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

e-Meeting, January 25th – February 5th, 2021

Source: Moderator (vivo)

Title: Email discussion for evaluation methodology and assumptions

Agenda Item: 8.14.2

Document for: Discussion and Decision

# Introduction

This contribution is a summary on the email discussion on other evaluation methodology and assumptions for XR and Cloud Gaming in the contributions [1-18] submitted under AI 8.14.2.

[104-e-NR-XR-02] Email discussion/approval for other evaluation methodology and assumptions – Xiaohang (vivo)

* 1st check point: 1/28
* 2nd check point: 2/2
* 3rd check point: 2/4

# Discussion

## Applications and deployment scenarios

Following companies discussed the applications and deployment scenarios for XR/CG evaluations.

[Ericsson] proposed a priority for evaluation: CG > AR > VR. For CG and AR, Dense urban is prioritized. For VR, indoor hotspot is prioritized.

[Huawei] proposed to prioritize Dense urban and Urban Macro for FR1.

[Qualcomm] proposed the suggested evaluation scenarios for VR/AR/CG.

[ZTE] proposed to prioritize indoor for AR2 and CG, CG and UMi for VR2.

[vivo] proposed to prioritize indoor hotspot for VR2, CG, Dense urban for CG and AR2, and Urban Macro for AR2.

[Xiaomi] proposed to prioritize indoor for VR, both indoor and outdoor for AR/CG.

**Q1: The deployment scenarios for evaluation may be applied to each of XR/CG applications of interest. However, if all the XR/CG applications are considered, there will be too many combinations of deployment scenarios and XR/CG applications, which could lead to numerous simulation work. Therefore, it may be desirable to consider prioritization of combinations of deployment scenarios and XR/CG applications, e.g.,**

* **For VR**
  + **Indoor hotspot**
* **For AR**
  + **Dense urban**
  + **Indoor hotspot**
* **For CG**
  + **Dense urban**
  + **Indoor hotspot**

**Please note that with such prioritization, companies can still submit evaluation results for de-prioritized scenarios.**

1. **Please share your views on the above question.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | We support prioritizing the following cases.   * For VR   + Indoor hotspot * For AR   + Dense urban (1st preference)   + Indoor hotspot (2nd preference) * For CG   + Dense urban (2nd preference)   Indoor hotspot (1st preference) |
| CATT | We are OK to have all of them. |
| ZTE , Sanechips | Firstly, FR1 should be prioritized for evaluation. In RAN1 #103-e meeting, evaluation methodology and assumption for FR1 were mostly accomplished. RAN1 still need more work on evaluation methodology including the bandwidth and UE antenna for FR2. It is much easier to have a set of agreeable simulation assumption for FR1.  Secondly, we prioritize indoor for AR2 and CG, Umi for CG and VR2. For VR2, it is a rendered version of a delivered visual and audio scene requiring a user to wear a head mounted display, to completely replace the user's field of view with a simulated visual component, and to wear headphones, to provide the user with the accompanying audio. For AR2, XR conversational, one of applications of AR2, is an application when a user is provided with additional information or artificially generated items or content overlaid upon their current environment featuring more UL traffic. People usually have a meeting at office or at home. For CG, it can be played using a device, and used in both indoor and outdoor scenarios. |
| OPPO | We can postpone this discussion until the traffic models are agreed. If the traffic models are the same or similar for different types of applications, then we don’t need to differentiate the applications for RAN1 evaluation. From RAN1 perspective, we only need to discuss the combination of agreed traffic models and deployment scenarios. |
| AT&T | We are fine with the proposed prioritization. |
| Intel | Ok to have all the scenarios. Can prioritize Dense Urban Micro for AR/CG. |
| DOCOMO | We are fine with the proposed prioritization. |
| vivo | We support FL’s proposal. |
| Facebook | Fine with proposal |

## Capacity evaluation methodology

### Methodology

**DL and UL evaluation dependency**

[Xiaomi, Nokia, OPPO, vivo, Qualcomm] discussed the dependency of DL and UL evaluation

[Xiaomi, Nokia, OPPO, vivo] proposes that DL and UL capacity are evaluated separately.

[Qualcomm] proposes to simulate DL and UL together to capture interaction between DL and UL in power evaluation.

For simulation purpose, DL and UL capacity can be evaluated independently to simplify the simulation. On the other hand, since there are interactions between DL and UL for XR/CG applications, it would be good to evaluate XR/CG considering the dependency of DL and UL. Besides, considering both DL and UL transmission in the simulation, it is more accurate to evaluate the performance of capacity or power for XR/CG. However, the evaluation considering DL and UL together would bring additional complexity for simulation. So it can be optional for companies to do such evaluation.

**Proposal 1: For XR/CG evaluation, for DL and UL**

* **Option 1: DL and UL performances are evaluated independently (baseline)**
* **Option 2: DL and UL performance are evaluated together (optional)**

