**3GPP TSG RAN WG1 #110 R1-220xxxx**

**Toulouse, France, August 22nd – 26th, 2022**

**Agenda item:** 9.11.1

**Source:** Moderator (Qualcomm Incorporated)

**Title:** Moderator Summary #1 on XR specific power saving techniques

**Document for:** Discussion and Decision

# Introduction

In RAN1 #109-e, several issues were identified for power saving enhancements for Rel-18 XR SI [1]. In this meeting, companies’ proposals and evaluation results will be further discussed. It was also agreed that Rel-17 evaluation methodology for XR power consumption will be used as baseline for Rel-18 XR SI [1]. Companies are expected to provide thorough comparison with existing power saving features. For the SI, evaluation results are necessary for any proposed enhancement to be captured as RAN1 input to TR 38.835 [1].

This document contains the following main sections:

* Section 2 for proposals and discussions for CDRX enhancements
* Section 3 for proposals and discussions for PDCCH monitoring enhancements
* Section 4 for proposals and discussions for other enhancements

Under each section, subsections are structured to reflect Issues identified in the RAN1 #109-e meeting. For the proposals and evaluation results, the following potential decision can be made in the RAN1 #110 meeting:

* Support the proposed enhancement in Rel-18
* Capture the evaluation results in TR 38.835
* Further study the proposed enhancement via evaluations
* Deprioritize the issue and/or the proposed enhancement (e.g., at least for RAN1)

Please check Questions under the “Discussions” Subsections 2.1.2, 2.2.2, 2.3.2, 2.4.2, 2.6.1, 3.2.2, 3.3.2, 4.1.1, 4.2.2, 4.3.2.

# CDRX Enhancements

Periodicity Alignment between CDRX and XR Traffic

Proposals in this subsection correspond to the high priority Issue 1-1 identified in the RAN1 #109-e meeting

* High priority Issue 1-1: Alignment between CDRX and XR traffic for resolving the mismatch between CDRX cycle and XR traffic periodicity for each flow

**Table 1: Proposals and evaluation results for periodicity alignment between CDRX and XR traffic**

|  |  |
| --- | --- |
| **Company** | Proposals and evaluation results |
| Ericsson | Observation 1 Existing C-DRX solutions do not achieve a short traffic delay and low UE power consumption at the same time.Proposal 1 Candidate C-DRX solutions should take into account all agreed XR traffic characteristics jointly, i.e. non-integer traffic periodicity, multiple traffic flows, and traffic jitter.Proposal 2 Adopt enhancements to C-DRX that achieve simultaneously a high number of satisfied users (i.e. with short traffic delay) and low UE power consumption.Observation 2 Depending on the network load and the traffic generation rate, different C-DRX solutions need to be applied, to maximize power savings and also achieve a high percentage of satisfied UEs.Observation 3 In order to enhance C-DRX power saving features, the gNB needs per-XR flow information, including: - application packet periodicity and periodicity changes; - application packet jitter information; - delay budget or remaining PDB of the application packet for radio interface; - application packet sequence number in each constituent PDU; and - application packet size.Observation 4 Matching the DRX cycle with the non-integer video periodicity is the prefered solution to achieve high power saving gains (~9%), while maintaining a high percentage of satisfied UEs (~83%), under the condition of high network loads and high traffic generation rate.Proposal 3 Introduce new integer values in ms for DRX cycle lengths (e.g. {8, 9, 11, …, 16, …33, …} ms), close to non-integer XR traffic periodicities.Proposal 4 Enhance DRX formula to match non-integer (ms) XR traffic periodicities as described in this section, by adding two new parameters: (i) a fixed time shift for the start of *drx-onDurationTimer*; and (ii) a number of DRX cycles after which the new shift should be added.Table 3: Results for CDRX, for FR1, high load, Dense Urban scenario, and VR multi-stream traffic: DL video (60 fps, 30 Mbps, 10 ms PDB), DL audio (10 ms periodicity, 30 ms PDB), UL pose (4 ms periodicity, 10 ms PDB)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Tdoc #** | **Power Saving Scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **Load H/L** | **avg # UEs/Cell** | **floor (Capacity)** | **% of satisfied UE** | **Mean PSG of all UEs** | **Mean PSG of satisfied UEs** |
| R1-2205916 | Always On | - | - | - | H | 8 | 8 | 90.1% | - | - |
| R1-2205916 | R15/16 DRX(Long DRX) | 10 | 8 | 4 | H | 8 | 7 | 82.6% | 4.2% | 4.1% |
| R1-2205916 | R15/16 DRX(Short DRX) | 4 | 2 | 4 | H | 8 | 5 | 69.8% | 9.8% | 9.7% |
| R1-2205916 | Matched CDRX (with our solution) | 16.6 (16-16-18 equivalent) | 10 | 4 | H | 8 |  7 | 82.5% | 9.1% | 9.0% |
| R1-2205916 | Matched CDRX (solutions from other companies) | 16.6 (17-17-16) | 10 | 4 | H | 8 | 7 | 83.7% | 9.5% | 9.4% |

 |
| vivo | **Observation 3: It is beneficial to introduce RRC signalling based DRX enhancement to align DRX cycle with XR traffic periodicity with the following approaches:*** **Approach 1: Configure DRX cycle set/pattern and each DRX cycle set contains multiple DRX cycles e.g., {16ms, 17ms, 17ms}. And apply the DRX cycle set cyclically in the time domain.**
* **Approach 2: Multiple DRX configurations with different *drx-StartOffset* values.**
* **Approach 3: Single DRX configuration and one DRX cycle can contain multiple DRX ondurations.**

**Observation 4: The specific spec design for the higher layer signalling based DRX enhancements can be decided by RAN2.****Observation 5: For DL XR traffic for FR1 in InH scenario, compare to R15/16 DRX power saving scheme, enhanced DRX scheme can achieve {5%~10%} power saving gain with no capacity loss.****Proposal 2: Study higher layer based DRX enhancements to accommodate the non-integer XR traffic characteristics in collaboration with RAN2.****Table I. Power consumption results in FR1 DL Indoor Hotspot with 30Mbps traffic model**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **DRX configuration****(ms)** | **avg # UEs/ cell = N1** | **C1=floor****(Capacity)** | **% of satisfied UEs when #UEs/cell = N1** | **Power saving gain (%)** | **Notes** |
| AlwaysOn | - | 5 | 10 | 100% | - | Note1 |
| R15/16 DRX  | 16\_14\_4 | 5 | 10 | 100% | 3.67% | Note1 |
| 10\_8\_4 | 5 | 10 | 100% | 5.72% | Note1 |
| 4\_3\_1 | 5 | 10 | 100% | 4.63% | Note1 |
| 16\_8\_4 | 5 | 10 | 11.67% | 19.71% | Note1 |
| 10\_5\_2 | 5 | 10 | 78.33% | 15.41% | Note1 |
| 10\_4\_2 | 5 | 10 | 52.22% | 22.17% | Note1 |
| Enhanced DRX  | 16\_8\_4 | 5 | 10 | 100% | 13.05% | Note1 |
| AlwaysOn | - | 10 | 10 | 92.50% | - | Note1 |
| R15/16 DRX | 16\_14\_4 | 10 | 10 | 91.81% | 3.46% | Note1 |
| 10\_8\_4 | 10 | 10 | 91.25% | 5.10% | Note1 |
| 4\_3\_1 | 10 | 10 | 91.68% | 4.03% | Note1 |
| 16\_8\_4 | 10 | 10 | 2.78% | 18.21% | Note1 |
| 10\_5\_2 | 10 | 10 | 45.00% | 13.10% | Note1 |
| 10\_4\_2 | 10 | 10 | 22.50% | 18.70% | Note1 |
| Enhanced DRX | 16\_8\_4 | 10 | 10 | 91.94% | 10.08% | Note1 |
| Note1: jitter range = [-4, +4]ms |

5.2 Power Saving Techniques5.2.1 Techniques for handling non-integer XR traffic periodicityPotential CDRX enhancement techniques for handling mismatch between CDRX cycle and non-integer XR traffic periodicity in this study are summarized as follows,* Configure DRX cycle set and each DRX cycle set contains multiple DRX cycles, e.g., {16ms, 17ms, 17ms}.
* Multiple active DRX configurations and each of them contains different drx-StartOffset value.
* Single DRX configuration and one DRX cycle can contain multiple DRX ondurations.

5.2.2 Techniques for handling jitterPotential PDCCH monitoring enhancement techniques for handling jitter in this study are summarized as follows,* PDCCH monitoring adaptation enhancements based on Rel-17 PDCCH skipping or sparse/dense SSSG switching

The UE performs sparse PDCCH monitoring during the active time. Once a scheduling DCI is detected, the UE switches to dense PDCCH monitoring. In case indicated by gNB, e.g. by DCI scheduling the last packet of a burst, the UE will skip the PDCCH monitoring until the possible arrival time of the next burst.* Low power wake-up signal (LP-WUS) triggered PDCCH monitoring

The UE performs LP-WUS detection during active time, and triggers PDCCH monitoring once LP-WUS is received. The UE power consumption of the LP-WUS monitoring is significantly lower than that of the PDCCH monitoring (e.g. 50% reduction) with limited wake-up latency.Annex A:Evaluation MethodologyRel-17 evaluation methodology for XR power saving captured in [4] is used as the baseline evaluation methodology for UE power saving evaluation of Rel-18 XR**.**…Omitted part…=========================End of Text proposal of TR 38.835==============================**Proposal 5: Capture the above text proposal into R18 XR TR 38.835.** |
| OPPO | **Observation 1: XR and CG have the following characters:*** **High data rate, up to 60Mbps with limited latency, around 10-30ms**
* **Non-integer period with jitter**
* **Large and various packet size**

**Observation 2: The mismatch between non-integer XR traffic arrival cycle and integer DRX cycle may lead to larger scheduling latency and/or excessive UE power consumption.****Proposal 1: The following DRX enhancements can be further studied to solve periodicity mismatch issue:*** **To generate a DRX cycle pattern with two inter-DRX interval lengths, either by derivation from configured parameters or by configuration directly;**

**Proposal 2: The two-cycle DRX pattern is configured to UE via {**$T\_{P}$**(traffic periodicity),** $t\_{ref}$ **(reference time in integer multiple of slot), e (traffic arrival offset in relative to referenced time)}. The** $m$**-th DRX-ON duration for** $m\geq 0$ **has the semi-static start at the** $n\_{s}$**-th slot in SFN-th radio frame in the hyper-frame that contains the starting instance of the m-th DRX-ON duration, where SFN and**$ n\_{s}$ **satisfy** $$SFN∙10∙2^{μ}+n\_{s}=\left(t\_{ref}+\left⌈\left(m∙T\_{P}+e\right)∙2^{μ}\right⌉\right) mod \left(10240∙2^{μ}\right)$$**Observation 4: In FR1 Dense Urban, AR/VR 30Mbps and 60fps, the following is observed:*** **For R15/16 C-DRX, the power saving gain is 5.12% with loss of satisfied UE rate limited to 1%;**
* **For non-uniform CDRX cycle pattern, the power saving gain is 18.69% with loss of satisfied UE rate limited to 1%;**

**Table 2: Power saving results in FR1 DL Dense Urban with 60fps and 30Mbps traffic model**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **Another ODT (ms)** | **#UE /cell= floor (Capacity)** | **satisfied UE rate** | **Mean PSG of all UEs (%)** |
| Always On | - | - | - | - | 5 | 89.12% | / |
| R15/16 CDRX | 16 | 14 | 2 | - | 5 | 88.07% | 5.12% |
| Non-uniform CDRX cycle pattern | {17,17,16} | 10 | 2 | - | 5 | 88.07% | 18.69% |

 |
| Intel | **Observation 1: For DRX (8, 6, 6), 6% (4.4%) and 2.7% (3%) power saving gain (capacity gain) are observed with C-DRX alignment compared to legacy C-DRX for jitter OFF and jitter ON, respectively, for PDB 10ms.****Observation 2: Given XR traffic is periodic and DRX cycle is expected to be short for typical XR traffic periodicity, Rel-16 WUS does not seem to be a good fit for power saving for XR applications.****Proposal 1: RAN1 studies solutions to align C-DRX cycle to XR traffic periodicity.*** **Consider configuration a periodic pattern of CDRX cycles such as consecutive DRX cycles with two DRX cycle values or start offset adjustment every N DRX cycles**

**Table 1: Power consumption and capacity performance of enhanced DRX and legacy C-DRX. Results are presented for VR and CG in Dense Urban scenario, 4 UEs, DL only with SU-MIMO scheduler. DRX (Cycle, IAT, ON).**

|  |  |
| --- | --- |
| **Power Saving Scheme** | **Jitter ON** |
| Power consumption (PC) | #satisfied UEs per cell/ #UEs per cellPDB 10ms | #satisfied UEs per cell/ #UEs per cellPDB 15ms |
| Baseline | Optional |
| Mean PC | PC of 5%-tile UE in PC CDF | PC of 50%-tile UE in PC CDF | PC of 95%-tile UE in PC CDF |
| Always On | 116.76 | 108.24 | 116.13 | 127.31 | 3.93/4 | 3.95/4 |
| Legacy CDRX | DRX (8,6,6) | 111.36 | 98.98 | 109.41 | 127.46 | 3.72/4 | 3.81/4 |
| DRX (16,4,14) | 112.99 | 102.69 | 111.63 | 126.18 | 3.82/4 | 3.89/4 |
| w/eDRX | DRX (8,6,6) | 108.36 | 98.04 | 107.36 | 121.26 | 3.83/4 | 3.9/4 |
| DRX (16,4,14) | 111.43 | 102.32 | 110.63 | 123.13 | 3.89/4 | 3.93/4 |

|  |  |
| --- | --- |
| **Power Saving Scheme** | **Jitter OFF** |
| Power consumption (PC) | #satisfied UEs per cell/ #UEs per cellPDB 10ms | #satisfied UEs per cell/ #UEs per cellPDB 15ms |
| Baseline | Optional |
| Mean PC | PC of 5%-tile UE in PC CDF | PC of 50%-tile UE in PC CDF | PC of 95%-tile UE in PC CDF |
| Always On | 115.19 | 107.43 | 114.42 | 126.9 | 3.97/4 | 3.99/4 |
| Legacy CDRX | DRX (8,6,6) | 109.67 | 98.19 | 107.4 | 126.03 | 3.80/4 | 3.89/4 |
| DRX (16,4,14) | 111.58 | 101.94 | 109.78 | 125.95 | 3.84/4 | 3.93/4 |
| w/eDRX | DRX (8,6,6) | 103.05 | 93.34 | 102.26 | 116.97 | 3.97/4 | 3.99/4 |
| DRX (16,4,14) | 105.55 | 97.76 | 104.77 | 117.26 | 3.97/4 | 3.99/4 |

 |
| MediaTek | **Proposal 3: RAN1 aims to identify the necessity of CDRX enhancement for XR. If the necessity is identified, send an LS to RAN2 to let RAN2 handle the remaining works (Ex. spec impact). Scope wise, CDRX related enhancements should be belonging to RAN2.****Observation 5:** **It is not possible to align DRX on-duration occasions with XR traffic using legacy DRX cycles with integer values. This can cause a drop in UE satisfaction rate as shown in Table 1 below.****Observation 6:** **As shown by SLS results in Figure 5, eC-DRX using rational DRC cycle value matching CG traffic improves both power savings and UE satisfaction rate compared to Rel-17 C-DRX (PSG improved by 4.5%, UE satisfaction rate improved by 1.6%).** **Proposal 4: Introduce non-integer (rational number) DRX cycles to match typical XR traffic patterns.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Power saving scheme | CDRX cycle (ms) | ODT (ms) | IAT (ms) | #UE /cell | floor (Capacity) | % of DL satisfied UE | Mean PSG of all UEs (%) |
| AlwaysOn - baseline | 0 | 0 | 0 | 12 | 12 | 94.6% | 0% |
| R17 CDRX | 16 | 12 | 8 | 12 | 12 | 92.7% | 5.4% |
| eCDRX (rational DRX cycle) | (50/3) | 12 | 8 | 12 | 12 | 94.3% | 9.9% |

Table 1 SLS evaluation results with eC-DRX, FR1, DL-only, DU, CG 30Mbps |
| ZTE, Sanechips | Observation 1: The power saving gain from solutions such as dynamic indication, non-uniform CDRX cycle, uniform non-integer CDRX cycle, multiple CDRX configurations is close and within a small value range. Observation 2: It is not necessary to achieve a periodic alignment between CDRX cycle and XR traffic periodicity, via additional dynamic signalling in each CDRX cycle.**Proposal 1: The dynamic indication to adjust CDRX configuration frequently should be avoided from RAN1 perspective.**Observation 3: RRC signalling and specification impact can be considered in terms of comparison among semi-static RRC configuration approaches. **Proposal 2: RAN 1’s evaluations and comparisons of solutions of matching periodicities of XR traffic and CDRX via semi-static RRC configuration should be captured in TR.38.835****Proposal 3: RAN 1 sends LS to RAN 2 and provide the information of evaluations and comparison among solutions of matching periodicities of XR traffic and CDRX via semi-static RRC configuration.**Table 1 FR1 power consumption results in Indoor Hotspot scenario (VR30M, fps=60, DL + pose/control)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **#UE /cell** | **floor (Capacity)** | **Percentage of satisfied UE** | **Mean PSG of all UEs (%)** |
| Baseline | - | - | - | 11 | 11 | 93.18% | - |
| R15 CDRX | 10 | 8 | 4 | 11 | 11 | 90.15% | **6.65%** |
| 16 | 10 | 5 | 11 | 11 | **81.82%** | 13.9% |

Table 2 FR1 power consumption results in Indoor Hotspot scenario (VR30M, fps=60, DL only)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **#UE /cell** | **floor (Capacity)** | **Percentage of satisfied UE** | **Mean PSG of all UEs (%)** |
| Baseline | - | - | - | 11 | 11 | 93.18% | - |
| R15 CDRX | 10 | 8 | 4 | 11 | 11 | 90.15% | **7%** |
| 16 | 10 | 5 | 11 | 11 | **81.82%** | 18.47% |

Table 3 FR1 power consumption results in Indoor Hotspot scenario (VR30M, fps=60, DL + pose/control)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **#UE /cell** | **floor (Capacity)** | **Percentage of satisfied UE** | **Mean PSG of all UEs (%)** |
| Dynamic indication | 50 | 6 | 4 | 11 | 11 | 90.1% | 23% |
| Non-uniform CDRX cycle  | 17-17-16 | 6 | 4 | 11 | 11 | 90.15% | 23.86% |
| Uniform non-integer CDRX cycle | (1000/60) | 6 | 4 | 11 | 11 | 90.15% | 23.85% |
| Multiple CDRX (3 CDRX configurations) | 50ms DRX cycle | 6 | 4 | 11 | 11 | 90.11% | 24% |

Table 4 FR1 power consumption results in Indoor Hotspot scenario (VR30M, fps=60, DL only)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **#UE /cell** | **floor (Capacity)** | **Percentage of satisfied UE** | **Mean PSG of all UEs (%)** |
| Dynamic indication | 50 | 6 | 4 | 11 | 11 | 90.1% | 33% |
| Non-uniform CDRX cycle  | 17-17-16 | 6 | 4 | 11 | 11 | 90.15% | 33.9% |
| Uniform non-integer CDRX cycle | (1000/60) | 6 | 4 | 11 | 11 | 90.18% | 33.8% |
| Multiple CDRX (3 CDRX configurations) | 50ms DRX cycle | 6 | 4 | 11 | 11 | 90.1% | 34% |

 |
| Qualcomm | **Observation 1: There is a time mismatch issue between periodic XR DL traffic and R15/16/17 CDRX configuration. This would lead to XR capacity loss due to larger latency or larger UE power consumption to keep the same latency performance.****Observation 2: By adopting the rational number in DRX cycle and adding the floor operations in DRX formulas, DRX cycles could be adjusted to address the mismatch between DL traffic arrival times and DRX on-duration start times.****Observation 3: Enhanced CDRX for DRX cycle and XR video periodicity alignment can be based on** * **Dynamic adjustment of DRX start**
* **Semi-static configuration of DRX cycles, semi-static configuration is simpler for implementation and more robust to missed detection.**

