaluation of power saving effect of different power saving schemes, the following references are defined.

* Case 1 (baseline): UE power consumption assuming UE is always ON, i.e., UE is always available for gNB scheduling.
* Case 2 (FFS optional or baseline): UE power consumption assuming Rel-15/16 CDRX configuration
  + FFS CDRX configuration details
* Company can also optionally evaluate ~~for~~ other cases, e.g.
  + Genie: UE power consumption assuming 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, UE is always available for scheduling, i.e., there is no difference from Baseline in gNB scheduling and corresponding UE Tx/Rx. ~~It is noted that Genie is not a power saving scheme but the result may serve as an upper bound of power saving gain of power saving techniques, which may potentially motivate development of new power saving techniques that can approach the Genie performance.~~
  + R15/16/17 power saving techniques for connected mode, e.g., BWP, PDCCH skipping, search space switching, etc.

**Decision:** As per email posted on Feb 5th,

Agreements:

UE power consumption (i.e., power saving gain of the evaluated scheme) for XR is evaluated in conjunction with impact on latency, user experience, and capacity.  In this regard, the following table is used to collect results for system level simulation from companies as a starting point.

* FFS all UEs or only satisfied UEs are included for obtaining the PS gain

Table 1 Evaluation of UE power saving schemes for e.g., {dense urban, AR, FR1}

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Power Saving Scheme | Power Saving Gain (PSG) compared to Case 1 | | | | #satisfied UEs per cell2 / #UEs per cell3 |
| Baseline | Optional | | |
| Mean PS gain | PS gain of 5%-tile UE in PSG CDF1 | PS gain of 50%-tile UE in PSG CDF1 | PS gain of 95%-tile UE in PSG CDF1 |
| Case 1 | - | - | - | - | K1 / N |
| Case 2 | X1 % | Y1 % | Z1 % | U1% | K2/ N |
| Case X | X2 % | Y2 % | Z2 % | U2% | K3 / N |
|  |  |  |  |  |  |

Note 1: CDF of power saving gains of ~~each~~ UE

Note 2: # of satisfied UEs per cell among # of UEs per cell (=N).

Note 3: # of dropped UEs per cell (=N) that needs to be the same for all power saving schemes to be evaluated.

Note 4: company to provide the detailed simulation assumptions including parameter values for each case, e.g. CDRX parameters

~~Note 5: company can report one or more power saving gain metrics (i.e. mean PS gain or PS gain of 5%/50%/95%/-tile UE in PSG CDF) for each power saving scheme~~

Agreements: For UL UE power consumption evaluation for UE with transmit power X [0,23] dBm, adopt the following

* Option 1 ~~(Baseline)~~: 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.
    - M = [20]
    - Other value(s) of M can be optionally evaluated
  + ~~Companies to provide detailed assumptions on UE power consumption for Tx power values other than 0 and 23 dBm~~ 
    - ~~E.g. Power number is given as~~ **~~A~~** ~~for X= [0, 20)dBm and~~ **~~B~~** ~~for X =[20, 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.~~
* Option 2 ~~(FFS mandatory or optional)~~: Linear interpolation method in linear scale for Tx power values other than 0 dBm and 23 dBm
* FFS whether or not to differentiate the two options (e.g., mandatory vs. optional)
* FFS whether or not to consider UE with transmit power less than 0 dBm