1. **Please share your views on the above** **proposal.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| Nokia, NSB | We would like to adjust the listed proposal a bit, as there might be some confusion here related to “DL and UL separately” vs. “DL and UL together”.  There are several possibilities:  Option 1: DL and UL traffic are modelled separately. In this case, one simulation is run with only DL traffic, while the other one with only UL.  Option 2. DL and UL traffic are modelled together, but the DL-related and UL-related metrics are captured separately. These metrics can be further combined into unified metrics, but they are originally captured separately.  Option 3. DL and UL traffic are modelled together, there is no separation between DL-related and UL-related metrics.  Out of these options, we prefer Option 2 (modelling both DL and UL traffic together but distinguishing the DL and UL metrics).  Option 1 is the easiest to simulate, but the obtained results for capacity and UE power consumption may be too optimistic. E.g., if the cell supports 10 XR devices in DL (DL-only traffic) and 10 XR devices in UL (UL-only traffic), this doesn’t mean that the cell supports 10 XR devices if both DL and UL traffic are present together. In fact, this doesn’t tell us much on how may XR devices the cell supports with both DL and UL traffic (the value may range anywhere from 0 to 10).  Option 3 is similar to Option 2 in modelling assumptions, but it does not allow to carefully analyse the possible bottlenecks in supporting XR services. Particularly, it is important to see, which direction of traffic is a limiting factor: e.g., a higher-rate but less critical video in DL or a lower-rate but delay-sensitive pose update in UL. If the companies just report “12 XR devices are satisfied”, we lose a lot of important and useful information. |
| QC | We support Proposal 1.  Ideally it would be the best to simulate jointly DL and UL to accurately evaluate the performance affected by interaction between DL and UL. However, considering simulation complexity, separate simulations can be considered as baseline, which would be able to capture most of key performance aspects especially for capacity evaluation. When it comes to power evaluation, result from separate evaluations would not capture accurately UE sleeping behaviour (in reality, UE cannot sleep when there is activity in either DL or UL), and therefore joint DL & UL simulation would be beneficial. But, again taking into account simulation complexity, we are okay to make joint DL & UL simulations optional even in power evaluation. |
| CATT | Option 1: DL/UL are simulated independently. |
| ZTE , Sanechips | We support Option 1.  Firstly, XR applications are characterized by more intensive DL traffic, hence, we ought to prioritize evaluation for DL.  Secondly, DL-related simulation and UL-related simulation separately can facilitate the result reporting/collection from companies.  Thirdly, DL-related simulation and UL-related simulation separately has simpler workload than simulation simultaneously. |
| OPPO | Support proposal 1. Which option is used in evaluation is up to companies |
| AT&T | We prefer Option 2, especially as clarified by Nokia. Option 1 is not realistic and may miss key aspects of practical system operation which impact XR performance. |
| Intel | Ok with current proposal with Option 1 as baseline. For Option 2, we prefer Option 2 from Nokia above with the clarification that DL and UL traffic is modelled based on independent parameters but in the same simulation. |
| DOCOMO | We prefer Option 2 clarified by Nokia. |
| vivo | We support the proposal and the clarification of option 2 by Nokia. |
| Facebook | Fine with option 1 |
| Apple | Fine with FL proposal |

### Evaluation assumptions

**Channel estimation**

In RAN1 #103e, it was agreed that realistic channel estimation is adopted for XR/CG evaluations. Regarding whether or not the include ideal channel estimation for the XR/CG evaluations, companies’ views are summarized as below based on the input.

|  |  |
| --- | --- |
| Channel estimation | Realistic  FFS:Ideal(optional) |

* Ideal is also considered
  + *Nokia, CATT, LG, Samsung, Huawei, vivo*

Realistic channel estimation is necessary to evaluate the performance in practical deployment. Meanwhile, Ideal channel estimation can be useful for evaluation. Hence,

**Proposal 2: in addition to realistic channel estimation, ideal channel estimation can be optionally evaluated.**

1. **Please share your views on the above** **proposal.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | To reduce workload, we propose realistic only. |
| CATT | No need for IDEL channel estimation |
| ZTE , Sanechips | Object. Companies’ simulation results are largely based on the realistic assumption including realistic channel estimation. We don't see the benefit of providing additional results for ICE. |
| OPPO | If the realistic channel estimation is used as the baseline, we are not sure what the benefit of the additional evaluation with ideal channel estimation is.  If companies are free to select one of them, we are ok to keep the two options (realistic and ideal) |
| AT&T | Realistic channel estimation is sufficient |
| Intel | IMT-2020 assumed realistic channel estimation and this should be sufficient for XR. Interested companies can always submit additional results. |
| DOCOMO | Realistic channel estimation is sufficient but we are OK to keep ideal channel estimation as optional. |
| vivo | We support the proposal. |
| Facebook | Realistic channel estimation should be sufficient. |

**TDD configuration for XR/CG evaluation**

Regarding TDD configuration for XR/CG evaluation, companies input in RAN1 #104e is summarized as below.

* FR1:
  + Option 1: DDDSU
    - *MTK*
  + Option 2: DDDUU
    - *Apple (for AR2), Samsung*
* FR2:
  + Option 1: DDDSU
  + Option 2: DDDUU is also introduced
    - *Qualcomm*

S slot format is constructed as

* S = 10:2:2
  + *Qualcomm, MTK, Nokia, ZTE, DCM, vivo*
* S = 11:1:2
  + *CATT*
* S = D or U
  + *Huawei*

**Proposal 3: 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**

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

1. **Please share your views on the above** **proposal.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | We support Proposal 3. |
| CATT | We are OK with Proposal 3 |
| ZTE , Sanechips | Firstly, we regard 10D:2F:2U as an example of the detailed S slot format. Other formats are also considered. Companies can report the S slot format and evaluate with other S slot formats. This can be one of further studying points.  Secondly, according to agreement in RAN1-103-e meeting, it has been noted that other TDD configuration or FDD can be optionally evaluated. Hence, it is not necessary to add another option in FR2.   |  | | --- | | 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. |   Moreover, due to various possibilities of S slot format, the frame structure of Option 1 in FR2 can achieve that of Option 2 by using S slot format: 2F:12U. |
| AT&T | We are OK with Proposal 3. |
| DOCOMO | Support the proposal. |
| vivo | We support the proposal. |
| Facebook | OK with the proposal |