**Observation 4: For FR1, DL VR 30Mbps in Dense Urban environment, eCDRX achieves 28.8% power saving gain with satisfied UE ratio 83% when PDCCH skipping and SSSG skipping are enabled. CDRX achieves power saving gain of 29.7% but satisfied UE ratio significantly degrades to 14%.****Observation 5: For FR2, DL VR 30Mbps in Indoor Hotspot environment, eCDRX achieves considerable capacity gains over Re115/16 CDRX (especially in case of jitter) with comparable power saving gains. For eCDRX, the number of satisfied UEs degrades when jitter is enabled, and a complementary method (e.g., dynamic CDRX) may be needed to better handle jitter.****Proposal 1: Support the semi-static configuration of enhanced DRX for the alignment between XR video periodicity and DRX cycle.****Proposal 2: Introduce non-integer rational numbers in short/long DRX cycles and add floor operations in DRX formulas for CDRX enhancement in Rel.18 with minimal spec impact.**Table 2: Enhanced CDRX, FR1, DL evaluation, DU, VR30

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Power saving scheme | CDRX cycle (ms) | ODT (ms) | IAT (ms) | Load H/L | #UE /cell | floor (Capacity) | % of satisfied UE | Mean PSG of all UEs (%) |
| Always On |  |  |  | H | 13 | 13 | 90% | 0% |
| Rel15/16 CDRX | 16 | 12 | 8 | H | 13 | 13 | 79% | 6.0% |
| eCDRX | 16/17/17 | 12 | 8 | H | 13 | 13 | 90% | 3.9% |
| Rel15/16 CDRX + PDCCH skipping | 16 | 12 | 8 | H | 13 | 13 | 38% | 25.7% |
| eCDRX + PDCCH skipping | 16/17/17 | 12 | 8 | H | 13 | 13 | 87% | 24.5% |
| Rel15/16 CDRX + PDCCH skipping + SSSG switching | 16 | 12 | 8 | H | 13 | 13 | 14% | 29.7% |
| eCDRX + PDCCH skipping + SSSG switching | 16/17/17 | 12 | 8 | H | 13 | 13 | 83% | 28.8% |

**Table 3**: **Summary of InH Capacity and Power Consumption Results for 7UE per Cell, VR (30Mbps), PDB =10ms**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  | No Jitter | With Jitter |
| Power saving scheme | CDRX cycle (ms) | ODT (ms) | IAT (ms) | % of satisfied UE | Mean PSG of all UEs (%) relative to Always On | % of satisfied UE | Mean PSG of all UEs (%)relative to Always On |
| Always On | NA | NA | NA | 90% | 0% | 90% | 0% |
| Rel15/16 CDRX | 16 | 4 | 4 | 0% | 28.60% | 0% | 28.44% |
| Rel15/16 CDRX | 16 | 8 | 8 | 42% | 8.70% | 50% | 9.64% |
| Rel15/16 CDRX | 16 | 8 | 16 | 90% | 0.29% | 65% | 4.10% |
| eCDRX | 16/17/17 | 4 | 4 | 90% | 18.93% | 27% | 25.10% |
| eCDRX | 16/17/17 | 8 | 8 | 90% | 7.71% | 84% | 8.28% |
| eCDRX | 16/17/17 | 8 | 16 | 90% | 0.30% | 88% | 2.43% |

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|  |  |

**Table 2: Proposals without evaluation results for alignment between CDRX and XR traffic**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Spreadtrum | **Proposal 1: In order to address periodicity mismatch problem, adjusting the drx-startoffset or configuring the non-uniform CDRX cycle pattern should be further studied.****Proposal 2: The semi-static RRC configuration can be used to carry the CDRX configuration, such as the non-uniform CDRX cycle pattern, drx-onDurationTimer, drx-InActivityTimer, start-offset of CDRX On Duration.****Proposal 3: Further clarification is needed on how to understand the uniform non-integer CDRX cycle (e.g., 50/3 ms).****Proposal 9: It is preferred to adopt a solution that can address multiple issues on the basis of obtaining a certain power saving gain. Or, the combination of multiple solutions which are not mutually exclusive can also be considered.** |
| NEC | **Observation 1: the traffic characteristics of XR services (e.g., the non-integer periodicity, jitter of packet arrival time, delay budget and the large and varying packet size) are quite different from traditional eMBB and URLLC, and should be considered in the enhancement for XR.****Proposal 1: Study the mechanism to address the mismatch between DRX cycle and the non-integer periodicity of XR packet arrival time.** |
| TCL | **Observation 1: XR services have the following characteristics.** * **The non-integer periodicity**
* **Jitter of packet arrival time**
* **Low latency and large packet size**
* **Varying packet size**
* **Multiple flows**

**Observation 2：There is a gap between XR periodic DL traffic and current C-DRX configuration, large delay will be caused.** **Proposal 1: A fixed pattern for DRX within an integer periodicity for XR power saving can be considered.**  |
| Rakuten Mobile | **Proposal 4: Consider dynamic configuration of the DRX parameters.** |
| Lenovo | **Proposal 1: Study impact of updating a configured DRX parameter/timer on (a) other configured DRX parameters/timers and (b) DRX configuration restrictions (e.g., when two DRX groups are configured).****Proposal 2: Study DCI monitoring and timeline aspects for a DCI updating a configured DRX parameter/timer.** |
| Samsung | **Observation 1**: *Short C-DRX cycles are preferable over long C-DRX cycles for XR QoS. No C-DRX operation is optimal.* **Observation 2**: *Adjusting the start of the drx-OnDuration timer of a long C-DRX cycle based on a formula or by higher layers cannot address the existence of multiple traffic flows.*  |
| CMCC | **Proposal 1. The following enhanced DRX schemes can be considered for alignment between CDRX and XR traffic:*** **Scheme #1: Configure multiple DRX cycles which used in a round;**
* **Scheme #2：Configure multiple *drx-StartOffset* values in one DRX cycle.**
 |
| DOCOMO | **Proposal 1: The following DRX configuration enhancements can be further studied to adjust misalignment between C-DRX cycle and XR traffic periodicity*** **Semi-static DRX configuration (e.g., predefined patterns of multiple C-DRX cycles)**
* **DCI based DRX enhancements (e.g., adjusting start-offset via DCI indication)**
 |
| ETRI | **Proposal 1: To efficiently serve XR traffics with non-integer arrival rate, support non-uniform CDRX cycle patterns for a single DRX configuration.** |
| China Telecom | **Proposal 1: Double period or multiple periods, or sequence based DRX On Duration/DRX Cycle should be studied for XR-specific power saving.****Proposal 2: Support multiple CDRX cycles in one DRX configuration to resolve the mismatch between CDRX cycle and XR traffic periodicity for each flow, such as supporting two different cycles in one DRX configuration.** **Proposal 3: Use the scheduling or non-scheduling DCI to indicate DRX cycle configuration, or the network side indicates DRX configuration to UE by other signaling based on XR traffic.** **Proposal 4: Support semi-static/dynamic adjustment of CDRX start offset/duration to resolve the mismatch between XR service arrival and CDRX cycle.****Proposal 5: DCI/WUS or other additional signaling can be used to indicate adjustment of DRX cycle parameters.** |
| III | **Suggestion#1:** **To align CDRX with XR traffic, we slightly prefer having CDRX of non-uniform periodicity.** |
| Sony | Observation 1 – An XR application may have a traffic rate that is not aligned with any integer DRX periodicity in the order of msec. This causes misalignment as the downlink packet may arrive outside of the DRX ON duration.Observation 2 – UE power saving can be optimally obtained by arranging the DRX configuration:* The starting of ON duration is aligned with periodic XR traffic
* The duration of ON duration is matched with the packet transmission time

Proposal 1 – Consider enabling dynamic DRX parameters of the pre-assigned DRX configuration, such as the start of DRX ON duration can be advancing / delaying. |
| Panasonic | **Proposal 1: SPS/CG/DRX should efficiently handle the non-integer periodicity transmissions, including the video stream frame periodicities like 16.66667, 11.11111, and 8.33333 ms.****Proposal 2: Among followings, which approach(s) are taken should be discussed further.****Approach 1: Rounding the non-integer transmission instances: the beginning of SPS/CG/DRX resource is rounded according to the non-integer periodicity matched to the radio resource granularity.****Approach 2: Enabling/disabling the non-integer periodicity instances: A new virtual cycle is defined, which contains enable/disable states and supports non-integer periodicities. The SPS/CG/DRX configurations can be linked to the virtual cycle. Only the overlapping resources with the enable state should be considered as valid for transmission or reception.****Approach 3: An SPS/CG/DRX configuration is configured with alternating periodicities, each periodicity is associated to a number of occasions.****Approach 4: DCI to reconfigure Group of SPS/CG/DRX: A DCI (re)configures several SPS/CG/DRX configurations together.****Proposal 3: The combination between DCI based (approach 4) and semi-static based (approach 1/2/3) should be taken.** |
| Rakuten Mobile | **Proposal 1: Support non-integer DRX cycle values for XR.** |
| Xiaomi | **Proposal 1: For enhancements on C-DRX for** **non-integral periodicity, two alternatives can be considered:****Alt 1, configure multiple C-DRX configurations with different offset for a single XR flow;****Alt 2, configure only one C-DRX configurations but with multiple on durations that can be located by a flexible setting.** |
| Google | 1. **Define new C-DRX cycles for the XR traffic.**
* **FFS: 9 ms, 11 ms, 17 ms, 33 ms, 34 ms.**
* **FFS: rounding XR traffic periodicities up and down to nearest integers ( if it is not already supported)**
1. **Re-use the 38.321 equation with some modification for the start of On-Duration timer .**
2. **Adopt one of the two porposed formulas for the start of On-Duration timer:**
* **Solution 1:**
	1. **Increment the counter:**

**drx-CorrectionCounter = 0;** **if (([(SFN × 10) + subframe number] modulo [(drx-CorrectionCounter + 1) × drx-CyclesAdjust × drx-Cycle] = drx-CorrectionCounter × drx-CyclesOffset ) && [(SFN × 10) + subframe number - drx-StartOffset > 0 ] )****drx-CorrectionCounter = drx-CorrectionCounter + 1;** * 1. **Start of On-Duration:**

**[(SFN × 10) + subframe number] modulo (drx-Cycle) = (drx-StartOffset + [drx-CorrectionCounter × drx-CyclesOffset]) modulo (drx-Cycle), where SFN is the current System Frame Number, and the subframe number is the current subframe number.*** **Solution 2:**
	1. **Increment the counter:**

**m is increased by 1 every n drx-Cycles** * 1. **Start of On-Duration:**

 **[(SFN × 10) + subframe number] modulo (drx-Cycle) = (drx-StartOffset + floor(m ×d)) modulo (drx-Cycle))** |
| LGE | **Observation 1: High throughput and capacity should also be taken into account for XR-specific PS enhancements.****Observation 2: Upon use for XR service, current CDRX mechanism would cause frequent reconfigurations of the CDRX and/or increase the overall latency.****Proposal 1: For resolving the mismatch between CDRX cycle and XR traffic periodicity, consider to support semi-statically configured pattern of offsets or DRX cycles.****Proposal 2: For the study of dynamic signaling that indicates adjustment of CDRX start offset, consider potential ambiguity issue between the network and UE due to case of the missing signaling****Proposal 6: Study enhancements to the secondary DRX group taking into account the XR traffic characteristics such as non-integer periodicity and jitter.****Observation 3: Discussion on the baseline CDRX scheme that can serve as the baseline for potential enhancements would be useful.** |
|  |  |

### Summary of evaluation results

**Enhanced CDRX for periodicity alignment with XR video**

[Ericsson] proposed to configure a new DRX cycle, (i) a fixed time shift for the start of drx-onDurationTimer; and (ii) a number of DRX cycles after which the new shift should be added to align the DRX and XR periodicity. Evaluation in FR1 Dense Urban with VR DL+UL multi-stream traffic (DL video, DL audio and UL pose) shows additional 4.9% power saving gain for all UEs in the cell in comparison to R15/16 long DRX cycle and 82.5% satisfied UE rate.

[vivo] proposed to adopt higher layer based DRX enhancements to accommodate the non-integer XR traffic characteristics. Evaluation in FR1 DL Indoor Hotspot with 30Mbps traffic model shows 8.42% to 9.38% and 6.05% to 6.62% additional power saving gain compared to R15/16 DRX (here R15/16 DRX with < 80% satisfied UE rate is not counted) and 100% and 91.94% satisfied UE rate for low load and high load, respectively.

[OPPO] proposed a DRX cycle pattern with two inter-DRX interval lengths to resolve mismatch between non-integer XR traffic arrival cycle and integer DRX cycle. Evaluation in FR1 DL Dense Urban with 60fps and 30Mbps traffic shows additional 13.57% power saving gain compared to R15/16 CDRX and the 88.07% satisfied UE rate.

[Intel] proposed to configure a periodic pattern of CDRX cycles such as consecutive DRX cycles with two DRX cycle values or start offset adjustment every N DRX cycles. Evaluation in VR and CG in Dense Urban scenario DL shows additional 2.57% and 5.74% power saving gain compared to R15/16 CDRX and the 97.5% and 99.75% satisfied UE rate when jitter is on and off, respectively.

[MediaTek] proposed to configure non-integer (rational number) DRX cycles to match typical XR traffic patterns. Evaluation in FR1, DL-only, DU with CG 30Mbps shows additional 3.5% power saving gain compared to R15/16 CDRX and 94.3% satisfied UE rate.

[ZTE] compared performance for various solutions including dynamic indication, non-uniform CDRX cycle, uniform non-integer CDRX cycle, multiple CDRX configurations. Similar performance is observed for FR1 in Indoor Hotspot scenario with VR30M DL + UL (>16% power saving gain when both R15/16 CDRX and eCDRX have ~90% satisfied UE rate, and 10% power saving gain when R15/16 CDRX has 81.82% satisfied UE rate) and Indoor Hotspot scenario with VR30M DL only ((>26% power saving gain when both R15/16 CDRX and eCDRX have ~90% satisfied UE rate, and >15% power saving gain when R15/16 CDRX has 81.82% satisfied UE rate). [ZTE] further points out it is not necessary to achieve a periodic alignment between CDRX cycle and XR traffic periodicity, via additional dynamic signalling in each CDRX cycle.

[Qualcomm] proposed semi-static configuration of enhanced DRX with non-integer rational numbers in short/long DRX cycles and add floor operations in DRX formulas. Evaluation results in FR1, DL VR 30Mbps in Dense Urban environment, PDCCH skipping and SSSG switching helps eCDRX achieve 28.8% power saving gain with satisfied UE rate 83%, but for CDRX the satisfied UE rate significantly degrades to 14%. For FR2, DL VR 30Mbps in Indoor Hotspot environment, eCDRX achieves considerable capacity gains over Re115/16 CDRX (especially in case of jitter) with comparable power saving gains. The observation is that to enable the large power saving gain provided by Rel-17 PDCCH adaptation, eCDRX is needed to align the CDRX cycle with XR video frame periodicity first. Otherwise, capacity degrades significantly which essentially removes PDCCH adaptation as an option for power saving. This makes eCDRX more important than just as an enhancement to the Rel-15/16 CDRX.

### Discussions

Issue 1-1 has the largest number of companies who provided evaluation results. In the meanwhile, several other companies expressed support for the study of this issue.

**Question 2.1-1:** Can it be confirmed that Issue 1-1 should be studied?

Between semi-static and dynamic solutions, the semi-static one has less signalling overhead and lower implementation complexity. Besides, the semi-static solution is a RAN2 design.

**Question 2.1-2:** Do you agree that RAN1 should leave the design of semi-static alignment between CDRX and XR video periodicity to RAN2?

Please provide your views if necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Google | Question 2.1-1Yes Issue 1-1 should be studied in RAN1. Question 2.1-2:We support a semi-static solution for the mentioned reasons. RAN1 can study different (semi-static and dynamic) solutions and provide evaluation results and recommendations to RAN2 and let RAN2 decide on the best solution and do the design of the alignment between C-DRX and XR traffic. RAN1 can be involved in the design if a dynamic solution is selected.  |
| MTK | **Question 2.1-1:** We confirm this issue should be studied.**Question 2.1-2:** Agree. |
| ZTE | Question 2.1-1: Yes, definitely.Question 2.1-2: We have similar views as Google. And with a lot of evaluation results we’ve achieved, we agree that semi-static solutions are more reasonable for CDRX enhancement; on the other hand, for specific cases such as variable video FPS, dynamic solution can be further studied in RAN1. |
| InterDigital | Q 2.1-1: Confirm to study Issue 1-1 Q 2.1-2: Yes. We think RAN1 can perform evaluations of both dynamic and semi-static solutions and leave to RAN2 on the design of aligning semi-static CDRX with XR traffic pattern (e.g. periodicity) |
| Samsung | Question 2.1-1: Yes.Question 2.1-2: Yes |

Jitter Handling for CDRX

Proposals in this subsection correspond to the high priority Issue 1-2 identified in the RAN1 #109-e meeting

* High priority Issue 1-2: C-DRX enhancements to handle jitter

**Table 3: Proposals and evaluation results for jitter handling for CDRX**

|  |  |
| --- | --- |
| **Company** | Proposals and evaluation results |
| Huawei, HiSilicon | **Observation 2: According to the data in real deployment, there is correlation between the jitters of adjacent XR frames, which can be used to further reduce UE power consumption.****Proposal 1: Further study the following C-DRX enhancements to handle periodicity mismatch between C-DRX cycle and XR traffic. A simple solution with less signaling overhead, less specification impact and good forward compatibility is preferred.*** **Non-uniform C-DRX cycle pattern**
* **Uniform non-integer C-DRX cycle**
* **Semi-static configurations of drx\_startoffset to match the traffic periodicity**
* **Multiple active C-DRX configurations**

**Proposal 2: To handle jitter issue, support that gNB can configure PDCCH monitoring occasions flexibly (e.g., through bitmap) within C-DRX On Duration.**Table 1 Simulation results of the non-uniform PDCCH monitoring occasions within C-DRX On Duration (High Load Case, 11 UEs per cell on average where the capacity is 11.5 UEs/cell)

|  |  |  |  |
| --- | --- | --- | --- |
| Case | Monitoring pattern within C-DRX On Duration(‘1’ denotes monitoring, ‘0’ denotes sleeping) | Satisfied UE Ratio | Power Saving Gain |
| 1 | Always On | 93.42% | - |
| 2 | Legacy C-DRX (DRX cycle=10, ODT=8, IAT= 4) | 91.34% | 3.98% |
| 3 | [1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1] | 90.30% | 14.98% |
| 4 | [0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1] | 87.71% | 18.50% |
| 5 | [0, 0, 0, 0, 1, 1, 0, 1, 1, 0, 1, 0, 1, 0, 1, 1] | 84.85% | 20.26% |
| Note: Case 3, 4, 5 assumes periodicity mismatch issue already solved. |

 |
| Ericsson | Observation 5 It is necessary to enhance C-DRX to cope with traffic jitter, in order to save more UE power, while not increasing the traffic delay significantly.Observation 6 Two-stage DRX is suitable for low network loads, where it saves significant UE power (16.6%), while also achieving a high percentage of satisfied UEs (96.4%).Proposal 5 Adopt the two-stage DRX solution to handle jitter for quasi-periodic XR traffic flows.Table 4: Results for CDRX, for FR1, high load, Dense Urban scenario, and VR multi-stream traffic: DL video (60 fps, 30 Mbps, 10 ms PDB), DL audio (10 ms periodicity, 30 ms PDB), UL pose (4 ms periodicity, 10 ms PDB)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Tdoc #** | **Power Saving Scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **Load H/L** | **avg # UEs/Cell** | **floor (Capacity)** | **% of satisfied UE** | **Mean PSG of all UEs** | **Mean PSG of satisfied UEs** |
| R1-2205916 | Always On | - | - | - | H | 8 | 8 | 90.1% | - | - |
| R1-2205916 | R15/16 DRX(Long DRX) | 10 | 8 | 4 | H | 8 | 7 | 82.6% | 4.2% | 4.1% |
| R1-2205916 | R15/16 DRX(Short DRX) | 4 | 2 | 4 | H | 8 | 5 | 69.8% | 9.8% | 9.7% |
| R1-2205916 | Matched CDRX (with our solution) | 16.6 (16-16-18 equivalent) | 10 | 4 | H | 8 |  7 | 82.5% | 9.1% | 9.0% |
| R1-2205916 | Matched CDRX (solutions from other companies) | 16.6 (17-17-16) | 10 | 4 | H | 8 | 7 | 83.7% | 9.5% | 9.4% |
| R1-2205916 | Two-stage DRX | outer DRX: 16.6;inner DRX: 4 | outer ODT: 10; inner ODT: 2 | 4 | H | 8 |  5 | 71.7% | 14.2% | 14.1% |