**Downtilt for XR/CG evaluation**

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

* Dense Urban
  + 12 degree
    - *FutureWei, Samsung (Dense urban), Qualcomm (Dense Urban, FR1, no need for FR2), Huawei, ZTE (Dense urban), OPPO (Dense Urban), vivo (Dense urban)*
  + 6 MDT and 6 EDT
    - *Nokia*

**Proposal 4: For XR/CG evaluation, adopt 12 degree for downtilt for Dense Urban in FR1.**

1. **Please share your views on the above** **proposal.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | Prefer 12 degree. |
| CATT | We are OK with proposal 4 but considering the assumption not realistic |
| ZTE , Sanechips | Support. |
| OPPO | Support proposal 4 |
| Intel | The down tilt should be a function of ISD and BS antenna height. Typically, 12 degree for Dense Urban Macro with 25m BS height provides good coverage. For Dense Urban Micro with 10m BS height, 10 degrees yields better spectral efficiency. |
| DOCOMO | Support the proposal. |
| vivo | We support the proposal. |

**System bandwidth for XR/CG evaluations**

* FR1
  + 100MHz baseline
    - *CATT*
  + No need to support 200 MHz
    - *Samsung, OPPO*
  + CA with 20/40 MHz per CC can be used optionally
    - *Samsung*
  + CA with 2\*100 MHz can be used optionally
    - *MTK, ZTE, vivo*
* FR2
  + 400 MHz
    - *Samsung, Qualcomm, DCM, OPPO, vivo*
  + 800 MHz as optional
    - *Qualcomm*
  + 100 MHz as baseline
    - *Nokia, CATT, DCM, OPPO*
  + 2\*100 MHz and 4\*100 MHz can be optional
    - *Nokia*

It is also proposed by [ZTE] that companies can report CA setting and evaluate with other system bandwidth using CA

It is needed for companies to clarify the motivation and potential benefit for CA modeling in XR/CG evaluation.

**Proposal 5: 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**

1. **Please share your views on the above** **proposal.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | Support Proposal 5. |
| CATT | We are OK with Proposal 5 |
| ZTE , Sanechips | Support. |
| OPPO | Support in principle. |
| AT&T | We are OK with Proposal 5 |
| DOCOMO | Support the proposal |
| vivo | We support the proposal. |

**BS antenna parameters**

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

* FR1,
  + Option 1: 64 TxRU, (M, N, P, Mg, Ng; Mp, Np) = (8,8,2,1,1;4,8)
    - *Qualcomm, Huawei, MTK, ZTE, vivo*
  + Option 2: 32 TxRU, (M, N, P, Mg, Ng; Mp, Np) = (8,2,2,1,1,8,2)
    - *Samsung, CATT, LG, OPPO*
  + Option 3: 32TxRUs (M, N, P, Mg, Ng; Mp, Np) = (4,4,2,1,1,4,4)
    - *Nokia (baseline)*

(dH, dV) = (0.5λ, 0. 5λ)

**Proposal 6: For outdoor scenarios, the  BS antenna parameters are as**

* **(M, N, P, Mg, Ng) = (8,8,2,1,1), (Mp, Np ) is reported by companies**

**(dH, dV) = (0.5λ, 0. 5λ)**

1. **Please share your views on the above** **proposal.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | We support Proposal 6 as a compromised solution. |
| CATT | We are OK with Proposal 6 |
| ZTE , Sanechips | **Proposal 6: For outdoor scenarios, the  BS antenna parameters are as**   * **~~(M, N, P, Mg, Ng) = (8,8,2,1,1), (Mp, Np ) is reported by companies~~** * **64 TxRU, (M, N, P, Mg, Ng; Mp, Np) = (8,8,2,1,1;4,8)**   **(dH, dV) = (0.5λ, 0. 5λ)**  Is this a typo? For the BS antenna parameters, we support Option 1.Large number of antennas can increase the system capacity. In TR 38.830, BS antenna configuration of (M,N,P,Mg,Ng) = (8,8,2,1,1) can be used for Urban deployment. |
| OPPO | Ok with Proposal 6 since it seems the only way for progress/compromise |
| AT&T | Ok with the FL proposal |
| Intel | It would be more ideal to agree on TXRUs, otherwise simulation results comparison and averaging across companies can be difficult (as seen in IMT-2020). Option 1 can be used. |
| DOCOMO | Support the proposal |
| vivo | We support the proposal. |
| Apple | We support Option 2, we don’t need to repeat the discussion in RAN1 103-e. |

**UE antenna parameters**

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
    - 1T/2R
      * *Apple, Samsung*
* FR2:
  + Option 1 (Follow Rel-17 evaluation methodology for FeMIMO in R1-2007151)
    - (M, N, P)=(1, 4, 2), 3 panels (left, right, top)
    - (Mp, Np) is up to company. Need to be reported with simulation result.
    - *Samsung, Qualcomm, Nokia, LG(optional), OPPO (panel setting is up to company), vivo*
  + 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°
    - *MTK, ZTE, CATT, LG (baseline)*

**Proposal 7: For FR2, adopt Option 1 (Follow Rel-17 evaluation methodology for FeMIMO in R1-2007151) for UE antenna parameters for XR/CG evaluations.**

* **(M, N, P)=(1, 4, 2), 3 panels (left, right, top)**

1. **Please share your views on the above** **proposal.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | Support Proposal 7. Option 1 is already widely being used in other WI and also capture typical FR2 antenna panel design. |
| CATT | Option 2. We would like to align with TR38.802 |
| ZTE , Sanechips | Object. We prefer Option 2. In our opinion, Option 1 would require companies to report (Mp, Np) parameters, risking having different results due to the different settings. To better compare the companies' results, unified parameters are better choice. |
| OPPO | ok |
| AT&T | Ok with proposal 7 |
| Intel | Note that in R1-2007151, the UE panels are (left, right **and back**) and not top. |
| DOCOMO | Fine with the proposal |
| vivo | We support the proposal. |

**UE antenna height for Dense urban**

[Intel] discussed the UE antenna height for indoor UEs in Dense urban. It is proposed that indoor UEs are considered to be evenly distributed in different floors of a building (buildings ranging in height from 4 floors to 8 floors)

FL comment: the suggestion by Intel is valid. For indoor UEs in Dense urban, UEs are distributed in different floors. The modelling of building height for UEs in UMi is considered in 38.901, which refers to 3D-UMi in TR36.873. For Dense urban for XR/CG evaluations, the same modeling can be adopted.

**Proposal 8: the UE antenna height for indoor UEs is updated as following based on Table 6-1 in TR 36.873.**

|  |  |  |
| --- | --- | --- |
|  |  | Urban Micro cell  with high UE density  (3D-UMi) |
| **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) |

1. **Please share your views on the above** **proposal.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | Support the update. |
| CATT | We are OK for the update |
| ZTE , Sanechips | We prefer to implement this as a RAN1 conclusion or add a note for clarification. Frankly speaking, our understanding of the previous agreement is what this proposal means. |
| DOCOMO | OK with the update. |
| vivo | We support the proposal. |

**BS antenna height for Dense urban**

[Qualcomm] mentioned that BS height of 25ms for Dense urban scenario does not match with UMi BS height of 10m assumed in 38.901 and proposed to update the BS height for dense urban to 10m according to UMi model (38.901).

FL comment: the suggestion by Qualcomm is valid. For Dense urban, it was agreed that the UMi Channel model refers to TR 38.901 is adopted. According to Table 7.2-1 in TR 38.901, the BS antenna height for UMi is 10 m. So the BS antenna height for Dense Urban scenario for XR/CG evaluations is proposed to update to 10 m.

Table 7.2-1: Evaluation parameters for UMi-street canyon and UMa scenarios

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters | | UMi - street canyon | UMa |
| Cell layout | | Hexagonal grid, 19 micro sites, 3 sectors per site (ISD = 200m) | Hexagonal grid, 19 macro sites, 3 sectors per site (ISD = 500m) |
| BS antenna height | | 10m | 25m |
| UT location | Outdoor/indoor | Outdoor and indoor | Outdoor and indoor |
| LOS/NLOS | LOS and NLOS | LOS and NLOS |
| Height | Same as 3D-UMi in TR36.873 | Same as 3D-UMa in TR36.873 |
| Indoor UT ratio | | 80% | 80% |
| UT mobility (horizontal plane only) | | 3km/h | 3km/h |
| Min. BS - UT distance (2D) | | 10m | 35m |
| UT distribution (horizontal) | | Uniform | Uniform |

**Proposal 9: the BS antenna height for Dense Urban scenario for XR/CG evaluations is proposed to update to 10 m, according to the Table 7.2-1 in TR 38.901.**

1. **Please share your views on the above** **proposal.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | Support the update to 10m. |
| CATT | We are OK with the update |
| ZTE , Sanechips | We insist 25m BS antenna height with no modification. |
| AT&T | OK with the update |
| Intel | OK with update since UMi Channel model is designed to model a below roof-top street canyon. |
| DOCOMO | OK with the update |
| vivo | We support the proposal. |

## Evaluation of UE Power Consumption for XR

### XR applications and deployment scenarios for Power Evaluation

Taking into account simulation workload, we may want to further prioritize or down-select deployment scenarios and XR applications for evaluation of UE power consumption, e.g.,

1. For FR1
   1. Prioritize AR in dense urban scenario
2. For FR2
   1. Prioritize AR in indoor hotspot scenario

while companies can still submit power evaluation results for other applications and deployment scenarios. (Note: AR may be a representative application for power evaluation as its form factor, e.g., AR glasses may be more sensitive to power consumption)

1. **Please share your view on prioritization of XR applications and deployment scenarios for evaluation of UE power consumption.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | We think AR is one of applications with higher preference among companies. Furthermore, AR has heavier UL of which power contribution is higher than other applications. Therefore, the need for power study and identification of potential power problem is higher than other cases. We support this prioritization, however at the same time, we also want to optionally support other applications. |
| CATT | No need to prioritize the scenario for power consumption. |
| ZTE , Sanechips | Support. |
| OPPO | Similar comments as for Question 1 |
| DOCOMO | Would prefer not to make down-selection among the applications but if it is really needed, the proposed prioritization seems fine. |
| vivo | We agree that AR services may be more sensitive to power consumption, thus AR can be prioritized for power evaluation. |
| Facebook | Share the same view as QCOM and vivo |
| Apple | We support AR applications be prioritized. |

### Power Saving Schemes to be evaluated

The following Table 1 summarizes proposals from companies [1-18] on power saving schemes to be evaluated for XR applications.