Table 5 Results for two-stage DRX, for low load, FR1, Dense Urban scenario, and VR multi-stream traffic: DL video (60 fps, 30 Mbps, 10 ms PDB), DL audio (10 ms periodicity, 30 ms PDB), UL pose (4 ms periodicity, 10 ms PDB)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Tdoc #** | **Power Saving Scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **Load H/L** | **avg # UEs/Cell** | **floor (Capacity)** | **% of satisfied UE** | **Mean PSG of all UEs** | **Mean PSG of satisfied UEs** |
| R1-2205916 | Always On | - | - | - | L | 2 | 8 | 99.5% | - | - |
| R1-2205916 | R15/16 DRX(Long DRX) | 10 | 8 | 4 | L | 2 | - | 98.3% | 4.6% | 5.0% |
| R1-2205916 | R15/16 DRX(Short DRX) | 4 | 2 | 4 | L | 2 |  - | 96.5% | 10.8% | 11.7% |
| R1-2205916 | Matched CDRX (with our solution) | 16.6 (16-16-18 equivalent) | 10 | 4 | L | 2 | - | 97.0% | 10.2% | 10.9% |
| R1-2205916 | Two-stage DRX | outer DRX: 16.6;inner DRX: 4 | outer ODT: 10; inner ODT: 2 | 4 | L | 2 |  - | 96.4% | 15.7% | 16.6% |

 |
| Qualcomm | Table 2: Enhanced CDRX, FR1, DL evaluation, DU, VR30

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Power saving scheme | CDRX cycle (ms) | ODT (ms) | IAT (ms) | Load H/L | #UE /cell | floor (Capacity) | % of satisfied UE | Mean PSG of all UEs (%) |
| Always On |  |  |  | H | 13 | 13 | 90% | 0% |
| Rel15/16 CDRX | 16 | 12 | 8 | H | 13 | 13 | 79% | 6.0% |
| eCDRX | 16/17/17 | 12 | 8 | H | 13 | 13 | 90% | 3.9% |
| Rel15/16 CDRX + PDCCH skipping | 16 | 12 | 8 | H | 13 | 13 | 38% | 25.7% |
| eCDRX + PDCCH skipping | 16/17/17 | 12 | 8 | H | 13 | 13 | 87% | 24.5% |
| Rel15/16 CDRX + PDCCH skipping + SSSG switching | 16 | 12 | 8 | H | 13 | 13 | 14% | 29.7% |
| eCDRX + PDCCH skipping + SSSG switching | 16/17/17 | 12 | 8 | H | 13 | 13 | 83% | 28.8% |

 |
| vivo | **Observation 1: SA4 has updated the XR video traces and configurations files which are captured in the latest TR 26.926 agreed in SA4 #117-e.** **Observation 2: As per the latest XR traces document of TR 26.926, the variance of jitter extends to around 5ms and the jitter range (truncated by 5%-tile and 95%-tile in CDF) extends to [-8ms, +8ms].** **Proposal 1: For R18 XR study, jitter model in accordance with the latest SA4’s inputs in TR 26.926 should be considered, e.g. jitter range of [-8ms, +8ms].** **Observation 6: R17 PDCCH monitoring adaptation can be applicable to handle jitter, however, it cannot completely avoid the unnecessary PDCCH monitoring due to the sparse SSSG monitoring before data arrival.** **Observation 7: The feasibility of the MAC CE or DCI based jitter handling approach heavily depends on whether jitter can be predictable and how accurate the prediction could be.** **Observation 8: Based on the latest SA4 trace files, it can be observed that there is no jitter correlation among the adjacent frames.****Observation 9: LP-WUS based jitter handling scheme will not rely on the jitter predication, compared with the scheme to solve jitter by adjustment the start-offset of DRX onduration via MAC CE or DCI.****Observation 10: For jitter handling, compared to R17 PDCCH monitoring adaptation scheme, LP-WUS scheme can provide {6%~15%} additional power saving gain with no capacity loss.****Observation 11: The larger jitter range, the more additional power saving gain can be obtained by LP-WUS scheme.****Proposal 3: Study LP-WUS based jitter handling scheme.****Table I. Power consumption results in FR1 DL Indoor Hotspot with 30Mbps traffic model**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **DRX configuration****(ms)** | **avg # UEs/ cell = N1** | **C1=floor****(Capacity)** | **% of satisfied UEs when #UEs/cell = N1** | **Power saving gain (%)** | **Notes** |
| AlwaysOn | - | 5 | 10 | 100% | - | Note1 |
| R15/16 DRX  | 16\_14\_4 | 5 | 10 | 100% | 3.67% | Note1 |
| 10\_8\_4 | 5 | 10 | 100% | 5.72% | Note1 |
| 4\_3\_1 | 5 | 10 | 100% | 4.63% | Note1 |
| 16\_8\_4 | 5 | 10 | 11.67% | 19.71% | Note1 |
| 10\_5\_2 | 5 | 10 | 78.33% | 15.41% | Note1 |
| 10\_4\_2 | 5 | 10 | 52.22% | 22.17% | Note1 |
| Enhanced DRX  | 16\_8\_4 | 5 | 10 | 100% | 13.05% | Note1 |
| R17 PDCCH monitoring adaptation | 16\_8\_4 | 5 | 10 | 100% | 30.45% | Note1,5 |
| 16\_8\_4 | 5 | 10 | 100% | 25.53% | Note2,5 |
| 16\_8\_4 | 5 | 10 | 100% | 21.33% | Note3,5 |
| 16\_8\_4 | 5 | 10 | 100% | 18.23% | Note4,5 |
| LP-WUS scheme | 16\_8\_4 | 5 | 10 | 100% | 37.02% | Note1,5,6 |
| 16\_8\_4 | 5 | 10 | 100% | 35.61% | Note2,5,6 |
| 16\_8\_4 | 5 | 10 | 100% | 35.12% | Note3,5,6 |
| 16\_8\_4 | 5 | 10 | 100% | 35.93% | Note4,5,6 |
| AlwaysOn | - | 10 | 10 | 92.50% | - | Note1 |
| R15/16 DRX | 16\_14\_4 | 10 | 10 | 91.81% | 3.46% | Note1 |
| 10\_8\_4 | 10 | 10 | 91.25% | 5.10% | Note1 |
| 4\_3\_1 | 10 | 10 | 91.68% | 4.03% | Note1 |
| 16\_8\_4 | 10 | 10 | 2.78% | 18.21% | Note1 |
| 10\_5\_2 | 10 | 10 | 45.00% | 13.10% | Note1 |
| 10\_4\_2 | 10 | 10 | 22.50% | 18.70% | Note1 |
| Enhanced DRX | 16\_8\_4 | 10 | 10 | 91.94% | 10.08% | Note1 |
| R17 PDCCH monitoring adaptation | 16\_8\_4 | 10 | 10 | 92.22% | 25.82% | Note1,5 |
| 16\_8\_4 | 10 | 10 | 92.16% | 21.46% | Note2,5 |
| 16\_8\_4 | 10 | 10 | 92.20% | 17.46% | Note3,5 |
| 16\_8\_4 | 10 | 10 | 91.01% | 15.43% | Note4,5 |
| LP-WUS scheme | 16\_8\_4 | 10 | 10 | 92.22% | 31.97% | Note1,5,6 |
| 16\_8\_4 | 10 | 10 | 92.20% | 30.97% | Note2,5,6 |
| 16\_8\_4 | 10 | 10 | 92.10% | 32.02% | Note3,5,6 |
| 16\_8\_4 | 10 | 10 | 91.11% | 32.42% | Note4,5,6 |
| Note1: jitter range = [-4, +4]msNote2: jitter range = [-6, +6]msNote3: jitter range = [-8, +8]msNote4: jitter range = [-10, +10]msNote5: with enhanced DRX configurationNote6: with R17 PDCCH skipping indication |

5.2 Power Saving Techniques5.2.1 Techniques for handling non-integer XR traffic periodicityPotential CDRX enhancement techniques for handling mismatch between CDRX cycle and non-integer XR traffic periodicity in this study are summarized as follows,* Configure DRX cycle set and each DRX cycle set contains multiple DRX cycles, e.g., {16ms, 17ms, 17ms}.
* Multiple active DRX configurations and each of them contains different drx-StartOffset value.
* Single DRX configuration and one DRX cycle can contain multiple DRX ondurations.

5.2.2 Techniques for handling jitterPotential PDCCH monitoring enhancement techniques for handling jitter in this study are summarized as follows,* PDCCH monitoring adaptation enhancements based on Rel-17 PDCCH skipping or sparse/dense SSSG switching

The UE performs sparse PDCCH monitoring during the active time. Once a scheduling DCI is detected, the UE switches to dense PDCCH monitoring. In case indicated by gNB, e.g. by DCI scheduling the last packet of a burst, the UE will skip the PDCCH monitoring until the possible arrival time of the next burst.* Low power wake-up signal (LP-WUS) triggered PDCCH monitoring

The UE performs LP-WUS detection during active time, and triggers PDCCH monitoring once LP-WUS is received. The UE power consumption of the LP-WUS monitoring is significantly lower than that of the PDCCH monitoring (e.g. 50% reduction) with limited wake-up latency.Annex A:Evaluation MethodologyRel-17 evaluation methodology for XR power saving captured in [4] is used as the baseline evaluation methodology for UE power saving evaluation of Rel-18 XR**.**…Omitted part…=========================End of Text proposal of TR 38.835==============================**Proposal 5: Capture the above text proposal into R18 XR TR 38.835.** |
| Nokia, NSB | **Observation 1:** There is a clear tradeoff between power saving gain and capacity loss for any power saving scheme and enhancement. Therefore, both performance metrics are important when evaluating any enhancement.**Proposal 1:** When evaluating power saving enhancements, capacity loss should be considered jointly with power saving gain.**Observation 2**: A single CDRX configuration for multiple XR applications, which have different QoS characteristics, results in suboptimal performance. For example, the CDRX configuration (DRX long cycle, inactivity timer value, On duration timer value)=(16, 8, 8) cannot satisfy any UE when PDB decreases from 15ms to 10ms.**Observation 3**: The possibility to quickly reconfigure the parameters of the CDRX configuration can reduces the capacity loss while improving the power saving gain computed with respect to the baseline “always ON”.**Observation 4**: Enabling dynamic change of both, the Start Offset and On Duration of the CDRX cycle, keeps the XR traffic and CDRX cycle aligned and allows to optimize the CDRX configuration according to the XR jitter, thus improving both capacity loss and power saving gain.**Observation 5**: the non-integer and recurrent periodicity of XR traffic and the integer periodicity of the DRX cycle results in the misalignment between XR traffic and DRX cycle. This misalignment causes a time drift between the XR frame arrivals and the start of the DRX cycles. The drift accumulates over time and eventually the start of the DRX cycle falls outside expected arrival interval of the XR traffic.**Proposal 2**: We propose to consider L1/L2 signalling to quickly change multiple parameters of the CDRX configuration. Also, configuration to enable period change to start offset to align the onDuration timing to XR frame arrival could be considered. Table 1 – Evaluation of enhanced ADRX enhancement for {Dense Urban, CG, DL Only, 30Mbps, FR1}. Option 1: PS gain computed with All UEs.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Power Saving Scheme | Power Saving Gain (PSG) compared to ‘Always ON’ | #satisfied UEs per cell with PS / #satisfied UEs per cell w/o PS | Capacity with PS[#satisfied UEs/cell with PS] | Percentage of satisfied UEs per cell with PS at #satisfied UEs cell w/o PS |
| Baseline | Optional |
| 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 |
| Always ON | - | - | - | - | - / 8 | 8 | - |
| CDRX(16,8,8) | 13.3% | 16.7% | 14.3% | 7.5% | 6 / 8 | 6 | 75% |
| ADRX 1 (16,0,0,[1,16]) | 9% | 10% | 9.5% | 2% | 6.5 / 8 | 6 | 82% |
| ADRX 2 (16,0,[0,2],[8,16]) | 9% | 12.7% | 10.3% | 2% | 7.2 / 8 | 7 | 90% |
| ADRX 3 (16,0,[0,4],[4,12]) | 22% | 23% | 21.5% | 24% | 3 | 3 | 38% |

Table 2 – Evaluation of enhanced ADRX enhancement for {Dense Urban, AR/VR, DL Only, 30Mbps, FR1}. Option 1: PS gain computed with All UEs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Power Saving Scheme | Power Saving Gain (PSG) compared to ‘Always ON’ | #satisfied UEs per cell with PS / #satisfied UEs per cell w/o PS | Capacity with PS[#satisfied UEs/cell with PS] | Percentage of satisfied UEs per cell with PS at #satisfied UEs cell w/o PS |
| Baseline | Optional |
| 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 |
| Always ON | - | - | - | - | - / 6 | 6 | - |
| CDRX(16,8,8) | - | - | - | - | 0 / 6 | 0 | 0% |
| ADRX 1 (16,0,0,1,16) | 9.3% | 10.7% | 10% | 2.5% | 4 / 6 | 4 | 66% |
| ADRX 2 (16,0,[0, 2],[8,16]) | 13% | 17.8% | 15% | 1% | 5 / 6 | 5 | 83% |
| ADRX 3 (16,0,[0,4],[4,12]) | 18.2% | 23% | 21.8% | 7.6% | 3 / 6 | 3 | 50% |

 |
| Xiaomi | **Observation2: LP WUS combined with PDCCH skipping scheme shows 13% more power saving gain than PDCCH skipping compared to baseline, and shows no delay performance loss.****Proposal 5: LP WUS combined with C-DRX/PDCCH skipping should be studied to cope with jitter issue.****Table 4: Relative time fraction of different UE power consumption states**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | PDCCH without PDSCH | PDCCH with PDSCH  | Deep sleep | Light sleep | Micro sleep |
| Baseline | 91.72% | 8.28% | 0 | 0 | 0 |
| genie | 0 | 8.28% | 5.35% | 66.84% | 3.80% |
| PDCCH skipping case 1 | 32.77% | 8.28% | 0 | 58.95% | 0 |
| Scheme 1 | 4.31% | 8.28% | 0 | 58.95% | 28.46% |

**Table 5: Relative energy of different UE power consumption states**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | PDCCH without PDSCH | PDCCH with PDSCH | Deep sleep  | Deep sleep transition | Light sleep | Light sleep transition | Micro sleep | WUS Monitor | Total | PSG |
| Baseline | 91.72 | 24.84 | 0 | 0 | 0 | 0 | 0 | N/A | 116.56 | N/A |
| genie | 0 | 24.84 | 0.0535 | 1.38 | 13.37 | 5.65 | 1.71 | N/A | 47.00 | 59.67% |
| PDCCH skipping case 1 | 32.77 | 24.84 | 0 | 0 | 2.84 | 7.46 | 0 | N/A | 67.91 | 41.74% |
| Scheme 1 | 4.31 | 24.84 | 0 | 0 | 2.84 | 7.46 | 12.81 | 0.2846 | 52.54 | 54.92% |

**Table 6: Summary of metrics**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | TotalEnergy | PSG | Delay(ms) | % of satisfied UEs |
| Baseline | 116.56 | N/A | 2.46 | 96.61% |
| PDCCH skipping case 1 | 67.91 | 41.74% | 2.70 | 95% |
| Scheme 1 | 52.54 | 54.92% | 2.70 | 95% |

 |
| MediaTek | **Observation 7: Stopping ODT early + eC-DRX provides significant power savings with marginal impact on UE satisfaction rate compared to Rel-17 C-DRX (11.2% PSG and 0.3% reduction in UE satisfaction rate) as shown in Table 2 and Figure 7.****Proposal 5: Reduce DRX on-duration after the arrival of data by stopping ODT to enable the UE to go to sleep early.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Power saving scheme | CDRX cycle (ms) | ODT (ms) | IAT (ms) | #UE /cell | floor (Capacity) | % of DL satisfied UE | Mean PSG of all UEs (%) |
| AlwaysOn - baseline | 0 | 0 | 0 | 12 | 12 | 94.6% | 0% |
| R15/16CDRX | 16 | 12 | 8 | 12 | 12 | 92.7% | 5.4% |
| eCDRX (rational DRX cycle) | (50/3) | 12 | 8 | 12 | 12 | 94.3% | 9.9% |
| eCDRX + stop ODT early | (50/3) | 12 | 8 | 12 | 12 | 92.4% | 16.6% |

Table 2 SLS evaluation results with stop ODT early, FR1, DL-only, DU, CG 30Mbps |
| OPPO | **Proposal 3: In case DRX on-duration timer can be configured long enough to cover jitter range, layer-1 based power saving schemes discussed in Rel-17 power saving WI can be applied to avoid unnecessary power consumption.****Observation 3: If DRX on duration timer is configured not long enough to cover jitter range, there would exist early/late packet arrival issue, and late packet arrival would lead to longer scheduling latency and additional power consumption.****Proposal 4: An additional DRX-on duration time can be dynamically indicated to UE to solve jitter issue.****Observation 4: In FR1 Dense Urban, AR/VR 30Mbps and 60fps, the following is observed:*** **For R15/16 C-DRX, the power saving gain is 5.12% with loss of satisfied UE rate limited to 1%;**
* **For non-uniform CDRX cycle pattern, the power saving gain is 18.69% with loss of satisfied UE rate limited to 1%;**
* **For Non-uniform CDRX cycle pattern with dynamic additional on duration timer, the power saving gain is 30.73% with similar satisfied UE rate.**

Table 2: Power saving results in FR1 DL Dense Urban with 60fps and 30Mbps traffic model

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **Another ODT (ms)** | **#UE /cell= floor (Capacity)** | **satisfied UE rate** | **Mean PSG of all UEs (%)** |
| Always On | - | - | - | - | 5 | 89.12% | / |
| R15/16 CDRX | 16 | 14 | 2 | - | 5 | 88.07% | 5.12% |
| Non-uniform CDRX cycle pattern | {17,17,16} | 10 | 2 | - | 5 | 88.07% | 18.69% |
| Non-uniform CDRX cycle pattern with dynamic additional ODT | {17,17,16} | 4 | 2 | 4 | 5 | 90.18% | 30.73% |

 |
| ZTE | Proposal 4: With jitter impact of the XR traffic, flexible additional active time either trigger implicitly or via signalling can be considered to improve the performance on the top of CDRX alignment with XR traffic periodicity. Table 6 FR1 power consumption results in Indoor Hotspot scenario (VR30M, fps=60, DL + pose/control){Iitter=[-8,8]ms; For the additional active time activated via WUS: Transition time=1 slot, and WUS is monitored every 1ms; For the additional active time activated via Non-data reception or signalling: additional DRX On duration = original DRX On duration}

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **#UE /cell** | **floor (Capacity)** | **Percentage of satisfied UE** | **Mean PSG of all UEs (%)** |
| Aligned CDRX with XR traffic | Aligned every 50ms | 12 | 4 | 11 | 11 | 88.36% | 7.5% |
| activate the additional active time  | Aligned every 50ms | 5 | 4 | 11 | 11 | 90% | 14.18% |

Table 7 FR1 power consumption results in Indoor Hotspot scenario (VR30M, fps=60, DL only){Jitter=[-8,8]ms; For the additional active time activated via WUS: Transition time=1 slot, and WUS is monitored every 1ms; For the additional active time activated via Non-data reception or signalling: additional DRX On duration = original DRX On duration}

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **#UE /cell** | **floor (Capacity)** | **Percentage of satisfied UE** | **Mean PSG of all UEs (%)** |
| Aligned CDRX with XR traffic | Aligned every 50ms | 12 | 4 | 11 | 11 | 88.36% | 10.4% |
| activate the additional active time  | Aligned every 50ms | 5 | 4 | 11 | 11 | 90% | 30% |

Table 8 FR1 power consumption results in Indoor Hotspot scenario (VR45M, fps=60, DL + pose/control, jitter=[-8,8]ms)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **#UE /cell** | **floor (Capacity)** | **Percentage of satisfied UE** | **Mean PSG of all Ues (%)** |
| Aligned CDRX with XR traffic | Aligned every 50ms | 12 | 5 | 11 | 11 | 90% | 7.5% |
| activate the additional active time  | Aligned every 50ms | 6 | 5 | 11 | 11 | 88.1% | 15.16% |

Table 9 FR1 power consumption results in Indoor Hotspot scenario (VR45M, fps=60, DL only, jitter=[-8,8]ms)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **#UE /cell** | **floor (Capacity)** | **Percentage of satisfied UE** | **Mean PSG of all Ues (%)** |
| Aligned CDRX with XR traffic | Aligned every 50ms | 12 | 5 | 11 | 11 | 90% | 8.47% |
| activate the additional active time  | Aligned every 50ms | 6 | 5 | 11 | 11 | 88.1% | 20% |