Table 1 Views on power saving schemes for XR evaluation

|  |  |
| --- | --- |
| Company | View |
| Huawei | *For power consumption evaluation of XR, “always on” (i.e., without C-DRX) is adopted as the baseline.*  *When evaluating power saving techniques, C-DRX mechanism can be considered.* |
| CATT | *Proposal 12: For XR service evaluation, the power consumption evaluation methodology and metric in TR38.840 could be reused and Rel-16 power saving scheme could be evaluated as baseline. And if needed, power saving enhancement for XR service should be considered for XR/CG service.* |
| Ericsson | Baseline XR performance should be evaluated assuming that the UE is always available for scheduling (i.e., without including DRX or other power saving techniques) and any studies on power savings techniques should consider latency/throughput impact compared to the baseline. |
| vivo | *Introducing enhanced power saving techniques, including starting time adaptation for ON Duration of C-DRX, and Rel-16/Rel-17 power saving schemes such as PDCCH skipping.*  *For XR/Cloud Gaming power consumption evaluation,*   * *Power consumption performance is evaluated by using power consumption model in TR 38.840.* * *Power consumption performance and capacity performance are evaluated together by considering different C-DRX configurations.*   + *Details of C-DRX configurations are reported by companies.* |
| MTK | Proposal 14: R15/R16/R17 available DL power saving techniques, including BWP switch, cross-slot scheduling, SCell dormancy, and MIMO layer adaptation, should be evaluated first for DL power consumption baseline determination in XR/CG scenario. |
| InterDigital | For analyzing performance of power saving techniques (e.g., DRX configuration, BWP switching, scheduling techniques, etc.) system level simulation can be used. |
| Intel | *Use new XR traffic models and define related baseline C-DRX parameters for UE power saving evaluations.* |
| Samsung | The need and identification of XR-specific UE power savings mechanisms is part of the XR SI. |
| QC | For XR power evaluation, RAN1 consider various power saving schemes including R15/R16/R17 power saving techniques and various assumptions having high impact on UE power consumption. |

In RAN1 103-e, the following was agreed.

* TR38.840 is the baseline methodology potentially with some modifications if necessary.  RAN1 aim to minimize modeling effort.

Given that the power evaluation methodology in TR38.840 only provides relative power numbers, power evaluations following the evaluation methodology are valid only for comparison of different scenarios and/or different power saving schemes.

**Proposal 10. To facilitate further discussion on evaluation of power saving effect of different power saving schemes, the following references are defined.**

* **Baseline**: UE power consumption assuming UE is always ON, i.e., UE is always available for gNB scheduling.
* **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.

**Proposal 11. Companies may submit evaluation result of UE power consumption for XR (i.e., gain/loss against the baseline) among the following candidate schemes.**

* R15/16/17 power saving techniques for connected mode, e.g., CDRX, BWP, PDCCH skipping, search space switching, etc.
* Other schemes are not precluded (e.g., new power saving techniques),

Note 1: CDRX is highly recommended to evaluate, and selection of other schemes are up to companies.

Note 2: Results of UE power consumption (i.e., gain/loss against the baseline) need to be presented with detailed description of the evaluated power saving schemes. For instance, CDRX result need to be presented with parameter values of inactivity timer, on duration, DRX cycle.

1. **Please share your view on Proposal 10 and 11.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | We support the definition of Baseline and Genie. As noted, results of both Baseline and Genie result can be collected from a single simulation, so additional workload would not be substantial . Genie can provide good amount of insight on power performance and possibility of potential enhancement.  For Proposal 11, CDRX is the most fundamental scheme, thus we support evaluation of CDRX first. The specific parameter values such as drx cycle, inactivity timer, on duration can be chosen by each company in their simulations taking into account impact to the performance of UE and network, i.e., maintaining a similar performance with baseline in terms of #satisfied UEs per cell. Companies need to report the selected parameters when reporting the results of power and #satisfied UEs per cell. |
| CATT | We don’t agree with Proposal 10. Proposal 10 should include Rel-15 DRX configuration with DRX cycle matched with the XR traffic mean iter-arrival time.  For Proposal 11, Rel-16 DRX adaptation with UE wakeup and Rel-17 PDCCH skipping power saving techniques should be considered for XR power saving. |
| ZTE , Sanechips | For Proposal 10, we think that Genie is not needed, for it is an ideal power saving scheme, which is difficult to implement. And introducing Genie power saving scheme leads to additional workload. By the way, it is enough for various power saving schemes to display their power saving gain compared with the Baseline.  For Proposal 11, we think the main bullet barely conveys any information. Maybe it can be simply revised to ‘Companies are encouraged to submit evaluation result of CDRX and BWP scheme for XR’. |
| OPPO | We are ok with proposal 10 to define some references.  As for proposal 11, it is up to companies to report what scheme(s) is used in the evaluation. |
| Intel | Ok with Proposal 10.  Proposal 11 may not be required; it is up to companies to submit results for chosen schemes. Rather may be beneficial to have a calibration effort based on agreed scheme to further align results across companies. |
| vivo | Fine with Proposal 10 and 11. |
| Facebook | We support proposal 10 for the provision of some reference performance.  For proposal 11, we agree with defining a few basic schemes, such as CDRX while up to the companies to provide additional schemes. |
| Apple | Fine with both proposals |

### Tradeoff between Performance Aspects

Table 2 captures the view from sources on tradeoff between different performance aspects and required methodology for XR evaluation.