Table 10 FR1 power consumption results in Indoor Hotspot scenario (CG30M + pose/control, jitter=[-4,4]ms)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **#UE /cell** | **floor (Capacity)** | **Percentage of satisfied UE** | **Mean PSG of all Ues (%)** |
| CDRX alignment | 16 | 6 | 4 | 12 | 12 | 84% | 21.2% |
| activate the additional active time | 16 | 6 | 4 | 12 | 12 | 88.19% | 21.3% |

Table 11 FR1 power consumption results in Indoor Hotspot scenario (CG30M, DL only, jitter=[-4,4]ms)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Power saving scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **#UE /cell** | **floor (Capacity)** | **Percentage of satisfied UE** | **Mean PSG of all Ues (%)** |
| CDRX alignment | 16 | 6 | 4 | 12 | 12 | 84% | 30.9% |
| 16 | 8 | 6 | 12 | 12 | 88.89% | 20.6% |
| activate the additional active time | 16 | 6 | 4 | 12 | 12 | 88.19% | 32.4% |

 |
|  |  |

**Table 4: Proposals without evaluation results for jitter handling for CDRX**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| TCL | **Proposal 3: An additional PDCCH monitor occasion can be configured for XR on DRX-OFF state.**  |
| Huawei, HiSilicon | **Proposal 3: To avoid unnecessary PDCCH monitoring after XR frame transmission finish, support stopping PDCCH monitoring in a DRX cycle based on the expiration of InactivityTimer.** |
| Spreadtrum | **Observation 1：The semi-statically configured starting position of the drx-onDurationTimer may cause a delay in data reception.****Proposal 4：Dynamic indication of CDRX configuration can be considered to solve Jitter issues.****Proposal 5：To reduce the impact on the specification, one or more adjustment values can be carried by semi-static RRC configuration, or it can be specified in the specification.****Proposal 6：It is necessary to further study how to indicate the starting position adjustment information in DCI.****Proposal 7: The design of PDCCH monitoring occasion should be based on the frame arrival time with jitter=0.*** **follow the design of the existing WUS signal**
* **PDCCH monitoring window should be within the jitter distribution range**

**Proposal 8：If DCI is not detected in the PDCCH monitoring window, the adjustment value is defaulted to 0.****Observation 2: If the drx-onDurationTimer or drx-InActivityTimer do not expire after the data transmission is completed, it is beneficial for power saving by letting UE go to sleep in advance.** |
| III | **Proposal#1:** **In order to handle jitter in a power saving way, we propose to utilize a LP-WUS detection channel to monitor the arrival of XR traffic.** |
| Sony | **Observation 3 – Adjusting only the length of the ON duration can result either in a long delay or unnecessary increased power consumption.**Proposal 2 – Consider dynamic DRX configuration to delay or advance DRX ON duration based on the experienced jitter.Proposal 3 – Two-level DRX configuration with finer granularity inactive indication during DRX ON can be considered for further power saving. |
| Nokia, NSB | **Observation 6**: If the UE and the network know the number of expected frames to be received and/or transmitted during a CDRX cycle, then the UE can automatically extend the active time if the number of received and/or transmitted frames are smaller than the expected values.**Observation 7**: Active time extension adds the flexibility required to configure CDRX with the best trade-off between user satisfaction and power saving for XR traffic, provided that network and UE knows the number of expected frames to be received and/or transmitted during a CDRX cycle.**Observation 8**: Automatic Active time extension improves the power saving gain with respect to CDRX since it allows to define a relatively short onDuration with respect to the jitter range that is extended automatically only when a frame(s) do not arrive before the onDuration timer is expired.**Observation 9**: Given the frame arrival distribution of XR traffic, Active time needs to be extended very seldomly beyond the (short) onDuration timer.**Proposal 3**: We propose to evaluate power saving schemes that automatically extend the UE Active Time of CDRX like based on the frame arrival.

|  |  |
| --- | --- |
| Chart, bar chart  Description automatically generated(a) Power saving gain – PDCCH only | Chart, bar chart  Description automatically generated(b) Power saving gain – PDCCH + PDSCH |

Figure 9 – Power saving gain of the four schemes: CDRX(16,8), CDRX(16,12), CDRX(16,4)+Act.time ext, CDRX(16,6)+ Act.time ext.[Moderator]: please note the simulation only provided power saving gain result. |
| NEC | **Proposal 2: Study the enhancement of the starting time of the DRX on-duration and the WUS monitoring window to get good balance between the power saving and packet delay.** |
| Intel | **Proposal 3: For jitter handling, Rel17 PDCCH monitoring adaptation solution can be considered as starting point.** * **UE could start with sparse PDCCH monitoring, and once traffic is scheduled, UE could switch to frequent PDCCH monitoring**

**Proposal 4: Discussion on support LP WUS for XR power saving may depend on outcome of LP WUR study, whether LP WUS is applicable in connected mode or not.** |
| Xiaomi | **Proposal 4: For C-DRX configuration, DCI 2-6 can be used to indicate whether to start PDCCH monitoring earlier than the on duration.** |
| China Telecom | **Proposal 6: Specify a dynamic or semi-static C-DRX mechanism to adjust the starting time of C-DRX on duration adapted to the random jitter.****Proposal 7: Support periodic XR-specific PDCCH monitoring in the On Duration and dormancy of DRX.****Proposal 8: Dynamic indication of DRX On Duration starting time can be applied to solve the jitter problem.****Proposal 9: The start-offset indication monitoring should be supported at least during C-DRX On Duration. Besides, start-offset indication monitoring can also be supported during DRX dormancy, when DCP is enabled.****Proposal 10: At least option 1 or option 2 should be supported, while option 3 needs FFS.** |
| Samsung | **Proposal #1: Consider DCI-based adaptation of the *drx-OnDuration*, the *drx-InactivityTimer*, and the *drx-StartOffset*.** |
| CMCC | **Proposal 2. A new DCI can be used to indicate UE the extension of DRX ON at the end of DRX ON to handle XR jitter, e.g., indicate a new extended *drx-onDurationTimer* value or indicate UE to restart *drx-onDurationTimer*.****Proposal 3. A new DCI field in DCI format 2\_6 can be used to indicate UE whether to wake up early from DRX ON to handle XR jitter.** |
| ETRI | **Proposal 2: To efficiently handle jitter in XR packet arrivals, support dynamic DRX start offset indication based on WUS.** |
| Google | 1. **Adopt the two stages C-DRX configurations to handle the jitter.**
2. **If coarse and fine C-DRX cycles are used for the jitter, adopt non-uniform On-Durations pattern for the fine C-DRX cycle to match the jitter distribution.**
 |
| LGE | **Proposal 3: To handle jitter, consider the method that triggers additional DRX OnDuration when the UE does not receive any data during the periodic DRX OnDuration, or the UE receives a triggering indication.****Proposal 4: To handle jitter, study enhancements on PDCCH monitoring adaptation methods from both power and latency perspective.****Proposal 5: To handle jitter, study enhancements to WUS for joint operation with CDRX for XR-specific power saving.** |
| Qualcomm | **Observation 8: Using fixed CDRX parameters may have negative impact on delays (PDB) and power consumption for XR traffic.****Observation 9: For FR2, DL VR 30Mbps in Indoor Hotspot environment, dynamically adapting CDRX parameters can achieve considerable capacity gains over Re115/16 CDRX.****Proposal 5: For XR, consider studying methods to dynamically adapt the CDRX parameters to the traffic bursts****Observation 10: In presence of jitter, the active part of the CDRX cycle needs to be set as long as the jitter tail distribution to avoid premature transition to the inactive part of the cycle before receiving the burst of data. This extended duration of the active part of the CDRX cycle increases UE power consumption.****Proposal 6: UE can transition to the CDRX inactive state after reception of the DL frame. The transition can happen within the configured active part of the CDRX cycle if the Early CDRX conditions are satisfied.****Observation 11: Early CDRX reduces the active part of the CDRX cycle without impacting packet latency resulting in UE power saving.****Observation 12: The power savings achieved by Early CDRX on top of eCDRX are 4.9% and 10.4% for 60 and 120 FPS respectively for [-4, +4]ms jitter. Similarly, for [-5, +5] ms jitter, these savings are 7.8% and 13.3% respectively.** **Observation 13: Compared to Early CDRX, Release 17 PDCCH skipping with 3 skip durations scheme requires 12.9% and 22.2% additional PDCCH slots per frame for [-4, +4] ms and [-5, +5] ms jitter respectively resulting in higher power consumption.**[Moderator]: please note the simulation only provided power saving gain result. |
| InterDigital | **Proposal 4:** Support adaptation (e.g. via DCI) for advancing/delaying the CDRX ON duration per cycle by a start offset time **Proposal 5:** Study single indication (e.g. single DCI) for dynamically adapting the start offset time of CDRX ON duration for multiple cycles |
| DOCOMO | **Proposal 2: Further study the following directions for C-DRX enhancements to handle jitter.*** **Early termination of DRX On duration timer**
* **Dynamic adjustment of C-DRX starting time**
 |
|  |  |

### Summary of evaluation results

**Wider jitter range**

[vivo] pointed out that SA4 has added new XR video traces to TR 26.926. Their calculation shows that in the new data jitter range has increased to [-8ms, +8ms] for the truncated Gaussian distribution. [vivo] also provided evaluation results with the new jitter range. Companies please check whether the new jitter range can be added to Rel-18 evaluation. If yes, whether it is optional or mandatory. Besides, [vivo] based on the latest SA4 trace files, observed that there is no jitter correlation among the adjacent frames. This implies that jitter is not predictable given Rel-17 jitter model is derived from the SA4 trace files.

**Non-uniform PDCCH monitoring occasions within C-DRX On Duration**

[Huawei, HiSilicon] proposed to configure non-uniform PDCCH monitoring occasions (e.g., through bitmap) within C-DRX On Duration. UE monitors PDCCH more frequently around the centre of jitter distribution (i.e., expected data arrival time) and less frequently at the tail of jitter distribution. Evaluation results show an additional 1.76% power saving gain and 2.86% capacity loss compared to uniform sparse PDCCH monitoring. Given the small power saving gain with capacity loss, companies please assess whether it is worthwhile to further study non-uniform PDCCH monitoring occasions.

**Two-stage DRX**

[Ericsson] proposed to adopt the two-stage DRX solution to handle jitter for quasi-periodic XR traffic flows. Simulation result shows about 5.1% to 5.7% power saving gain and some capacity loss compared to eCDRX without the two-stage DRX. It is noticed that the non-consecutive PDCCH monitoring by two-stage DRX can also be enabled by sparse PDCCH monitoring (and switch to dense PDCCH monitoring by SSSG switching at the first scheduling DCI within the On Duration). [Qualcomm]’s results show a comparable power saving gain of 4.3% when sparse PDCCH monitoring within On Duration followed by SSSG switching. Then it is suggested to compare the two-stage DRX with sparse PDCCH monitoring and discuss whether the two-stage DRX is needed.

**Jitter handling by low power-wake up signal (LP-WUS)**

[vivo] and [Xiaomi] proposed the LP-WUS based jitter handling scheme. Evaluation results show that compared to PDCCH monitoring adaptation scheme, LP-WUS scheme can provide large ({6%~15%} and 13%) additional power saving gain compared to Rel-17 PDCCH monitoring adaptation schemes. However, nothing about the LP WUS (e.g., power modelling, gap for MR to wake up) is official available yet. The evaluations are based on companies’ own assumptions.

**Reducing C-DRX On-Duration after data arrival**

[MediaTek] proposed the early termination of the DRX On-Duration after the arrival of data by stopping ODT. This intends to enable the UE to go to sleep early. The On-Duration is first configured long enough to cover the jitter range. Together with eC-DRX this scheme can provide additional 6.7% power saving gain compared to eCDRX and 0.3% reduction in UE satisfaction rate compared to Rel-17 C-DRX. However, the proposed enhancement was not compared with PDCCH skipping which may achieve similar effect if indicated at the end of the XR frame.

**Additional On-Duration**

[OPPO] proposed that gNB can send a dynamic signaling (e.g., DCI) to UE to indicate another On-Duration if the packet arrives too late. Power saving comes from the smaller initial On-Duration (i.e., smaller than jitter range). Evaluation results show additional 12.73% power saving gain with similar satisfied UE rate compared to eCDRX configured with 10ms On-Duration. In the meanwhile, [OPPO] also points out that “in case DRX on-duration timer can be configured long enough to cover jitter range, layer-1 based power saving schemes discussed in Rel-17 power saving WI can be applied to avoid unnecessary power consumption.” In this case, it seems unnecessary to design a new mechanism to achieve same effect.

[ZTE] proposed to activate additional active time if a data packet arrives later than the end of DRX On-Duration. An additional active time can be activated for receiving this data packet. The proposed enhancement shows 6.68% to 19.6% additional power saving gain compared to eCDRX for optional jitter range [-8ms, 8ms], and 0.1% to 1.5% additional power saving gain compared to eCDRX for optional jitter range [-4ms, 4ms]. Similar to [OPPO] proposal, this is equivalent to the early termination of DRX time when long On-Duration is configured to cover jitter range. It would be necessary to compare with early go-to-sleep by PDCCH skipping at the end of XR frame.

**Dynamic adaptation of DRX On Duration start and On Duration**

[Nokia, NSB] proposed to configure [MinStartOffset , MaxStartOffset], [MinOnDuration, MaxOnDuration] and use L1/L2 signalling to quickly change multiple parameters of the CDRX configuration. In Dense Urban, CG, DL Only, 30Mbps, FR1, the proposed adaptation achieves -4.3% power saving gain and 7% to 15% capacity gain compared to CDRX. In Dense Urban, AR/VR, DL Only, 30Mbps, FR1, the proposed adaptation achieves 13% power saving gain compared to AlwaysOn with 83% satisfied UE rate (Note: only results with 80% or higher satisfied UE rate are counted).

Could the proponent clarify what L1/L2 signaling is used in the evaluation and how it is monitored (e.g., occasions)? E.g., for companies to understand the power consumption for the monitoring the signaling. Regarding “Enabling dynamic change of both, the Start Offset …”, does it assume the jitter value is predictable? Regarding “Regarding “Enabling dynamic change of both, … On Duration of the CDRX cycle”, PDCCH skipping indicated at the end of the video frame may also achieve similar effect if skipping duration goes beyond active time. It would be helpful to compare with PDCCH skipping.

### Discussions

There seem different understandings in companies’ contributions on whether jitter is predictable. This will have a major impact on the jitter handling mechanism. [vivo] analysed the latest SA4 trace files and observed that there is no jitter correlation among the adjacent frames.

**Question 2.2-1:** Do you think RAN1 should assume jitter for a frame is predictable or not before further input from other work groups?

[vivo] proposed [-8ms, 8ms] jitter range based on trace files in latest SA4 TR 26.926.

**Question 2.2-2:** Should the [-8ms, 8ms] jitter range be added as optional evaluation condition?

**Question 2.2-3:** Do you think “two-stage CDRX On-Duration” should be compared with PDCCH adaptation such as sparse PDCCH monitoring before data arrival followed by SSSG switching to dense PDCCH monitoring for data reception?

**Question 2.2-4:** Do you think “non-uniform PDCCH monitoring occasions within CDRX on duration” needs to be further studied given the small power saving gain and capacity loss compared to uniform sparse PDCCH monitoring?

**Question 2.2-5:** Do you think “Reducing C-DRX On-Duration after data arrival”, “Additional On-Duration” and “Dynamic adaptation of DRX On Duration start and On Duration” should be further compared with PDCCH adaptation, i.e., PDCCH skipping at the end of XR frame?

Please provide your views if necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Google | Question 2.2-1: RAN1 cannot assume jitter is predictable and that the jitter information is available at RAN at this stage. RAN1 can study both assumptions but this requires a lot of extra effort. SA2 and RAN2 are still discussing XR awareness and it is not decided yet what information about XR traffic characteristics would be available at 5G-RAN. In the meantime, RAN1 can assume jitter statistics are available and can send an LS to SA2/SA4/RAN2 to get more inputs on this question. Question 2.2-2 We think [-4,+4] ms is enough for the evaluation. Not sure what difference in conclusions would the new jitter range make in evaluating the different proposed solutions. Would a solution work better than another solution in a specific jitter range and not for another jitter range? Question 2.2-3: Yes. “two-stage CDRX On-Duration” is a very promising enhancement of C-DRX and should be further studied. It can be compared to SSSG switching. C-DRX is an advanced and effective power saving mechanism and is widely adopted and should be enhanced anyway to support XR traffic. Not outperforming SSSG switching or PDCCH skipping shouldn’t be a reason to exclude any enhancement to C-DRX.Question 2.2-4: With information about the jitter statistics potentially available at 5G-RAN “non-uniform PDCCH monitoring occasions within CDRX on duration” matching the jitter distribution could have some potential. However, in the pattern we should monitor more at the end of the tail compared to the start of the tail. Can Huawei provide an explanation why there is capacity loss? Question 2.2-5 Yes “Reducing C-DRX On-Duration after data arrival”, “Additional On-Duration” and “Dynamic adaptation of DRX On Duration start and On Duration” should be further compared with PDCCH adaptation. The concern with PDCCH skipping at the end of XR frame is that the current PDCCH skipping durations are not enough to cover the possible durations till the start of the next XR frame.  |
| MTK | **Question 2.2-1:** No, we do not think jitter is predictable.**Question 2.2-2:** Fine to us to include [-8,8] ms as optional one.**Question 2.2-3:** For some NW vendors, they may want to implement RAN1-based and RAN2-based power saving methods separately or with different implementation timeline. Hence, we think “two-stage CDRX On-Duration” does NOT have to be compared with PDCCH adaptation.**Question 2.2-4:** We are open to discuss it if the power saving gain is evident. **Question 2.2-5:** Same reply as Question 2.2-3. |
| ZTE | Question 2.2-1: RAN1 may know the jitter range (or statistics information) from assistance information. And RAN needs to have the assumption of jitter range so that gives designs based on the assumption. But we don’t thinks RAN1 can assume to have instant jitter value for a frame, we can ask RAN2/SA2 whether or not this information can be provided. Question 2.2-2: [-8ms, 8ms] jitter range happens truly based on SA’s input, and even for [-4ms,4ms] truncated jitter range, the real jitter value of XR DL packet can be -8ms or 8ms. Moreover, according to the evaluations of companies including ZTE’s, it is justified that different jitter range can bring different deterioration of the performance for aligned CDRX. Thus we’re fine to add [-8ms,8ms] as an **optional** evaluation condition.Question 2.2-3: Regarding the details to handle jitter, firstly we need to clarify that the problem really exists as discussed in Question 2.2-2. And in fact we could assume either having a long DRX Onduration or NOT to resolve the jitter issue, furthermore, two-stage CDRX On-Duration was proposed for reducing the power consumption. Of course the SSSG switching can also be applied to reduce the power consumption, and taken as a reference according to the previous conclusion. Question 2.2-4: If the power saving gain is small and with capacity loss, we don’t think the solution needs to be further studied.Question 2.2-5: For “Reducing C-DRX On-Duration after data arrival”, we thinks it can be further compared with PDCCH adaptation, and in our view, it can be realized with existing specification.For “Additional On-Duration” and “Dynamic adaptation of DRX On Duration start and On Duration”, if that means to **add** on-duration, then it’s different from reducing on-duration as what PDCCH skipping performs. Thus these two solutions should be separated to discuss for handling jitter issue.  |
| InterDigital | Q 2.2-1: Since discussions in RAN2 and SA2 are ongoing, to what extent the jitter is predictable (e.g. per-frame/PDU set or per-multiple frames) and what type of jitter info (e.g. statistics, real-time) may be available at gNB can be discussed at later stage in SI. For the purpose of evaluations, similar to Google, we think RAN1 can assume the jitter statistics are available at gNB.Q 2.2-2: No strong view. If companies would like to optionally provide evaluation results for [-8, 8] ms they may do so. RAN1 can still use [-4, 4]ms jitter range as baseline. Q 2.2-3: The benefit of using 2-stage CDRX in terms of robustness when handling jitter is not clear, especially when assuming only jitter statistics are available at gNB. In this case, we think further comparison between the 2-stage CDRX and PDCCH adaptation schemes in terms of the amount of PSG achievable is needed. Q 2.2-4: We think it is reasonable to further study the pattern used for non-uniform PDCCH monitoring within CDRX ON duration and how such pattern is aligned with jitter distribution. Q 2.2-5: Yes. At least “Dynamic adaptation of DRX On Duration start and On Duration” should be compared with a PDCCH skipping scheme in terms of both power savings gain and capacity. |
| Samsung | Question 2.2-1: RAN1 should not assume that jitter is predictable.Question 2.2-2: OK to also discuss a jitter range of [-8, 8] msec.Question 2.2-3: The question may simply be whether any mechanism proposed for XR should be compared to Rel-17 ones. Our opinion is ‘yes’. If a proposed mechanism does not materially outperform Rel-17 ones (not only for XR), it should not be introduced.Question 2.2-4: No, it does not. Search space set configurations, together with Rel-17 mechanisms, provide full flexibility. Question 2.2-5: Yes. Absence of C-DRX by relying on PDCCH skipping should also be considered. |

Multiple CDRXs for Multiple Flows

Proposals in this subsection correspond to the medium priority Issue 1-3 identified in RAN1 #109-e meeting

* Medium priority Issue 1-3: CDRX enhancements for multiple XR traffic flows [Note 2]
* Note 2: It can also be adopted for addressing issue 1-1

**Table 5: Proposals and evaluation results on multiple CDRX for multiple XR traffic flows**

|  |  |
| --- | --- |
| **Company** | **Proposals and evaluation results** |
| Ericsson | Observation 7 Multiple simultaneous DRX configurations, each matching a traffic flow, is suitable to achieve both high UE power saving gains (up to 13.6%) and a high percentage of satisfied UEs (88.4%), if a single DRX configuration matched to one flow does not satisfy the PDBs of other flows.Observation 8 If multiple DRX configurations are required, combining this with two-stage DRX is the preferred solution to achieve the highest UE power saving gains (17.2%) and a high percentage of satisfied UEs (81.8%).Proposal 6 Adopt multiple simultaneous DRX configurations.Table 6 Results for CDRX, for FR1, high load, Dense Urban scenario, and VR multi-stream traffic: DL video (30 fps, 30 Mbps, 10 ms PDB), DL audio (10 ms periodicity, 10 ms PDB), UL pose (4 ms periodicity, 10 ms PDB)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Tdoc #** | **Power Saving Scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **Load H/L** | **avg # UEs/Cell** | **floor (Capacity)** | **% of satisfied UE** | **Mean PSG of all UEs** | **Mean PSG of satisfied UEs** |
| R1-2205916 | Always On | - | - | - | H | 5 | 5 | 94.0% | - | - |
| R1-2205916 | R15/16 DRX(Long DRX) | 10 | 8 | 4 | H | 5 |  5 | 90.7% | 3.0% | 3.3% |
| R1-2205916 | R15/16 DRX(Short DRX) | 4 | 2 | 4 | H | 5 |  4 | 85.9% | 6.9% | 7.2% |
| R1-2205916 | Matched CDRX (with our solution) | 33.3 (33-33-34 equivalent) | 10 | 4 | H | 5 |  0 | 0% | 18.4% | - |
| R1-2205916 | Multi-flow DRX | 33.3 (33-33-34 equivalent) | 10 | 4 | H | 5 |  4 | 88.4% | 13.4% | 13.6% |
| 10 | 2 | 0 |
| R1-2205916 | Multi-flow and two-stage DRX | outer DRX: 33.3;inner DRX: 4 | outer ODT: 10; inner ODT: 2 | 4 | H | 5 |  4 | 81.8% | 16.9% | 17.2% |
| 10 | 2 | 4 |

 |
|  |  |

**Table 6** captures companies’ views on multiple CDRX configurations for the support of multiple XR traffic flows.

**Table 6: Proposals without evaluation results on multiple CDRX for multiple XR traffic flows**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| TCL | **Proposal 4: Study the enhancement of multiple DRX configurations to support XR services with multiple traffic flows.** |
| Sony | Observation 4 -The existing C-DRX configuration is not optimized for XR traffic characteristics, resulting in unnecessary activation of inactivity timer and consequently leading to increased power consumption at the UEs.Proposal 4 - Application aware multi-C-DRX configuration can be considered as an enhanced C-DRX mechanism to further reduce power consumption in UEs with XR traffic.  |
| III | **Observation#1:** **Having multiple CDRX configurations for multiple XR traffic flows might be a solution. About it, we prefer to remain neutral.** |
| NEC | **Proposal 3: Study the enhancement of multiple DRX configurations to better support XR services with multiple traffic flows.** |
| Rakuten Mobile | **Proposal 2: Support multiple DRX cycles and independent operation of DRXs.** |
| Lenovo | **Proposal 3: For simultaneous DRX configurations, study the following:*** **(de)activation of DRX configurations (by DCI or MAC-CE)**
* **WUS enhancements**
* **whether to associate a number of HARQ process IDs to a DRX configuration**
* **whether to define csi-Mask per DRX configuration**
 |
| Xiaomi | **Proposal 2: Multiple C-DRX configurations can be configured for traffic flows of XR and other types.** |
| Intel | **Proposal 2: RAN1 studies multiple active DRX configurations to support XE media with multiple flows.** |
| ETRI | **Proposal 3: To handle multi-flow XR traffic, support multiple DRX configurations within a serving cell (or a DRX group).** |
| InterDigital | **Proposal 7:** Support multiple active CDRX configurations for handling multiple flows with different traffic patterns**Proposal 8:** Support dynamic activation/deactivation of multiple CDRX configurations**Proposal 9:** Support UE requesting activation of preconfigured CDRX configurations |
| Apple | **Observation: Rel-18 NR enhancements for XR should be motivated by XR services’ traffic characteristics, especially the multiple data flow aspects.****Proposal 1: if enhancement is taken over DG based transmission, consider one enhancement for DRX:*** + **support of multiple DRX configurations to support multiple data flows in DL/UL with different periodicities.**
 |
|  |  |

### Summary of evaluation results

**Multiple active CDRX configurations**

[Ericsson] proposed to configure multiple simultaneous DRX configurations to serve multiple data flows with stringent PDB requirements. In the evaluation, one DRX is configured for the DL video and the other DRX is configured for the DL audio. The DL video is configured with a 30fps frame rate to illustrate that second traffic flow is useful when the periodicity of the first DRX configuration is longer than the PDB of the second traffic flow. For FR1, high load, Dense Urban scenario, and VR, multiple CDRX configurations acheive 6.4% to 10.3% power saving gain and 88.4% satisfied UE rate compared to CDRX. Together with two-stage DRX, it achieves 10% to 13.9% power saving gain and 81.8% satisfied UE rate compared to CDRX.

It is noticed that in Table 5.1.2.2-1 in TR 38.835, the DL audio has a relatively low data rate compared to DL video and fixed packet size. This seems to imply the DL SPS configuration is suitable for the DL audio transmission. Then the seond DRX configuration may not be necessary. It would be helpful to compare the multipel active CDRX configurations with the other existing schemes such as one CDRX for DL video and one SPS for DL audio. Another alternative solution could be to configure CDRX cycle that matches with 60fps XR video periodicity for the 30fps XR video and DL audio and use DCP to skip CDRX cycles where video or audio data is scheduled.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 5.1.2.2 Option 2 (video + audio/data)For Option 2, two streams (video + audio/data) are modelled.- Stream 1: video- Stream 2: audio/dataThe stream 1 - video stream follows the generic single stream model given in clause 5.1.1. The stream 2 - audio/data a periodic traffic with following parameters. Table 5.1.2.2-1: Statistical parameter values for Option 2 multi streams model

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

 |

### Discussions

DRX for XR DL video and SPS DL audio may have similar effects to the multiple CDRX configurations. Please note both the multiple CDRXs and CDRX+SPS are not dynamic mechanism.

**Questions 2.3-1:** Do you think “multiple active CDRX configurations” should be further compared with legacy mechanism such as CDRX with aligned periodicity for DL video and SPS for DL audio?

Please provide your views if necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Google | Multiple active C-DRX configurations should work better for the multiple flows XR traffic. Further comparison with the legacy mechanism is needed. |
| MTK | We are open to study while we think it may be better to discuss this in RAN2 as it is more related to CDRX configuration. |
| ZTE | Multiple flows may contain multiple DL video flows, and DL audios flows, etc.. In our view, the intention of this solution is that multiple active CDRX configurations can be used in this case, even through the solutions for single XR traffic can be extend to this scenario with minor change. Besides, there’s no doubt legacy mechanism can be a reference for given scenarios. |
| InterDigital | Yes. Comparison of multiple active CDRX with that of legacy single CDRX aligned to handle 2 traffic flows with different periodicities is reasonable.  |
| Samsung | RAN1 can consider multiple C-DRX configurations for comparison with Rel-17 mechanisms such as PDCCH skipping. RAN1 may then inform RAN2 if multiple C-DRX configurations are found to be beneficial.  |

Dynamic Adjustment of CDRX to Data or Frame Rate

Proposals in this subsection correspond to the low priority Issue 1-4 identified in RAN1 #109-e meeting

* Low priority Issue 1-4: CDRX enhancements to adjust to variable burst sizes and frame rate
	+ Note: Some companies think the adjustment for variable burst sizes can be realized by existing spec already

**Table 7: Proposals and evaluation results for dynamic adjustment of CDRX**

|  |  |
| --- | --- |
| **Company** | **Proposals and evaluation results** |
| InterDigital | **Observation 1:** XR traffic patterns (e.g. defined by non-integer/high integer periodicity, jitter, variable data rates and multiple correlated flows), make it extremely challenging for achieving power savings with legacy semi-static techniques**Observation 2:** The earliest cycle at which the mismatch between XR traffic (e.g. PDU sets) and CDRX occasions occur depends on the CDRX periodicity configured for a given PDU set generation rate**Observation 3:** Applying semi-static approaches to CDRX enhancements for XR (e.g. non-unform cycle pattern) are less robust against a variety of data generation rates and traffic patterns that the application/network may support**Proposal 1:** Support configuring multiple CDRX parameters (e.g. ON duration, inactivity timer) for handling adjustments to CDRX configuration**Proposal 2:** Support adaptation (e.g. via DCI) for increasing/decreasing the length of CDRX active time per cycle**Proposal 3:** Study single indication (e.g. single DCI) for dynamically adapting the length of CDRX active time for multiple cycles**Observation 4:** There is a trade-off relation between PSG and capacity (i.e., ratio of satisfied UEs per cell). However, the trade-off can be balanced to certain extent when using CDRX configurations with short cycle durations (e.g., CDRX 4 with (5,4,1)).**Observation 5:** Compared to all other PSG schemes evaluated, CDRX4 (5,4,1) provides the best trade-off in terms of PSG vs. satisfied UEs per cell in all simulated scenarios while CDRX1 (16,12,4) provides the worst trade-off. This is expected as the relatively short cycle duration of CDRX4 is only 31% of that of CDRX1, which is better aligned with XR traffic. **Observation 6:** The DL traffic characteristics for XR (e.g. 30Mbps vs. 45 Mbps, with 10ms PDB) can significantly impact in determining the CDRX schemes or CDRX adaptations that can be supported for balancing the trade-off between power saving gain and capacity.**Observation 7:** For CG InH, CDRX4 (5,4,1) provides the best performance in terms of PSG while supporting the highest number of satisfied UEs with the least cost to the PSG. **Observation 8:** Adaptive CDRX scheme improves the PSG performance by 5% over CDRX4 configuration from 9.1% to 16.3% when the number of satisfied UE is set to 5UEs/cell and traffic load is varied between 8Mbps and 30Mbps. Chart, bar chart  Description automatically generatedChart, bar chart  Description automatically generatedFigure 7: (a) Number of satisfied UEs, (b) Resource Utilization**Figure 8**: Power saving gain for various CDRX configs |
|  |  |

**Table 8: Proposals without evaluation results for dynamic adjustment of CDRX**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| III | **Proposal#2:** **We propose that the CDRX configuration shall be dynamically adjusted according to the present frame rate.** |
| Qualcomm | **Observation 8: Using fixed CDRX parameters may have negative impact on delays (PDB) and power consumption for XR traffic.****Observation 9: For FR2, DL VR 30Mbps in Indoor Hotspot environment, dynamically adapting CDRX parameters can achieve considerable capacity gains over Re115/16 CDRX.****Proposal 5: For XR, consider studying methods to dynamically adapt the CDRX parameters to the traffic bursts**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Power saving scheme | CDRX cycle (ms) | ODT (ms) | IAT (ms) | Median PSG of all UEs (%) relative to always ON |
| Always On | NA | NA | NA | 0% |
| Rel15/16 CDRX | 16 | 4 | 4 | 24.2% |
| Rel15/16 CDRX | 16 | 8 | 8 | 8.1% |
| Rel15/16 CDRX | 16 | 8 | 16 | 3.0% |
| Adaptive CDRX | 16 | 4 | 4 | 62.5% |
| Adaptive CDRX | 16 | 8 | 8 | 57.1% |
| Adaptive CDRX | 16 | 8 | 16 | 56.4% |

[Moderator] please note these are upper bound gains due to the genie aided start and end of the data transfer and the gains for a more realistic design may be lower. |
|  |  |

### Summary of evaluation results

**Adaptation of CDRX timers**

[InterDigital] proposed to configure multiple CDRX parameters (e.g., ON duration, inactivity timer) and use dynamic signaling to select a set of active CDRX parameter. In evaluation, CDRX configuration with parameters (5,2,3) is used when the UE is expecting 8 Mbps data rate and CDRX parameters of (5,4,1) is used when the UE is expecting 30 Mbps data rate. Evaluations show that adaptive CDRX scheme improves the PSG performance compared to fixed CDRX configuration from 9.1% to 16.3% when traffic load varies between 8Mbps and 30Mbps.

The proponent may help clarify how often the traffic load is changed between 8 Mbps and 30 Mbps. An assumption for the proposed adaptive CDRX seems that the change is frequent so that RRC configuration of new CDRX parameters cannot respond. In the RAN1 #109-e meeting, some companies had concerns that the adjustment for variable burst sizes can be realized by existing spec already. For example, configure long On-Duration such as (5,4,1) and use PDCCH skipping to terminate the CDRX early if data load is small. It would be helpful if further comparison can be made.

### Discussions

**Question 2.4-1**: Do you think RAN1 can assume frequent/dynamic switch of different XR video data rates or frame rates without further input?

There is the following note from the RAN1 #109-e meeting

* + Note: Some companies think the adjustment for variable burst sizes can be realized by existing spec already

**Question 2.4-2**: Do you think “Adaptation of CDRX timers” should be further compared with PDCCH adaptation such as PDCCH skipping for early termination of On Duration for lower traffic load?

Please provide your views if necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Google | RRC reconfiguration should be able to handle the switch between different XR video data rates. There is no need for RAN1 to use dynamic signalling to adapt the configuration when there is a switch between different XR video data rates or frame rates |
| MTK | **Question 2.4-1**: It is **not** clear to us RAN1 can assume frequent/dynamic switch of different data rates or frame rates without further input.**Question 2.4-2**: If dynamic (L1) based signaling is required for “Adaptation of CDRX timers”, then we think it should be compared with PDCCH adaptation such as PDCCH skipping and early termination of On Duration. |
| ZTE | Question 2.4-1: For switch of different XR video data rates or frame rates, we thinks the scenario should be clarified by SA/RAN2 firstly.Question 2.4-1: In this case (e.g., variable XR video frame rates), dynamic solutions can be studied, and existing PDCCH adaption can be references. |
| InterDigital | Q 2.4-1: We think it is reasonable for RAN1 to assume frequent changes in traffic pattern/load since different video frames types (e.g. I-frames, P/B frames) could be generated at different periods/occasions. Ongoing discussions in SA2 (TR 23.700-60) use similar assumption. When such changes occur, using the same semi-static CDRX configuration, irrespective of the traffic pattern/load, results in lower potential for power savings. Also, frequent reconfiguring the CDRX via RRC each time when traffic pattern changes causes additional latency and high overhead. Q 2.4-2: Yes. Comparison between dynamic CDRX parameter adaptation and PDCCH skipping can be useful. However, since dynamic CDRX adaptation scheme provide sufficient flexibility to address multiple issue such as jitter, non-integer periodicity, and variable traffic load/pattern, seeing only marginal/similar gain over PDCCH adaptation should not prevent further consideration and study of dynamic CDRX schemes.  |
| Samsung | Question 2.4-1: No. Such input cannot be determined by RAN1 – SA/RAN2 should be consulted.Question 2.4-2: Yes. |

Low Latency Handling

Proposals in this subsection correspond to the low priority Issue 1-5 identified in the RAN1 #109-e meeting. No evaluation result was provided by any company for these proposals.

* Low priority Issue 1-5: low latency handling

**Table 9: Proposals without evaluation results on low latency handling**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Qualcomm | **Observation 14: In R15/16/17 MG operation, all configured MGs are always activated with a higher priority than PDSCH and PUSCH except Msg2/3/4/A/B, which may cause a frequent XR traffic interruption and highly degrades the user experience.****Observation 15: When CDRX is configured with MG, UE may enter the inactivity state during MG, and the remained packets should be buffered and delivered when the next DRX on-duration cycle starts.****Proposal 7: For XR traffic, MG should be enhanced by handling the priority of data packets or dynamically activating/deactivating the MG occasions from gNB.** |
| Apple | **Proposal 3: to achieve UE power saving:*** **configure latency budget for SPS configuration and/or CG configuration, e.g., through SPS configuration specific drx-RetransmissionTimerDL or CG configuration-specific drx-RetransmissionTimerUL.**
* **HARQ process number can be associated with different latency budget.**
 |
|  |  |

SFN Wraparound Mismatch

Proposals in this subsection correspond to the low priority Issue 1-5 identified in the RAN1 #109-e meeting. No evaluation result was provided by any company for these proposals.

* Low priority Issue 1-6: SFN wraparound mismatch (if handled in RAN1)

**Table 10: Proposals without evaluations results for SFN wraparound mismatch**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Qualcomm | **Observation 6: In R15/16/17 DRX operation, the mismatch happens between DRX on-duration times and XR DL traffic arrivals when SFN returns to 0 every hyper frame 10,240ms. This would lead to XR capacity loss due to larger latency and/or larger UE power consumption to keep the same latency performance.****Proposal 3: Introduce a timing reference value of SFN\_M which can be updated as SFN\_M = (SFN\_M + 1) mod M when SFN is changed. The modulo number M can be configured as 1000 for XR and CG applications. This is required for CDRX alignment with XR periodicities.****Observation 7: By using SFN\_M instead of SFN in DRX formulas, the SFN wraparound issue can be resolved with the least spec impact.****Proposal 4: For CDRX cycle alignment with XR periodicity, adopt the TPs in the Appendix.** |
| Huawei, HiSilicon | **Proposal 5: Handle the SFN wraparound mismatch for C-DRX in RAN2 since RAN2 already discussed and solved this issue for CG and same solution is expected.** |
| Ericsson | Proposal 8 Address the SFN wrap-around problem in RAN2. |
| Apple | **Proposal 2: it may be possible to handle crossing of radio frame boundary without introducing the concept of hyperframe.** |
|  |  |

**Timing reference to resolve SFN wraparound mismatch**

[Qualcomm] proposed to resolve the SFN wraparound mismatch issue when CDRX cycle is matched to XR traffic periodicity. The issue is because 1024 frames do not contain an integer multiple of CDRX cycles. A timing reference value SFN\_M is proposed to resolve the issue with SFN\_M = (SFN\_M + 1) mod M as SFN increments, e.g., M = 1000 for XR and CG applications.

[Huawei, HiSi] and [Ericsson] pointed out this issue belongs to RAN2 design and it is being discussed in RAN2.

### Discussions

**Question 2.6-1**: Do you agree “SFN wraparound mismatch” should be left to RAN2 to address?

Please provide your views if necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Google | Yes. RAN2 can address the “SFN wraparound mismatch” issue. |
| MTK | Yes. |
| ZTE | Yes we agree. |
| InterDigital | Yes |
| Samsung | Yes. |

Other CDRX Enhancements

This subsection captures new proposals submitted in RAN1 #110. No evaluation was provided by companies for these proposals. Companies are encouraged to check the proposals and submit evaluation results in the rest of Rel-18 XR SI meetings if necessary.