Table 2 Views on tradeoff between different performance aspects

|  |  |
| --- | --- |
| Source | View |
| Huawei | *Proposal 9: For the evaluations of UE power consumption for XR, the impact on user experience is considered in addition to power saving gains.* |
| Vivo | *Proposal 1:* *When evaluating the power consumption performance, the capacity performance should be jointly considered to show the potential trade-off between them.* |
| ZTE | Observation 3: Power saving technique will have impact on system capacity. Power saving and capacity should be jointly considered.  Proposal 7: Companies can provide simulation results of capacity impact together with power saving gain instead of power saving gains subject to predefined threshold on the capacity loss. |
| InterDigital | Proposal 4: Study aspects related to tradeoff between UE power savings and capacity in SL and LL evaluations |
| Ericsson | 1. Baseline XR performance should be evaluated assuming that the UE is always available for scheduling (i.e., without including DRX or other power saving techniques) and any studies on power savings techniques should consider latency/throughput impact compared to the baseline. |
| QC | Proposal 20:In case power saving gain of power saving techniques is quantified, the gain is evaluated, compared, and captured subject to a given capacity constraint. |

As captured in Table 2, multiple companies have observed and pointed out that there exist tradeoff relations among different performance aspects: capacity, power, coverage. One good example is tradeoff between power saving gain and capacity. In network/UE operation, applying a power saving scheme may result in delayed packet scheduling (as the UE is supposed to be in a sleep state for a certain duration depending the applied power saving scheme), which can increase the chance of violating packet delay budget and consequently lead to lower capacity. Therefore, UE power consumption needs to be carefully evaluated in conjunction with impact on latency, user experience, and capacity.

**Proposal 12. 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 from companies, to be captured in the TR.**

Table 3 Evaluation of UE power saving schemes for e.g., {dense urban, AR (30Mbps, 10ms FDB, …)}

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Power Saving Scheme | Power Saving Gain (PSG) compared to the baseline | | | #satisfied UEs per cell2 / #UEs per cell3 |
| 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 |
| Baseline | - | - | - | K14 / N |
| Genie | X1 % | Y1 % | Z1 % | K24/ N |
| CDRX | X2 % | Y2 % | Z2 % | K34 / N |
| Scheme A | X3 % | Y3 % | Z3 % | K44/ 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:

* K1 = K2 by the Genie definition (please note that Baseline and Genie results can be collected from the same simulation).
* Parameters of a power saving scheme should be carefully chosen to ensure that the degradation in #satified UEs per cell by the applied power saving technique, compared to the baseline is within a range (e.g., 5%).

1. **Please share your views on the above** **proposal 12.**

|  |  |
| --- | --- |
| **Company** | **Comment** |
| QC | We support the above Table format that facilitates our discussion on power evaluation by presenting the details of what data are to be collected and how. N determines system load and we can further discuss what value of N would be chosen in simulations. |
| CATT | We don’t agree with genie proposal. The baseline should be Rel-15 CDRX. |
| ZTE , Sanechips | Partly support.  Firstly, Genie is not needed. Hence, the ‘Genie’ row should be deleted.  Secondly, ‘PS gain of average PSG’ is enough. The power consumption for different UE is different, the average power consumption among multiple UEs can provide an overview of power consumption of XR.  Last but not least, we disagree the Note 4 and prefer it deleted. For the first bullet, we disagree the evaluation/simulation of Genie. For the second bullet, massive evaluations are needed to obtain a well-balanced power saving technique harnessing the capacity-power tradeoff. Hence, the simulation workload is high if many power saving techniques are evaluated. Companies can provide simulation results of capacity impact and power saving gain. And the simulation results provided from each company can be jointly used to find a ‘satisfied’ setting or a best power saving techniques. This may decrease the simulation workload and find a ‘satisfied’ setting given the TU allocated for this study. |
| OPPO | We share the same view with ZTE that the average power saving gain is preferred.  We also support to delete the send bullet of Note 4 based on the same reason explained by ZTE |
| Intel | Utility of genie aided scheme in the table is unclear. Comparison to baseline should be OK. Additionally, the last column can be reported as a metric but to optimize this within a given range especially with different traffic models may entail high simulation complexity. |
| vivo | Fine with proposal 12. |
| Facebook | OK with the proposal |

### Other Evaluation Methodology for Power Evaluation

#### Linear Interpolation based Power Estimation for UL Slot with Tx Power other than 0dBm and 23dBm

UE power consumption is composed of power contributed from DL rx and UL tx. However, due to the nature of DL heavy traffic, when it comes to power evaluation, in many cases, the focus has been on DL than UL. Accordingly, 38.840 has power model with focus on DL.

In XR application, UE makes lots of UL transmissions e.g., pose/control/scene upload. Their data rates range from 1Mbps ~ 10Mbps with very short interval (2ms ~ 100ms) between two consecutive transmissions. This makes UL power contribution increases significantly. Thus, UL power contribution should not be ignored in XR power study. Another reason to consider is UE tx power. In R16 power model, although 0dBm and 23dBm cases were defined, 23dBm cases were hardly considered. However, in real network, UEs’ tx power depends on pathloss, target SNR, etc could be quite high, i.e. higher than 0dBm. Thus, in such case, power consumption due to high tx power (PA) makes significant contribution to total power consumption.

The current power model in 38.840 does not support power level other than 0dBm and 23dBm. To estimate power consumption of Ue of which transmit power is X dBm with X ≠ 0dBm and 23dBm, we could use interpolation method.