**Table 11: Proposals on the other CDRX enhancements without evaluation results**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Huawei, HiSilicon | **Proposal 4: Further study C-DRX enhancements to save power considering UL retransmission handling, e.g., delay retransmission of UL frame to next C-DRX on duration when PDB can be satisfied.** |
| China Telecom | **Proposal 13: Support interconnecting DRX configuration and PDCCH search space configuration.****Proposal 14: Support automatic SSSG switching when receiving the dynamic signaling of DRX configuration adjustment.** |
| InterDigital | **Proposal 6:** Support UE requesting dynamic adaptation to CDRX parameters (e.g. ON duration, start offset) for receiving DL traffic |
| Qualcomm | **Observation 16: having a customizable CDRX configured for a specific purpose may be beneficial in terms of re-using rules defined in the current specifications hence minimizing impacts.****Proposal 8: Consider studying a “customizable” CDRX (cCDRX), where channels/signals/operations that are allowed in this CDRX are configured.** |
|  |  |

# PDCCH Monitoring Enhancements

Periodicity Alignment for PDCCH Monitoring

Proposals in this subsection correspond to the low priority Issue 2-1 identified in the RAN1 #109-e meeting. There is no evaluation result submitted by companies. Companies are encouraged to check the proposals and submit evaluation results in the rest of Rel-18 XR SI meetings if necessary.

* Low priority Issue 2-1: Alignment between PDCCH monitoring and XR traffic to resolve the mismatch between PDCCH monitoring periodicity and XR traffic periodicity.
	+ Note: some companies think Rel-17 PDCCH monitoring adaptation can solve issue 2-1 or achieve similar intended outcome
	+ Note: Solutions proposed for Issue 2-1 and those proposed for Issue 1-1 are motivated by the same issue, namely non-integer XR traffic periodicity. It is to be studied how they compare in in terms of power saving gain and capacity, (a) solutions proposed for Issue 1-1; (b) solutions proposed for Issue 2-1.

**Table 12: Proposals without evaluation result on periodicity alignment for PDCCH monitoring**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| III | **Suggestion#2: Either using a semi-static pattern of monitoring periodicity or adapting the start offset of PDCCH monitoring in a semi-static or dynamic way can resolve the mismatch between PDCCH monitoring periodicity and XR traffic periodicity. However, further performance comparison is needed.** |
| NEC | **Proposal 7: Specify XR specific PDCCH monitoring offset parameters such as k(µ) and jitter in Search Space Set configuration.****Proposal 8: Support DCI based dynamic adaptation of XR specific PDCCH monitoring offset such as ‘jitter’.****Proposal 9: Specify a higher layer parameter of ‘frame per second’ for the frame rate of XR traffic.** |
| China Telecom | **Proposal 11：Traditional SSSG switching should be verified whether it can satisfy XR service requirement on power-saving and latency.****Proposal 12: Multi-cycle PDCCH monitoring configuration can be FFS.** |
| LGE | **Observation 4: Discussion on alignment between PDCCH monitoring and XR traffic may overlap with alignment between CDRX and XR traffic.** |
|  |  |
|  |  |

XR-dedicated PDCCH Monitoring Window

Proposals in this subsection correspond to the low priority Issue 2-2 identified in the RAN1 #109-e meeting

* Low priority Issue 2-2: XR-dedicated PDCCH monitoring window to supplement CDRX for multi-flow traffic.
	+ Note: some companies think Rel-17 PDCCH monitoring adaptation can solve issue 2-2 or achieve similar intended outcome
	+ Note: Solutions proposed for Issue 2-2 and those proposed for Issue 1-3 are motivated by the same issue, namely multiple XR traffic flows. It is to be studied how they compare in in terms of power saving gain and capacity, (a) solutions proposed for Issue 1-3; (b) solutions proposed for Issue 2-2.

**Table 13: Proposals and evaluation results on XR-dedicated PDCCH monitoring window**

|  |  |
| --- | --- |
| **Company** | **Proposals and evaluation results** |
| CATT | **Proposal 6: DRX enhancement for XR service should not affect other data services.**Table 4: XR-PMW power saving schemes

|  |  |
| --- | --- |
| **Schemes** | **Procedure** |
| **XR-PMW scheme 1** | UE is configured with the XR-PMW which has the fixed PDCCH monitoring cycle and monitoring window disassociated with DRX. The window size of PDCCH monitoring at each cycle could be dynamically adapted to the delay variation of packet arrival caused by network jitter. UE monitors only XR scheduled PDCCH during a preconfigured PDCCH monitoring window.  |
| **XR-PMW scheme 2****(XR-PMW with go-to-sleep):** | UE is configured with the XR-PMW, which the PDCCH monitoring cycle and window are based on XR traffic generation cycle and network delay jitter. When traffic transmission is completed, UE would be indicated to go to sleep until the next XR-PMW cycle. |
| **XR-PMW scheme 3****(XR-PMW with enhanced PDCCH skipping and go-to-sleep)** | UE is configured with XR-PMW and would be indicated to skip the PDCCH monitoring at the beginning of the XR-PMW if XR packet arrives late. UE skips monitoring the PDCCH at the Monitoring Occasion (MO) until the traffic packet arrives. When traffic transmission is completed, UE would be indicated to go to sleep until the next XR-PMW cycle. |

Table 5: The evaluation result comparison between the XR-PMW with skipping and go-to-sleep and UE always-on

|  |  |  |
| --- | --- | --- |
| Evaluation Schemes | Capacity | Power saving |
| #satisfied UEs per cell  | % of satisfied UEs | Capacity Enhancement Gain | Power Saving Gain (PSG)  |
| DG scheduling and UE always-on  | 11.5 | 95.83% | 0.0% | 0.0% |
| DG scheduling with C-DRX(16,12,4)  | 10.9 | 90.83% | -5.2% | 2.4% |
| XR-PMW scheme 1:XR-PMW (16,12) | 10.8 | 90.00% | -6.09% | 4.13% |
| XR-PMW scheme 2:XR-PMW (16,12) with go-to-sleep | 10.8 | 90.00% | -6.09% | 24.39% |
| XR-PMW scheme 3:XR-PMW (16,12)with PDCCH skipping and go-to-sleep | 10.7 | 89.17% | -6.96% | 29.92% |

**Observation 2: Under the same system load, the XR-PMW could obtain the less than 10% capacity performance gap than that of the UE always-on** **for DG scheduling and obtain 24.39%~29.92% PSG compared to that of the UE always-on for DG scheduling.**Table 6: The performance comparison between and C-DRX (16,12,4) XR-PMW with PDCCH skipping and go-to-sleep

|  |  |  |
| --- | --- | --- |
| Evaluation Schemes | Capacity | Power saving |
| #satisfied UEs per cell  | % of satisfied UEs | Capacity Enhancement Gain | Power Saving Gain (PSG) |
| DG scheduling with C-DRX(16,12,4)  | 10.9 | 90.83% | 0.0% | 0.0% |
| XR-PWM scheme 1:XR-PMW with (16,12) | 10.8 | 90.00% | -0.92% | 1.69% |
| XR-PWM scheme 2:XR-PMW with go-to-sleep | 10.8 | 90.00% | -0.92% | 21.47% |
| XR-PWM scheme 3:XR-PMWwith PDCCH skipping and go-to-sleep | 10.7 | 89.17% | -0.93% | 26.88% |

**Observation 3: Under the similar capacity performance, the XR-PMW with go-to-sleep and XR-PMW with enhanced PDCCH skipping and go-to-sleep can obtain 21.47% and 26.88% power saving gain than that of the C-DRX (16, 12, 4), respectively.****Observation 4: Under the similar capacity performance, the XR-PMW with go-to-sleep and XR-PMW with enhanced PDCCH skipping and go-to-sleep can obtain 21.47% and 26.88% power saving gain than that of the C-DRX (16, 12, 4), respectively.****Proposal 7: The XR-dedicated PDCCH monitoring window should be supported for XR UE power saving due to the good balance between system capacity and UE power saving.**Table 7: The performance comparison between other enhanced schemes and XR-PMW with PDCCH skipping and go-to-sleep

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scheme | Power saving | System capacity | Impact on existing service | Note |
| Mean PSG (%) |  Mean percentage of DL satisfied UE | Capacity (#UEs per cell) | Dedicated to XR services |
| XR-PMW with PDCCH skipping and go-to-sleep | 29.68% | 89.2% | 12 | Yes | Note1 |
| Traffic arrival offset staggering[4] | 2.64~9.94% | 100% | 7~9 | Yes | Note2,Note 3 |
| Enhanced PDCCH monitoring[5] | 5.08%~21.84% | 60%~84% | 5 | No | Note2 |
| Enhanced C-DRX[6] | 9.36%~23.84% | 91.25%~91.94% | 10 | No | Note1 |
| Enhanced DRX with additional active time[7] | 29.43% | 86.36% | 11 | No | Note1 |
| Early C-DRX[8] | 4.9% | -- | -- | Yes | Note4 |
| Two-stage DRX[9] | 9% ~16% | -- | -- | Yes | Note2 |
| C-DRX and PDCCH skipping enhancement[10] | 21.01%~33.44% | 91.25%~100% | 10 | No | Note1 |
| Note1: The evaluated scenario is indoor hotspot. Note2: The evaluated scenario is dense urban.Note3: With different traffic arrival offset, i.e., random or evenly spaced, system capacity is different.Note4: 60FPS, jitter [-4, 4] ms . |

**Proposal 8: The XR-dedicated PDCCH monitoring window should be studied and supported for XR UE power saving due to the advantages that it doesn't affect other data services and is achievable.****Proposal 9: The SPS enhancement with PDCCH skipping and go-to-sleep should be supported for XR UE power saving.**Table 8: Evaluation results of SPS enhancement schemes compared to always-on

|  |  |  |  |
| --- | --- | --- | --- |
| Schemes | Considered UE set | Mean PSG compared to always-on | #satisfied UEs per cell / #UEs per cell |
| Baseline: Always-on | - | - | 12/12 |
| SPS enhancement | All UEs | 12.5% | 10.8/12 |
| Satisfied UEs | 12.6% |
| Multiple SPS configurations | All UEs | 47.4% | 0/12 |
| Satisfied UEs | -- |
| SPS enhancement with go-to-sleep | All UEs | 39.8% | 10.6/12 |
| Satisfied UEs | 39.9% |

**Observation 5: The SPS enhancement schemes can obtain the up to 39.9% power saving gain, which close to that of multiple SPS configurations. Moreover, the capacity of SPS enhancement schemes is near to that of DG scheduling.**Table 9: Evaluation results of SPS enhancement schemes compared to C-DRX

|  |  |  |  |
| --- | --- | --- | --- |
| Schemes | Considered UE set | Mean PSG compared to C-DRX | #satisfied UEs per cell / #UEs per cell |
| Baseline: C-DRX(16,12,4) | - | - | 10.9/12 |
| SPS enhancement | All UEs | 9.8% | 10.8/12 |
| Satisfied UEs | 9.9% |
| Multiple SPS configurations | All UEs | 46.1% | 0/12 |
| Satisfied UEs | -- |
| SPS enhancement with go-to-sleep | All UEs | 38.0% | 10.6/12 |
| Satisfied UEs | 38.1% |

**Observation 6: The SPS enhancement scheme can obtain the capacity performance of 10.8 UEs per cell and 9.9%~38.1% power saving gain compared to that of DG scheduling with C-DRX(16,12,4), additionally the single SPS configurations hardly provide UE the XR-specific service.****Proposal 10: The SPS enhancement that the pre-configured PDCCH monitoring window bundled with the reserved SPS resource for PDSCH would be provide the resource to meet the QoS requirement of XR-specific traffic with obvious power saving gain.** |
|  |  |

**Table 14: Proposals without evaluation results on XR-dedicated PDCCH monitoring Window**

|  |  |
| --- | --- |
| **Company**  | **Proposals**  |
| III | **Proposal#3:** **Because the multi-flow traffic is more involved, we propose that the window-based configuration, which depends on the traffic density level, shall be considered.** |
| LGE | **Observation 6: XR-dedicated PDCCH monitoring window can be implemented by Rel-17 PDCCH skipping.**  |
| Qualcomm | **Observation 19: using multiple time windows with different configurations can help adapt to PDCCH monitoring density depending on the XR traffic patterns with reduced signaling overhead, latency, and complexity.****Proposal 11: For XR, consider studying a configuration of multiple time windows have different configurations for messages, signals, and/or operations, where switching between windows can be configured, dynamic, or implicit.** |
|  |  |

### Summary of evaluation results

**XR-dedicated PDCCH monitoring window**

[CATT] proposed to introduce the XR-dedicated PDCCH monitoring window. Network configures the XR-dedicated PDCCH monitoring windows for XR service and CDRX for other services. Evaluation results showed withsimilar capacity performance, the XR-dedicated window with go-to-sleep or with enhanced PDCCH skipping and go-to-sleep can obtain 21.47% and 26.88% power saving gain w.r.t. the C-DRX (16, 12, 4), respectively.

Similar to the comments under the proposal of multiple DRX configurations in Section 2.3.2, it is preferrable to compare the proposed enhancement with the reference setup that uses eCDRX for XR video, SPS for audio and CG for UL pose.

**PDCCH monitoring adaptation indication by SPS**

[CATT] proposed the enhanced SPS providing PDCCH monitoring adaptation indication for the XR-dedicated PDCCH monitoring window in both DRX ON and OFF to activate additional PDCCH monitoring to receive additional data or to skip PDCCH monitoring until the next XR data arrival after the current XR data packet is completely received. Evaluation results showed that the SPS enhancement obtains 9.9% to 38.1% power saving gain compared to that of DG scheduling with C-DRX(16,12,4) . The proposal seems to assume that jitter is predictable.

### Discussions

As noted in RAN1 #109-e meeting agreement, there were concerns on that the proposed XR-dedicated PDCCH monitoring window can be realized ty Rel-17 PCCH monitoring adaptation. Also, this proposal and multiple CDRX configurations intend to resolve the same issue.

* Note: some companies think Rel-17 PDCCH monitoring adaptation can solve issue 2-2 or achieve similar intended outcome
* Note: Solutions proposed for Issue 2-1 and those proposed for Issue 1-1 are motivated by the same issue, namely non-integer XR traffic periodicity. It is to be studied how they compare in in terms of power saving gain and capacity, (a) solutions proposed for Issue 1-1; (b) solutions proposed for Issue 2-1.

To make the discussion on multiple flows more efficient, it seems beneficial to jointly discuss “XR-specific PDCCH monitoring window” and “multiple CDRX configurations for multiple flows”.

**Question 3.2-1**: Do you agree the “XR-specific PDCCH monitoring window” should be jointly discussed with “multiple CDRX configurations for multiple flows”?

* Please note Questions 2.3-1 also applies to “XR-specific PDCCH monitoring window”.

Please provide your views if necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Google | We prefer the use of multiple CDRX configurations for multiple flows. But OK to jointly discuss “XR-specific PDCCH monitoring window” |
| MTK | We are open to discuss this direction while RAN1 has to agree on a common evaluation assumption (CDRX parameters …) on this. |
| ZTE | For “XR-specific PDCCH monitoring window”, it is designed without considering the DRX-ON or DRX- OFF, so we don’t think the joint discussion more efficient; it makes the situation complicate. |
| InterDigital | OK to discuss jointly, although our preference is multiple CDRX configurations  |
| Samsung | No. Search space set configuration can achieve any PDCCH monitoring window and SSSG switching can adapt the PDCCH monitoring window. |

Enhancements to PDCCH Monitoring Adaptation

Proposals in this subsection correspond to the high priority Issue 2-2 identified in the RAN1 #109-e meeting:

* High priority Issue 2-3: Enhancements to Rel-17 PDCCH monitoring adaptation.
	+ Note: Discussion on some enhancements may depend on the outcome of Rel-17 PDCCH monitoring adaptation maintenance
	+ Note: The study on enhancement to R17 PDCCH monitoring adaptation should focus on the techniques that are used for addressing XR-specific issues, e.g., jitter

**Table 15: Proposals and evaluation results on enhancements of PDCCH monitoring adaptation**

|  |  |
| --- | --- |
| **Company** | **Proposals and evaluation results** |
| MediaTek | **Observation 1: In current Spec, no additional PDCCH monitoring for retransmission is allowed when PDCCH skipping is triggered. Due to XR application’s stringent latency requirement, further retransmission-aware mechanisms should be explored.****Proposal 1: (Solution 1) If the UE is indicated to skip PDCCH monitoring, then if any NACK is transmitted the UE resumes the monitoring and cancel the indication of PDCCH.****Proposal 2: (Solution 2) If the UE is indicated to skip PDCCH monitoring, then if any NACK is transmitted or if UL data is transmitted, the UE resumes the monitoring for a configured duration.****Observation 2:** **Solution 2 can be applied to both DL and UL. Also, it can get better power saving gain for an appropriate configured duration.****Observation 3:** **In Figure 1, it can be seen that if UE does not resume PDCCH monitoring for the potential retransmission (y=0), the outage rate (ratio of unsatisfied UE) grows fast when the PDCCH skipping duration exceeds 4ms for cloud gaming (CG), and 2ms for XR. This means only short skip durations are acceptable for Rel-17 PDCCH skipping if there is no reTX handling.****Observation 4: As shown in Figure 1, with Solution 2, UE performs PDCCH skipping with 12ms while resuming PDCCH monitoring for 5ms when a NACK is transmitted. With this ReTx handling method, it can achieve a significant power saving gain (20.78%~27.97%) w.r.t Rel-17 PDCCH skipping.**Figure 1 Power saving gain results by SLS for retransmission aware PDCCH skipping |
| Huawei, HiSilicon | **Proposal 6: To avoid unnecessary PDCCH monitoring after XR frame transmission finishes, support adaptive PDCCH skipping duration, which is determined by the gap between indication reception time and earliest possible arrival time of next frame.**Table 2 Simulation results of the PDCCH skipping with adaptive duration

|  |  |
| --- | --- |
| Scheme | High Load (11UEs per cell on average) |
| Satisfied UE Ratio | Power Saving Gain |
| Always On | 93.42% | - |
| Legacy PDCCH Skipping (D1=5, D2=10, D3=15) | 93.42% | 12.12% |
| Legacy PDCCH Skipping (D1=4, D2=16, D3=29) | 93.42% | 11.15% |
| PDCCH skipping with adaptive duration | 93.42% | 18.35% |

 |
| Ericsson | Observation 10 Enhancing PDCCH skipping to support more skipping durations does not outperform R17 PDCCH skipping with two skipping values.Proposal 10 Do not introduce larger duration sets that PDCCH skipping indication selects from.Proposal 11 Do not prioritize further enhancements of PDCCH skipping beyond those in R17.Table 7 Results for PDCCH skipping, for FR1, high and low load, Dense Urban scenario, and VR multi-stream traffic: DL video (60 fps, 30 Mbps, 10 ms PDB), DL audio (10 ms periodicity, 30 ms PDB), UL pose (4 ms periodicity, 10 ms PDB)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Tdoc #** | **Power Saving Scheme** | **CDRX cycle (ms)** | **ODT (ms)** | **IAT (ms)** | **Load H/L** | **avg # UEs/Cell** | **floor (Capacity)** | **% of satisfied UE** | **Mean PSG of all UEs** | **Mean PSG of satisfied UEs** |
| R1-2205916 | Always On | - | - | - | H | 8 | 8 | 90.1% | - | - |
| R1-2205916 | Matched DRX with R17 PDCCH skipping | 16.6 (16-16-18 equivalent) | 10 | 4 | H | 8 | 6 | 72.2% | 10.5% | 10.4% |
| R1-2205916 | Matched DRX with enhanced PDCCH skipping | 16.6 (16-16-18 equivalent) | 10 | 4 | H | 8 | 6 | 72.4% | 10.5% | 10.5% |
| R1-2205916 | Matched DRX with R17 PDCCH skipping | 16.6 (16-16-18 equivalent) | 10 | 4 | L | 2 |  - | 96.6% | 11.2% | 11.9% |
| R1-2205916 | Matched DRX with enhanced PDCCH skipping | 16.6 (16-16-18 equivalent) | 10 | 4 | L | 2 |  - | 97.3% | 11.2% | 12.0% |

 |
| Xiaomi | **Observation1: Compared with baseline, PDCCH skipping with 4 candidate durations has 6% more power saving gain, and 1.5% more satisfied UE rate. Average delay is increased a little but still within the PDB range.****Proposal 3:** **More candidate PDCCH skipping durations should be supported to be configured by RRC signalling.****Table 3: Summary of metrics**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | TotalEnergy | PSG | Delay(ms) | % of satisfied UEs |
| Baseline | 116.56 | N/A | 2.46 | 96.61% |
| PDCCH skipping case 1 | 67.91 | 41.74% | 2.70 | 95% |
| PDCCH skipping case 2 | 61.31 | 47.40% | 2.92 | 96.56% |

 |
| Nokia, NSB | **Observation 10**: Enabling DCP to indicate the SSSG to be applied at the start of the onDuration power saving gain can be achieved with limited capacity impact.**Proposal 4**: We propose to evaluate enhancements to DCP enabling the SSSG to be used in the onDuration to be indicated.

|  |  |
| --- | --- |
| 1. *Capacity for CG in FR1 in InH*
 | 1. *Power saving for CG in FR1 in InH*
 |

Figure 13 Capacity and power saving gain evaluation of DRX with PDCCH adaptive monitoring via SSSG switching for CG in InH at 30Mbps, PDB of 15ms, DRX=(16,8,8) , SSSG0 with ks = 2, and SSSG1 with ks=1. |
| CATT | **Proposal 1: Rel-17 PDCCH skipping adaptation should be enhanced to further reduce UE power consumption for XR services, e.g. non-scheduling DCI based PDCCH skipping.****Proposal 2: The extension of non-scheduling DCI format design could reuse the existing DCI format 1\_1 in Rel-16 and not increase the size of DCI format with additional function in extending the PDCCH monitoring adaptation in PCell without introducing additional information field.****Proposal 3: The procedure of Rel-17 PDCCH skipping adaptation should be enhanced for delay sensitive XR service to avoid frequent skipping indication signal overhead, e.g. continuous skipping indication.****Proposal 4: Rel-17 PDCCH skipping adaptation should be enhanced to support one code point of go-to-sleep indication for XR.**Table 1: PDCCH skipping enhancement schemes

|  |  |
| --- | --- |
| **Schemes** | **Procedure** |
| **Baseline 1：Always-on**  | PDCCH monitoring is based on the configured PDCCH monitoring cycle of the search space  |
| **Baseline 2：C-DRX(16,12,4)** | UE monitor PDCCH based on the configured PDCCH monitoring cycle of the search space in DRX ON and transforms to sleeping state in DRX OFF. |
| **PDCCH skipping enhancement scheme 1****(go-to-sleep)** | When the XR packet transmission is completed, a code point of skipping duration is configured as the go-to-sleep to allow UE fast transition to the sleeping state and return to normal PDCCH monitoring afterward.  |
| **PDCCH skipping enhancement scheme 2****(PDCCH skipping and go-to-sleep)** | UE can be indicated by non-scheduling and scheduling DCI to skip one or more MOs continuously; When the XR packet transmission is completed, a code point of skipping duration is configured as the go-to-sleep to allow UE fast transition to the sleeping state.  |

Table 2: Evaluation results of PDCCH skipping schemes compared to always-on

|  |  |  |  |
| --- | --- | --- | --- |
| Schemes | Considered UE set | Mean PSG compared to always-on | #satisfied UEs per cell / #UEs per cell |
| Baseline: Always-on | - | - | 11.5/12 |
| PDCCH skipping enhancement scheme 1(go-to-sleep) | All UEs | 24.01% | 10.8/12 |
| Satisfied UEs | 24.39% |
| PDCCH skipping enhancement scheme 2(PDCCH skipping and go-to-sleep)  | All UEs | 29.44% | 10.7/12 |
| Satisfied UEs | 29.92% |

Table 3: Evaluation results of PDCCH skipping schemes compared to C-DRX(16,12,4)

|  |  |  |  |
| --- | --- | --- | --- |
| Schemes | Considered UE set | Mean PSG compared to C-DRX(16,12,4) | #satisfied UEs per cell / #UEs per cell |
| Baseline: C-DRX(16,12,4) | - | - | 10.9/12 |
| PDCCH skipping enhancement scheme 1(go-to-sleep) | All UEs | 22.79% | 10.8/12 |
| Satisfied UEs | 23.1% |
| PDCCH skipping enhancement scheme 2(PDCCH skipping and go-to-sleep)  | All UEs | 28.34% | 10.7/12 |
| Satisfied UEs | 28.64% |

**Observation 1: The enhanced PDCCH schemes including: non-scheduling DCI based PDCCH skipping, continuous PDCCH skipping and go-to-sleep indication can obtain 22.79%~29.92% power saving gain with negligible capacity degradation.** **Proposal 5: The adaptation indication for PDCCH skipping should be separately between XR and other indicated to avoid different services latency requirements.** |
| Qualcomm | **Proposal 9: Extend the UE capacity from NTN HARQ feedback disabling feature to UL for XR pose/control information transmission by transmission-less CG so that UE does not monitor PDCCH for retransmission of pose/control information.****Observation 17: For FR1, 1 UE per cell, joint DL and UL VR 30Mbps in Dense Urban environment, disabling the retransmission allows the reduction of PDCCH monitoring and provides an average power saving gain of 21.0% w.r.t. CG with retransmission.**Table 8: Enhanced CDRX, FR1, DL+UL, DU, VR30

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Power saving scheme | CDRX cycle (ms) | ODT (ms) | IAT (ms) | Load H/L | #UE /cell | floor (Capacity) | % of satisfied UE | Mean PSG of all UEs (%) |
| Always On |  |  |  | H | 10 | 10 | 94.603% | 0% |
| eCDRX + CG with UL retransmission | 16/17/17 | 4 | 4 | H | 10 | 10 | 92.698% | 1.8% |
| eCDRX + CG without UL retransmission | 16/17/17 | 4 | 4 | H | 10 | 10 | 92.619% | 20.0% |
| Note 1: retransmission timer is set to 4ms when HARQ retransmission is enabled |

**Observation 18: For FR1, high load, joint DL and UL VR 30Mbps in Dense Urban environment, disabling the retransmission allows the reduction of PDCCH monitoring and provides an average power saving gain of 20.0% w.r.t. to AlwaysOn and an average power saving gain of 18.2% w.r.t. CG with retransmission.** |
|  |  |

**Table 16: Proposals without evaluation results on PDCCH monitoring adaptation**

|  |  |
| --- | --- |
| **Company**  | **Proposals**  |
| TCL | **Proposal 2: Whether to skip the DRX re-transmission timer of UL data or not can be studied.** **Proposal 5: PDCCH skipping and search space group switching can be considered for XR power saving.** |
| Ericsson | Observation 9 SSSG switching jointly with DRX can be used to handle XR traffic with jitter.Proposal 9 Enhance SSSG switching to address jitter without increasing signaling overhead: (a) an implicit SSSG applies at the start of drx-OnDuration and another SSSG applies when a PDCCH for data traffic is received. (b) align the search space set monitoring pattern w.r.t. the DRX cycle.Proposal 7 Introduce a mechanism in which the NW can dynamically indicate to the UE not to monitor PDCCH for retransmissions (e.g. by not starting the DRX retransmission timers) for a given HARQ process. |
| Huawei, HiSilicon | **Observation 1: If all the 2 bits are used to indicate PDCCH skipping, SSSG switching cannot work.****Proposal 7: At the beginning of each On-duration, UE switches to a SSSG in which UE monitors PDCCH sparsely. When the inactivity timer starts, UE switches to a SSSG in which UE monitors PDCCH densely.** |
| vivo | **Proposal 4: Study PDCCH skipping and interaction with HARQ retransmission, if not finalized in Rel-17.** |
| III | **Proposal#4a: If any NACK transmission is conducted within a PDCCH Skipping duration, this skipping will be cancelled and PDCCH monitoring will be restarted.****Proposal#4b: If any NACK transmission is conducted within a PDCCH Skipping duration, this skipping will be cancelled and PDCCH monitoring with a predefined duration will be restarted.** |
| Rakuten Mobile | **Proposal 3: Study extending the Rel-17 PDCCH skipping mechanism to support multiple DRX cycles.** |
| Lenovo | **Proposal 4: Study impact of PDUs/PDU set dropping on DRX timers (including drx-InactivityTimer, drx-RetransmissionTimerDL, drx-RetransmissionTimerUL).****Proposal 5: PDCCH skipping duration is selected from a larger set of RRC configured skipping durations to accommodate XR traffic jitter or varying video frame size.**  |
| Intel | **Proposal 5: Rel-17 PDCCH skipping and SSSG switching solutions should be considered as starting point for PDCCH monitoring enhancements.****Proposal 6: RAN1 considers supporting non-scheduling DCI to trigger PDCCH monitoring enhancements.** |
| Xiaomi | **Proposal 6: The feature that multiple PDSCH/PUSCH scheduling by a single DCI should also be allowed to apply in FR1.** |
| Samsung | **Observation 3**: *Enhancements to SSSG switching are not necessary for XR.* **Proposal #2: Enhance UE behavior for PDCCH skipping to capture aspects that occur with C-DRX operation.** |
| CMCC | **Proposal 4. PDCCH skipping can be considered to be applied when DRX is not configured to save PDCCH monitoring power consumption.****Proposal 5. Non-scheduling DCI can also be considered as PDCCH skipping and SSSG switching indication, e.g., repurpose some fields in DL/UL grant.** |
| ETRI | **Proposal 4: Discuss further whether enhancements on Rel-17 PDCCH monitoring adaptation are needed or not to handle the XR traffic characteristics.** |
| Google | 1. **Support the use of non-scheduling DCI format to trigger the PDCCH skipping.**
2. **Define new configurable PDCCH skipping durations in the range xr\_periodicity +/- jitter\_range.**
3. **PDCCH skipping should operate efficiently when the UE is configured or not with C-DRX**
4. **Define new configurable SSSG switching timers in the range xr\_periodicity +/- jitter\_range.**
 |
| LGE | **Observation 5: Rel-17 PDCCH monitoring adaptation in connected mode can also be applied to the UE not being configured with the CDRX, with enhancements if necessary.****Proposal 7: Consider enhancements on PDCCH monitoring adaptation in connected mode to mimic the CDRX function for a UE not being configured with the CDRX.****Proposal 8: Consider WUS outside DRX Active Time as well as the DCI inside DRX Active Time as a candidate for indicating the PDCCH monitoring adaptation.**Further UE power saving can be achieved if a UE does not monitor PDCCH in the SPS occasions overlapping with the DRX OnDuration or Active Time when the UE does not need to be dynamically scheduled by a DCI for XR packets.**Proposal 9: Consider SPS enhancement within DRX Active Time for XR UE power saving.****Proposal 10: For enhancements on PDCCH monitoring adaptation in connected mode, consider PDB margin as well as periodicity and jitter distribution of the XR traffic arrival time.** |
| ZTE, Sanechips | 1. Observation 4: Permission of re-transmission scheduling during PDCCH skipping duration can contribute to the capacity boosting to some extent.
 |
| NEC | **Proposal 5: support PDCCH monitoring adaptation triggered by a non-scheduling DCI, and consider indicating multi-cell PDCCH monitoring adaptation by a single DCI.****Proposal 6: further study the enhancement of PDCCH skipping duration, and mechanism of early termination of PDCCH skipping.** |
| OPPO | **Proposal 5: The value of monitoringSlotPeriodicityAndOffset and duration for a search space set can be changed dynamically by gNB to cope with jitter and packet size variation.****Proposal 6: RAN1 further studies PDCCH skipping interaction with HARQ retransmission by triggering an additional PDCCH monitoring window duration PDCCH skipping duration.** |
| Sony | **Observation 5: The proposed DCI linkage scheme have large power saving gain theoretically.** **Observation 6: Simulation results indicated the proposed DCI linkage scheme has at least 50% power saving gain.**Proposal 5 - Adding DCI linkage information in DCI can be considered as a mean to reduce PDCCH BD attempts for power saving.Table 1. 5%, 50% and 95% percentile of simulated *PSG\_DCIlinkage*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | **Mean** | **5%** | **50%** | **95%** |
| PSG\_DCIlinkage | 53.5% | 50.3% | 53.5% | 56.4% |

[Moderator]: please note the simulation only provided power saving gain results.  |
| InterDigital | **Proposal 10:** Support PDCCH monitoring adaptation for dynamically increasing/decreasing the PDCCH skipping duration**Proposal 11:** Study PDCCH skipping duration values that can be used for handling XR traffic patterns**Proposal 12:** Support UE dynamically indicating the duration for PDCCH skipping**Proposal 13:** Study PDCCH skipping triggered by non-scheduling DCI  |
| Qualcomm | **Proposal 10: For XR, consider studying ways to have additional DL control signaling opportunities between sparsely configured semi-static SS set occasions by:*** **Dynamically configuring SS set occasions**
* **Piggy-backing/multiplexing DL control signaling on already existing SCH messages (DG or SPS)**
 |
| DOCOMO | **Proposal 3: Rel-17 PDCCH monitoring adaptation can be baseline for Rel-18 PDCCH monitoring enhancements.** |
|  |  |

### Summary of evaluation results

**Retransmission after Rel-17 PDCCH skipping**

[MediaTek] proposed that if the UE is indicated to skip PDCCH monitoring, then if any NACK is transmitted or if UL data is transmitted, the UE resumes the monitoring for a configured duration. As a result, longer PDCCH skipping duration can be indicated and higher power saving gain can be achieved. It can achieve a significant power saving gain (20.78%~27.97%) with higher UE satisfied rate w.r.t Rel-17 PDCCH skipping.

**More PDCCH skipping durations**

[Huawei, HiSilicon] proposed to support an adaptive PDCCH skipping until the earliest possible arrival time of the next frame so that continuous PDCCH skipping duration is maximized. Additional 6.23% power saving gain is achieved compared to Rel-17 PDCCH skipping with three PDCCH skipping durations. Moderator could not find CDRX configuration in the evaluation. So, assume CDRX is not configured.

[Xiaomi] proposed to adopt four PDCCH durations (6/8/10/12ms). Compared with two durations (8/10ms), four durations have 6% more power saving gain and 1.5% more satisfied UE rate. Moderator could not find CDRX configuration in the evaluation. So, assume CDRX is not configured.

[CATT] proposed to enhance PDCCH skipping indication to indicate the UE to stop the PDCCH monitoring after data transmission until the next DRX ON cycle. In evaluation, Rel-15/16 CDRX was used as the performance reference. As the proposal is an enhancement to Rel-17 PDCCH skipping, it is preferrable to use Rel-17 PDCCH skipping as reference.

[Ericsson] evaluated two extreme cases when CDRX is configured: i) R17 PDCCH skipping with two durations only; ii) enhanced PDCCH skipping with arbitrary skipping duration. Evaluation results show negligible power saving or capacity gain. This implies two durations can well cover the remaining DRX active time after data transmissions. Consequently, enhancing PDCCH skipping by providing more choices of skipping durations is not necessary.

**Non-scheduling DCI based PDCCH skipping, continuous PDCCH skipping and go-to-sleep indication**

[CATT] proposed PDCCH adaptation enhancements including non-scheduling DCI based PDCCH skipping, continuous PDCCH skipping and go-to-sleep indication. For all UEs in the cell, the proposed enhancements can obtain 22.79%~28.34% power saving gain with negligible capacity degradation compared with CDRX.

However, only AlwaysOn and Rel-15/16 CDRX were used as the performance reference. It would be preferrable to use Rel-17 PDCCH adaptation as reference for the proposed PDCCH adaptation enhancements.

**DCP indicated SSSG switching**

[Nokia, NSB] proposed to use DCP (DCI 2\_6) to indicate the SSSG to be monitored at the start of On Duration as an enhancement to Rel-17 SSSG switching. For CG in InH at 30Mbps, PDB of 15ms, evaluation results show additional 13% power saving gain with 10% to 40% capacity loss compared to CDRX.

Evaluation comparison was made between CDRX and the proposed CDRX with DCP indicated SSSG. The proponent may clarify whether jitter is assumed to be predictable. If jitter is unpredictable, UE may start from sparse PDCCH monitoring in the On-Duration. Then SSSG switching can be indicated by the scheduling DCI at the end of XR frame in the past CDRX cycle and this should be used as performance reference. If jitter is assumed predictable, the proposal may be further discussion after the Question 2.2-1 is clarified.

**Disabling UL pose retransmission for PDCCH monitoring reduction**

[Qualcomm] proposed to disable the retransmission for UL pose/control information in UL CG for that conservative MCS can be configured. For FR1, high load, joint DL and UL VR 30Mbps in Dense Urban environment, disabling the retransmission allows the reduction of PDCCH monitoring and provides an average power saving gain of 20.0% w.r.t. to AlwaysOn and an average power saving gain of 18.2% w.r.t. CG with retransmission. It is proposed to extend the UE capacity from NTN HARQ feedback disabling feature to UL for XR pose/control information transmission by transmission-less CG.

### Discussions

Please note “Retransmission after Rel-17 PDCCH skipping” is still being discussed under Rel-17 connected mode power saving.

**Question 3.3-1**: Do you agree whether “Retransmission after Rel-17 PDCCH skipping” should be further studied for Rel-18 XR SI depends on Rel-17 power saving agenda outcome?

**Question 3.3-2**: Do you think “More PDCCH skipping durations” should be further studied given evaluation results by [Ericsson] show no gain for additional skipping durations?

**Question 3.3-3**: Do you think PDCCH adaptation enhancements including “Non-scheduling DCI based PDCCH skipping, continuous PDCCH skipping and go-to-sleep indication” should be further compared with Rel-17 PDCCH adaptation?

**Question 3.3-4**: Do you think “Disabling UL pose retransmission for PDCCH monitoring reduction” can be enabled by extending UE NTN HARQ feedback disabling feature to TN?

Please provide your views on Question if necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Google | Question 3.3-1: Yes the issue could be studied further in Rel-18 XR SI if not addressed in the Rel-17 power saving agenda. Question 3.3-2: As concluded, the two existing durations can well cover the remaining DRX active time after data transmissions. However, the scheme should still work even with no DRX configured. Hence, we support more PDCCH skipping durations. Question 3.3-3: “Non-scheduling DCI based PDCCH skipping” is addressing the retransmission issue. Hence, same answer as Question 3.3-1Question 3.3-4: yes “Disabling UL pose retransmission for PDCCH monitoring reduction” should be extended to XR. However, it should be supported for the Pose/Control information and not for the UL AR traffic.  |
| MTK | **Question 3.3-1**: Yes, it should be further studied if R17 maintenance can not include it in August meeting.**Question 3.3-2**: No, since there is no gain.**Question 3.3-3**: Yes, it should be compared with Rel-17 PDCCH adaptation.**Question 3.3-4**: “Disabling UL pose retransmission for PDCCH monitoring reduction” seems supported in NTN while we may need further check. |
| ZTE | Question 3.3-1: Yes, it can be discussed under specific XR use cases where the necessity seems more visible. Question 3.3-2: In our evaluations, we have similar observations as Ericsson, and we should limit the enhancement of PDCCH monitoring adaption under XR scenarios. That’s XR-specific solutions.Question 3.3-3: Yes, existing PDCCH monitoring adaption can be reference.Question 3.3-4: we’re fine to discuss dynamic indication for monitoring re-transmission scheduling based on the QoS requirement of XR traffics. |
| InterDigital | Q 3-3-1: Yes, subject to outcome of Rel-17 maintenance discussion on power savings.Q 3.3-2: We think there is benefit in evaluating different PDCCH skipping durations when used without configuring CDRXQ 3.3-3: Yes. Enhancements such as non-scheduling DCI are applicable for scenarios when retransmissions are not needed or cannot be accommodated due to low latency requirement. As such, comparison with Rel-17 PDCCH adaptation scheme is ok.Q 3.3-4: We are open to discuss further |
| Samsung | Question 3.3-1: YesQuestion 3.3-2: That can be deprioritized but not be precluded at this time – can also depend on other requirements.Question 3.3-3: Yes.Question 3.3-4: No. A relevance to NTN HARQ feedback disabling is also unclear. |

# Other Power Saving Enhancements

This section captures proposals for other XR power saving enhancements. Issues under this section were considered as low priority ones in the RAN1 #109-e meeting.

UE Transmission and Reception Alignment

Proposals in this subsection correspond to the low priority Issue 3-1 identified in the RAN1 #109-e meeting. There is no evaluation result provided by any company.

* Issue 3-1: Misaligned UE transmission and reception.