Table 4 Views on linear interpolation of power consumption numbers for tx power other than 0 and 23dBm.

|  |  |
| --- | --- |
| Company | View |
| QC | Linear interpolation in linear domain is reasonable method allowing approximation of power states with different UE tx power (other than 0dBm and 23dBm). The linear interpolation method already has been used / captured in 38.840 to estimate the power consumption for different number of BD. We observe good match between this interpolation method and data points. |
| vivo | *Proposal 2: For XR/Cloud Gaming power consumption evaluation, introduce interpolation algorithm for UL power between 0dBm and 23dBm.* |
| ZTE | Proposal 15: RAN 1 down-selects between the two methods for relative value modeling between UL transmission power with (0dBm 23dBm) for FR1,  Alt 1: UL(long PUCCH or PUSCH) power value is 250 within [0dBm, M], and UL power value is 700 within (M, 23dBm].  Alt 2: Y = 250 + 2.25\*X, X is transmission power in mw, Y is UL power at X mw.  Proposal 16: RAN 1 down-selects between the two methods for UL power between 0dBm and 23dBm for FR2,  Alt 1: UL(long PUCCH or PUSCH) power value is 350 within [0dBm, M], and UL power value is 800 within (M, 23dBm].  Alt 2: Y = 350 + 2.25\*X, X is transmission power in mw, Y is UL power at X mw. |

**Summary**

* **Use linear interpolation method to estimate power consumption for tx power other than 0dBm and 23dBm.**

**Proposal 13:** Power model supports linear interpolation technique for power consumption estimation.For example, the power consumption of a UL power state (Long PUCCH, PUSCH as defined in 38.840) for UE with transmit power X dBm can be determined by linear interpolation of existing power numbers for 0dBm and 23dBm tx power in linear domain.Note that this technique could be applied to short PUCCH/SRS power state in similar fashion or to the estimation of power with different number of UL tx symbols.

1. **Please share your comments on Proposal 13.**

|  |  |
| --- | --- |
| Company | View |
| QC | We support Proposal 13. This is necessary to evaluate UE power consumption for XR with minimal effort on power evaluation methodology. Linear interpolation is already being used in 38.840 power model to estimate different number of BDs. Thus, this proposal is to extend it to cases that are needed for our XR power evaluations. |
| CATT | The power consumption is NOT linear with respected to the Tx power. The UL power model was defined to have 0 dBm as the generic case and 23 dBm is an extreme case. The power consumption of power amplifier is not linear between 0 dBm and 23 dBm. We could use the 0 dBm power model for most of PUSCH model. |
| ZTE , Sanechips | In our opinion, linear interpolation (Alt 2 in [R1-2100529]) is reasonable. But quantization method (Alt 1 in [R1-2100529]) might be better, since it has a simple workload and avoids any excessive discussion. Alt 1 determines a M value as a threshold firstly, then the UL power value is 250 within [0,M] dBm, and 700 within [M, 23] dBm.  Moreover, we think that the linear interpolation method is also reasonable for short PUCCH/SRS power state in similar fashion or to estimation of power with different number of UL tx symbols.  Note that interpolation method and quantization method could be applied to antenna scaling for tx Power other than 0 and 23dBm. And we also think that Alt1 is preferable since it is simple and avoids any excessive discussion. |
| OPPO | Not support Proposal 13. From our understanding, the evaluation of power consumption is a relatively rough estimation of the real power consumption of active UE. The current model of TR 38.840 has considered all the key aspects which have obvious impact on UE power consumption. Thus, more elaborations on other aspects that are not modelled in TR 38.840 will not offer much additional benefit. |
| vivo | Support Proposal 13 at least for FR1.  For FR2 for UL, only one value 350 is provided in TR 38.840, but the Tx power level is undefined. Power model cannot be achieved by linear interpolation. |

#### Other Enhancements

The following tables summarize views on other enhancements for power evaluation.

**Special Slot Modelling**

Views on S slot modelling

|  |  |
| --- | --- |
| Company | View |
| Huawei | * Power model for “S” slot: As discussed in Section 3.3, we propose to consider the S slot as all D slot or all U slot, and this can be determined after the traffic models of different applications are stable. So there is no need to develop additional power consumption model for S slot. |
| ZTE | Proposal 18: Power of “PDSCH+PUCCH” is 450 at 23dBm, and power of “PDCCH+PDSCH+PUCCH” is 470 at 23 dBm.  Proposal 19: Power of “PDSCH+PUCCH” and “PDCCH+PDSCH+PUCCH” at other transmission power can be obtained according to the following 2 alternatives.  Alt 1: Power of “PDSCH+PUCCH” is 280 at [0dBm, M], and power of “PDSCH+PUCCH” is 450 within (M, 23dBm]. Power of “PDCCH+PDSCH+PUCCH” is 300 within [0dBm, M], and power of “PDCCH+PDSCH+PUCCH” is 470 at (M, 23dBm].  Alt 2: Power of “PDSCH+PUCCH” and “PDCCH+PDSCH+PUCCH” at other transmission power can be obtained using linear interpolation. |
| MTK | Proposal 16: Model the power consumption of S slot as DL slot. |
| QC | Observation 3: Power consumption for S slot needs to be discussed. |

**Summary**

* Model S slot as D or U slot instead of introducing new power state with DL and UL.
* Introduce a new S slot with tx power at 0/23dBm and define a rule for estimating power consumption for different tx power.