**Table 17: Proposals without evaluation results on transmission and reception alignment**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Nokia, NSB | **Observation 11:** Based on the applied traffic model and considered traffic models, there would appear to be limited possibility to attain power saving gain by aligning transmission and reception activity.**Observation 12:** It is possible for the network to adjust the PDSCH-to-HARQ feedback timing accounting the available delay budged, UL resource configuration, DL capacity and other factors, such as UE power saving.**Proposal 5:** Given a limited number of TU and a number of high priority issues listed during RAN1 #109-e it is proposed to study the issues 3\_1, 3\_2, and 3\_2 as lower priority. |
| Spreadtrum | **Proposal 10: Whether to align the downlink and uplink data should be based on the data type.****Observation 3: The uplink data with the pose/control traffic of XR session shall not be aligned with the downlink XR data.****Observation 4: The uplink data of non-XR session shall be aligned with the downlink XR data.** |
| NEC | **Proposal 4: Study the mechanisms for DL and UL alignment to further reduce the power consumption.** |
| CATT | **Proposal 12: How to reduce UL power consumption caused by UL data transmission and UL control information feedback should be studied for potential power saving gain for XR service.****Proposal 13: Alignment between PUSCH transmission and HARQ feedback should be studied and supported to reduce UL power consumption for XR UE, e.g, single DCI indicating UL transmission and DL transmission (including HARQ feedback for DL reception) simultaneously.** |
| Panasonic | **Proposal 4: The UE continues monitoring PDSCH occasions for a defined period of time after performing the CG transmission. It is similar to support *drx-RetransmissionTimerUL* after CG transmission.****Proposal 5: The linkage of SPS configuration to other UL resources (such as, CG) should be considered to multiplex HARQ-ACK reports in order to reduce the number of UL transmissions for carrying data and HARQ-ACK reports.** |
| Lenovo | **Proposal 6: Study the power-saving vs. delay trade-off of postponing HARQ-ACK of a PDSCH to a nearest UL resource that is close to a later PDSCH.** |
| Google | 1. **Issue 3-1 of the misalignment between UE transmission and reception should be deprioritized in Rel-18 XR SI.**
 |
| Apple | **Proposal 6: for UE power saving, support non-integer periodicity for periodic/semi-persistent CSI measurement resources, CSI reporting and periodic/semi-persistent SRS transmission.** |
|  |  |

### Discussions

The following RAN1 #109-e meeting agreement requires a decision is made for whether Issue 3-1/2/3 needs to be addressed. As there is no evaluation result for Issue 3-1 submitted from any company in this meeting, companies may want to decide whether Issue 3-1 should be addressed or dropped from the Rel-18 XR SI.

|  |
| --- |
| **Agreement**For Rel-18 XR power saving enhancements, RAN1 further discusses by RAN1 #110 whether the issues below are to be addressed, and if so, which solutions should be selected for evaluation in this study item. These issues are low priority.* Issue 3-1: Misaligned UE transmission and reception.
* Issue 3-2: Power saving by XR-aware scheduling.
	+ Note 1b: XR SI objective has XR-awareness in RAN listed as a specific topic of RAN2 study
* Issue 3-3: Unnecessary data transmission in allocated resources.

Note 1: Rel-18 XR SI objective only has CDRX enhancements and PDCCH monitoring enhancements explicitly listed as focus of RAN1 studyNote 2: Other considerations are not precluded |

**Question 4.1-1**: As there is no evaluation result for Issue 3-1 submitted from any company in this meeting, should it be deprioritized from Rel-18 XR SI in RAN1 #110?

Please provide your views if necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Google | Yes, it should be deprioritized from Rel-18 XR SI |
| MTK | Yes, we think we can deprioritize it if no evaluation result is submitted. |
| ZTE | Proponent companies can be encouraged to provide evaluation results. |
| Samsung | No. We have an opposite view. Evaluation results for a metric (UE power savings) that do consider an aspect that is problematic, does not make that aspect non-problematic – it is the opposite and the evaluation results for the metric may not be regarded as accurate. |
|  |  |

Power Saving by XR-Aware Scheduling

Proposals in this subsection correspond to the low priority Issue 3-2 identified in the RAN1 #109-e meeting

* Issue 3-2: Power saving by XR-aware scheduling.
	+ Note 1b: XR SI objective has XR-awareness in RAN listed as a specific topic of RAN2 study

**Table 18: Proposals and evaluation results on XR-awareness scheduling**

|  |  |
| --- | --- |
| **Company** | **Proposals and evaluation results** |
| **CATT** | Table 10: Evaluation of power saving cases with gNB scheduling awareness of UE XR-specific *playoutDelayForMediaStartup*

|  |  |  |  |
| --- | --- | --- | --- |
| Power saving cases with UE playout buffer | Considered UE set | Mean Power Saving Gain (PSG) compared to always-on | #satisfied UEs per cell / #UEs per cell |
| Baseline | - | - | 11.5 / 12 |
| C-DRX(16,8,4) with go-to-sleep | All UEs | 26.43% | 11.3 / 12 |
| Satisfied UEs | 26.78% |
| C-DRX(16,8,4) with PDCCH skipping and go-to-sleep | All UEs | 34.56% | 11.2 / 12 |
| Satisfied UEs | 34.77% |
| PDCCH skipping | All UEs | 30.26% | 11 / 12 |
| Satisfied UEs | 30.36% |

**Observation 7: Large power saving gain can be obtained by the awareness of UE XR-specific *playoutDelayForMediaStartup c*apacity gain.****Proposal 11: gNB awareness of UE playout buffer should be studied and supported for XR UE power saving.** |
|  |  |

**Table 19: Proposals without evaluation results on XR-aware scheduling**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Nokia, NSB | **Observation 13:** To avoid overlapping work, it is preferred that in first phase RAN2 focuses on XR-awareness evaluations.**Proposal 5:** Given a limited number of TU and a number of high priority issues listed during RAN1 #109-e it is proposed to study the issues 3\_1, 3\_2, and 3\_2 as lower priority. |
| Google | 1. **Issue 3-2 of power saving by XR-aware scheduling should be studied in RAN2 and deprioritized in RAN1.**
2. **The unnecessary data transmission in allocated resources could be addressed with multiple configured grant configurations with overlapping resources and the UE can choose which configured grant to use based on the UL packet payload**
 |
| LGE | **Observation 7: XR specific higher layer information such as information on traffic pattern, traffic size, and PDB margin can be used to enhance power saving for XR.****Proposal 11: Consider to configure CDRX and/or indicate PDCCH monitoring adaptation with awareness of XR specific higher layer information.** |
|  |  |

### Summary of evaluation results

**UE playout buffer for XR**

[CATT] proposed to introduce XR-application awareness of UE playout buffer size at the gNB scheduler with the intension to schedule the XR traffic in better favour of UE power saving with relaxed PDB requirements. As mentioned in the contribution the proposed enhancement allows for additional PDB (“If the size of the playout buffer is fed back to the gNB scheduler, gNB could have additional PDB for resource allocation of XR packet. Additional PDB can give gNB more time to schedule UE within the delay budget requirements of the XR service and more likely to successfully transmit packets with link adaptation gain.”). It is straightforward that relaxed PDB can boost power performance by enabling more aggressive sleep. Besides, XR-awareness is a direct topic for RAN2 but not for RAN1. Moderator would like to check whether RAN1 should deprioritize this proposal in RAN1 and leave it to RAN2 discussion.

### Discussions

Regarding the general XR-awareness designs, there was the following note from RAN1 #109-e agreement.

* Note 1b: XR SI objective has XR-awareness in RAN listed as a specific topic of RAN2 study

Companies have acknowledged the benefit of XR-awareness and are still proposing to leave XR-awareness to RAN2 to handle for Rel-18 XR SI.

**Question 4.2-1**: Do you agree RAN1 should leave “Power Saving by XR-Aware Scheduling” to RAN2 study in Rel-18 XR SI?

Please provide your views if necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Google | Yes |
| MTK | Yes, according to the R18 XR SID. |
| ZTE | We agree it’s more like a topic of RAN2 study, and we’re fine to discuss RAN1 impact e.g.,from scheduling aspects. |
| InterDigital | Yes |
| Samsung | Yes – can be revisited if RAN1 specification impact is identified. |

Unnecessary Data Transmission in Allocated Resources

Proposals in this subsection correspond to the low priority Issue 3-3 identified in the RAN1 #109-e meeting

* Issue 3-3: Unnecessary data transmission in allocated resources.

**Table 20: Proposals and evaluations result on unnecessary transmission**

|  |  |
| --- | --- |
| **Company** | **Proposals and evaluation results** |
| Qualcomm | **Observation 20: CG reduces the overhead of a scheduling DCI and provides lower latencies compared to SR/BSR scheduling. However, semi-static configuration of the resource allocation may not adapt to varying packet size and may not closely approximate the amount of resources required to transmit the available data at the UE. An overallocation results in an increase of PUSCH transmit power which increases power consumption.****Observation 21: Rel-15 Uplink Skipping allows a UE to completely skip a transmission in the UL but does not allow the UE to transmit over a sufficient allocation just enough to transmit the UL data.**Table 10: Power Saving Gains from Partial Uplink Transmission

|  |  |  |
| --- | --- | --- |
| Power Saving Scheme | Power Saving Gain (PSG)  | #satisfied UEs per cell (assuming 95% UEs satisfying reliability) |
| Baseline |  |
| Mean PS gain | PS gain of 5%-tile UE in PSG CDF | PS gain of 50%-tile UE in PSG CDF | PS gain of 50%-tile UE in PSG CDF |
| Baseline  | - | - | - | - | ~4 |
| Partial Uplink Transmission | 12.73% | 8.47% | 18.70% | 3.75% | ~4 |

**Observation 22: A UE that may transmit over a subset of the configured grant allows larger power savings. For VR application with uplink pose/control, a ~19% at the 50%-ile decrease in power consumption is observed assuming pose/control flow in UL assuming same capacity with baseline scheme assuming transmission over the UL BW.****Observation 23: Partial PUSCH transmission may allow power savings for both CG and DG.****Observation 24: For proper demodulation in the UL, gNB is required to know which of the UL resources the UE has utilized or skipped or which MCS the UE utilized to transmit the TBS.****Proposal 12: To reduce power consumption, study partial uplink transmission and investigate necessary signaling to enable it.****Proposal 13: UCI indicating the resources utilized/skipped in the PUSCH or the MCS selected by the UE allows adaptation of the transport block size based on the UL XR traffic.** |
|  |  |

**Table 21: Proposals without evaluation results on unnecessary data transmission**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Nokia, NSB | **Observation 14:** It is not clear if UE autonomous adaptation can achieve notable gains in power consumption.**Proposal 5:** Given a limited number of TU and a number of high priority issues listed during RAN1 #109-e it is proposed to study the issues 3\_1, 3\_2, and 3\_2 as lower priority. |
| China Telecom | **Proposal 15: C-DRX enhancements for SPS PDSCHs of different priorities should be studied.** |
| Google | 1. **Issue 3-3 of unnecessary data transmission in allocated resources can be studied in RAN1.**
 |
| ZTE, Sanechips | Proposal 6: Power saving techniques from UL transmission perspective can also be considered. |
| Apple | **Proposal 4: investigate inband signaling to indicate varying packet size and absence/presence of SPS PDSCH.****Proposal 5: Study CG-UCI -like design to adapt the resource utilization in the time/frequency/power domains.** |
|  |  |

### Summary of evaluation results

**Partial uplink transmission**

[Qualcomm] proposed enhancements to Rel-15 Uplink Skipping to allows a UE to transmit over a sufficient allocation among the allocated resource that is just enough to transmit the UL data. UCI can be used to indicate the resources utilized/skipped in the PUSCH. For VR application with uplink pose/control, a 12.73% power saving gain is achieved assuming pose/control flow in UL assuming same capacity with baseline scheme assuming transmission over the UL BW.

### Discussions

Any comments on the evaluation results?

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | If RAN1 wants to pursue this enhancement, a common evaluation assumption should be agreed for more companies to check. |
| ZTE | The evaluation results look reasonable for us. |
| Samsung | The simulation assumptions should be discussed. |
|  |  |
|  |  |

Other Enhancements

The subsection captures new proposals submitted in RAN1 #110.

**Table 22: Other enhancements**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| ZTE, Sanechips | Proposal 5: Enhanced SR/BSR can be considered to convey the assistance information |
|  |  |
|  |  |

# Meeting RAN1 #110 Outcome

# References

1. RAN1 #109-e Chairman’s Notes, May 2022
2. R1-2205055, Moderator Summary#1 on XR specific power saving techniques, Moderator (Qualcomm Incorporated)
3. R1-2205843, XR specific power saving techniques, TCL Communication Ltd.
4. R1-2205877, Discussion on XR-specific power saving techniques, Huawei, HiSilicon
5. R1-2205916, Discussion on power saving enhancements for XR, Ericsson
6. R1-2206007, Discussion on XR specific power saving techniques, Spreadtrum Communications
7. R1-2206061, Discussion on XR specific power saving enhancements, vivo
8. R1-2206105, Discussion on XR power saving techniques, III
9. R1-2206131, Considerations on power saving techniques for XR, Sony
10. R1-2206225, XR-specific power saving enhancements, Nokia, Nokia Shanghai Bell
11. R1-2206244, Discussion on XR specific power saving techniques, NEC
12. R1-2206328, Discussion on XR specific power saving techniques, OPPO
13. R1-2206384, Power saving techniques for XR, CATT
14. R1-2206436, Discussion on XR specific power saving techniques, Panasonic
15. R1-2206495, Power saving techniques for XR, Rakuten Mobile, Inc
16. R1-2206518, XR-specific power saving techniques, Lenovo
17. R1-2206601, Discussion on XR specific power saving techniques, Intel Corporation
18. R1-2206629, Discussions on techniques for XR Power Saving Xiaomi
19. R1-2206702, Discussion on XR specific power saving enhancement for NR, China Telecom
20. R1-2206846, Considerations on XR-specific Power Savings, Samsung
21. R1-2206931, Discussion on XR-specific power saving techniques, CMCC
22. R1-2206959, Discussion on power saving techniques for XR, ETRI
23. R1-2206965, On XR-specific power saving techniques, Google Inc.
24. R1-2207008, On XR specific power saving techniques, MediaTek Inc.
25. R1-2207042, Discussion on XR-specific power saving techniques, LG Electronics
26. R1-2207061, Evaluation on XR specific power saving techniques, ZTE, Sanechips
27. R1-2207253, Power saving techniques for XR, Qualcomm Incorporated
28. R1-2207263, Discussion on XR specific power saving techniques, InterDigital, Inc.
29. R1-2207351, XR specific power saving techniques, Apple
30. R1-2207426, Discussion on XR specific power saving techniques, NTT DOCOMO, INC.

# Appendix

Objective of SI

Objective of the Rel-18 XR enhancements SI is as follows

|  |
| --- |
| The study is to be based on Release 17 TR 38.838, on corresponding Release 17 work from SA4 (as per SP-210043) and on Release 18 work from SA2 (as per SP-211166). Objectives on XR-awareness in RAN (RAN2):* Study and identify the XR traffic (both UL and DL) characteristics, QoS metrics, and application layer attributes beneficial for the gNB to be aware of.
* Study how the above information aids XR-specific traffic handling.

Objectives on XR-specific Power Saving (RAN1, RAN2):* Study XR specific power saving techniques to accommodate XR service characteristics (periodicity, multiple flows, jitter, latency, reliability, etc...). Focus is on the following techniques:
	+ C-DRX enhancement.
	+ PDCCH monitoring enhancement.

Objectives on XR-specific capacity improvements (RAN1, RAN2):* Study mechanisms that provide more efficient resource allocation and scheduling for XR service characteristics (periodicity, multiple flows, jitter, latency, reliability, etc…). Focus is on the following mechanisms:
	+ SPS and CG enhancements;
	+ Dynamic scheduling/grant enhancements.
 |

RAN1 #109-e Agreements

|  |
| --- |
| **Agreement**For power saving study of Rel-18 XR SI, CDRX enhancements to evaluate in this study item are to be selected from the following:* High priority Issue 1-1: Alignment between CDRX and XR traffic for resolving the mismatch between CDRX cycle and XR traffic periodicity for each flow
* High priority Issue 1-2: C-DRX enhancements to handle jitter
* Medium priority Issue 1-3: CDRX enhancements for multiple XR traffic flows [Note 2]
* Low priority Issue 1-4: CDRX enhancements to adjust to variable burst sizes and frame rate
	+ Note: Some companies think the adjustment for variable burst sizes can be realized by existing spec already
* Low priority Issue 1-5: low latency handling
* Low priority Issue 1-6: SFN wraparound mismatch (if handled in RAN1)

FFS: how the solutions or the combination of the solutions can handle all the identified issues.Note 1: Other considerations are not precludedNote 2: It can also be adopted for addressing issue 1-1Note 3: Companies are encouraged to clarify or provide more details of the proposed solutions, for addressing concerns from the group.Additional details can be found in R1-2205411.**Agreement**For power saving study of Rel-18 XR SI, PDCCH monitoring enhancements to evaluate in this study item are to be selected from the following* Low priority Issue 2-1: Alignment between PDCCH monitoring and XR traffic to resolve the mismatch between PDCCH monitoring periodicity and XR traffic periodicity.
	+ Note: some companies think Rel-17 PDCCH monitoring adaptation can solve issue 2-1 or achieve similar intended outcome
	+ Note: Solutions proposed for Issue 2-1 and those proposed for Issue 1-1 are motivated by the same issue, namely non-integer XR traffic periodicity. It is to be studied how they compare in in terms of power saving gain and capacity, (a) solutions proposed for Issue 1-1; (b) solutions proposed for Issue 2-1.
* Low priority Issue 2-2: XR-dedicated PDCCH monitoring window to supplement CDRX for multi-flow traffic.
	+ Note: some companies think Rel-17 PDCCH monitoring adaptation can solve issue 2-2 or achieve similar intended outcome
	+ Note: Solutions proposed for Issue 2-2 and those proposed for Issue 1-3 are motivated by the same issue, namely multiple XR traffic flows. It is to be studied how they compare in in terms of power saving gain and capacity, (a) solutions proposed for Issue 1-3; (b) solutions proposed for Issue 2-2.
* High priority Issue 2-3: Enhancements to Rel-17 PDCCH monitoring adaptation.
	+ Note: Discussion on some enhancements may depend on the outcome of Rel-17 PDCCH monitoring adaptation maintenance
	+ Note: The study on enhancement to R17 PDCCH monitoring adaptation should focus on the techniques that are used for addressing XR-specific issues, e.g., jitter

Note 1: Other considerations are not precludedNote 2: Companies are encouraged to clarify or provide more details of the proposed solutions, for addressing concerns from the group. **Agreement**For Rel-18 XR power saving enhancements, RAN1 further discusses by RAN1 #110 whether the issues below are to be addressed, and if so, which solutions should be selected for evaluation in this study item. These issues are low priority.* Issue 3-1: Misaligned UE transmission and reception.
* Issue 3-2: Power saving by XR-aware scheduling.
	+ Note 1b: XR SI objective has XR-awareness in RAN listed as a specific topic of RAN2 study
* Issue 3-3: Unnecessary data transmission in allocated resources.

Note 1: Rel-18 XR SI objective only has CDRX enhancements and PDCCH monitoring enhancements explicitly listed as focus of RAN1 studyNote 2: Other considerations are not precluded**Agreement**Rel-17 evaluation methodology for XR power saving captured in TR 38.838 is used as the baseline evaluation methodology for UE power evaluation of Rel-18 SI on XR enhancements**Agreement**Companies are encouraged to compare performance of the following Rel-15/16/17 features with the proposed enhancements for Rel-18 XR power saving evaluations. Power saving gain is calculated w.r.t. the AlwaysOn baseline. * Rel-15/16 CDRX including long DRX cycle, short DRX cycle and DRX command MAC CE and DCP
* Rel-17 PDCCH adaptation including PDCCH skipping and SSSG switching

Note: up to companies to report the configuration of the Rel-15/16/17 features**Conclusion*** If no evaluation result is provided by any company for an issue, the issue is deprioritized. The issue and proposed enhancements for the issue will not be captured by RAN1 in TR 38.835.
* If no evaluation result is provided by the proponent company for a proposed enhancement, the proposed enhancement is deprioritized. The proposed enhancement will not be captured by RAN1 in TR 38.835.
* If multiple enhancement techniques are proposed for the same issue, there can be down selection among them for the consideration of candidate enhancement for study item recommendation by RAN1 at least based on performance (power saving and capacity), spec impact, signaling overhead and implementation complexity.
* Companies are encouraged to provide detailed information for both the proposed enhancement and the existing power saving features used as the performance reference so that the evaluation results for both can be reproduced by other companies.
* When using existing power saving features as the performance reference, companies are encouraged to configure the existing power saving features to achieve the best performance.

For evaluation of a proposed enhancement and evaluation of the existing power saving features as performance reference, companies are encouraged to provide the high load case (as defined in TR 38.838, Section A.2) results. Results for low load case can also be reported optionally. |