**New UL Power State**

Table 5 Views on New UL power slots

|  |  |
| --- | --- |
| Company | View |
| Huawei | * Power model for UL slots: The power model for long PUCCH, short PUCCH, PUSCH and SRS has been provided in TR 38.840. For the UL slots that are not defined in TR 38.840, it is preferred not to model them separately if the power consumption difference is small. |
| vivo | *Proposal 3: For power consumption evaluation, the following aspects should be considered:*   * *Improving power consumption models for (1) special slots, (2) multiple UL channels in a slot, such as PUSCH, PUCCH and SRS concurrent in a slot, etc.* |
| ZTE | 1. For XR evaluation, the following two alternatives for UL power states can be considered.   Alt 1: Use the original power states and do not add more power states.  Alt 2: Power of PUCCH or PUSCH with different number of symbols can be obtained by power of long PUCCH multiplied by a coefficient. The coefficient can be calculated by A = 0.3 + (N-1)/13\*0.7, N is the number of symbols the PUCCH or PUSCH or UL power state occupied. |
| MTK | Proposal 15: Do not introduce additional UL power model required on top of 38.840 due to the small delta values. |

**Summary**

* Do not introduce new UL power states if power difference is small.
* Use liner interpolation method for estimating UL slots with different number of UL symbols.

**Antenna Scaling for tx Power other than 0 and 23dBm**

Table 6 Antenna scaling for tx power other than 0 and 23dBm

|  |  |
| --- | --- |
| Company | View |
| ZTE | Proposal 13: RAN 1 down-selects from the following alternatives to model the antenna scaling for power consumption within [0dBm, 23dBm]:  Alt 1: 2Tx power is 1.4x 1Tx power within [0dBm,M] and 1.2x.within (M,23dBm]  Note: M is the median value of transmission power in mw domain instead of dB domain and is same for other related proposals.  Alt 2: The power state within (0dbm,23dbm) is obtained via linear interpolation  Proposal 14: 4Tx power is 1.4x 2Tx power within [0dBm,M] and 1.2x.within (M,23dBm] for FR1. If option 2 for UE antenna is used, the antenna scaling for FR1 will be reused for FR2. |

**Summary**

* Improve antenna scaling factor for tx power other than 0dBm and 23dBm.

1. **Please share your comments on the above aspects. One possibility is to leave the detailed assumptions up to companies.**

|  |  |
| --- | --- |
| Company | View |
| QC | Following the agreement made in RAN1 103e, “TR38.840 is the baseline methodology potentially with some modifications if necessary.  RAN1 aim to minimize modeling effort”, we can leave detailed assumptions on the above aspects up to companies as it would require lots of effort and time to agree upon such detailed power evaluation methodology in RAN1.  Another power modelling aspect we point out is FR2 power. There is some basic modelling which is not captured in 38.840, for example, power numbers for FR2 are incomplete, i.e., no tx power is specified. Further clarification is needed on this. At least FR1 equivalent details (e.g., 0dBm, 23dBm) needs to be added to FR2 part. |
| CATT | The power model does not associate with antenna scaling. No need to consider this factor |
| ZTE , Sanechips | Support. In our perspective, UE transmit power will be changed according to power control technique. Therefore the antenna scaling in TR 38.840 is not enough because the antenna scaling for the transmission power other than 0dBm and 23dBm isn't provided.  Two alternatives could be considered to this end in [R1-2100529],  *Alt 1: To simplify the scaling model and resultant simulation efforts, current two coefficients of antenna scaling can be reused for other transmission power.*  *Alt 2: The power state within (0dbm,23dbm) is obtained via linear interpolation*  And the antenna scaling for FR1 can be reused for FR2. |
| OPPO | Leave them to companies |
| vivo | Support model S slot as DL (if DL heavy) or UL (if UL heavy) slot.  Power model for different number of symbols can be deduced by linear interpolation between short PUCCH/PUSCH and long PUCCH/PUSCH by assuming 1 symbols for short and 14 symbols for 1ong.  For antenna scaling for 2Tx power modelling, reuse 1.4 scaling factor for 0dBm and 1.2 scaling factor for 23dBm from 1Tx. Other power level and 4Tx antenna scaling model can be further studied. |

# Summary

# Reference

1. [R1-2100056](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100056.zip) XR evaluation methodology FUTUREWEI
2. [R1-2100133](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100133.zip) Discussion on the XR evaluation methodology OPPO
3. [R1-2100242](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100242.zip) Discussion on evaluation methodology for XR and Cloud Gaming Huawei, HiSilicon
4. [R1-2100362](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100362.zip) Evaluation methodology and performance index for XR CATT
5. [R1-2100477](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100477.zip) Discussion on evaluation methodologies of XR vivo
6. [R1-2100529](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100529.zip) On XR Evaluation Methodology ZTE , Sanechips
7. [R1-2100556](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100556.zip) Discussion on evaluation assumption for XR study LG Electronics
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9. [R1-2100586](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100586.zip) On Evaluation Methodology for XR and CG MediaTek Inc.
10. [R1-2100681](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100681.zip) On evaluation methodology for XR Intel Corporation
11. [R1-2100725](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100725.zip) Development of the Evaluation Methodology for XR Study Nokia, Nokia Shanghai Bell
12. [R1-2100776](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100776.zip) XR Evaluation Assumptions AT&T
13. [R1-2101102](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101102.zip) Discussion on evaluation methodology for XR services Xiaomi
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15. [R1-2101315](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101315.zip) Evaluation methodology for XR Ericsson
16. [R1-2101366](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101366.zip) Views on XR evaluation methodology Apple
17. [R1-2101494](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101494.zip) Evaluation Methodology for XR Qualcomm Incorporated
18. [R1-2101636](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101636.zip) Discussion on evaluation methodology for XR NTT DOCOMO, INC.

# List of agreements