**3GPP TSG RAN WG1 #110-bis-e R1-22xxxxx**

**e-Meeting, October 10th – 19th, 2022**

**Agenda item:** 9.10.1

**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]. 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]. In this meeting, companies’ proposals and evaluation results will be further discussed.

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
* **Section 5** for low priority issues without evolution result

Under these sections, subsections are created to discuss Issues identified in the RAN1 #109-e meeting. For **every** proposal or open issue, one of the following potential decisions is expected to be made in the RAN1 #110-bis-e meeting:

* **Decision 1**: Deprioritize the issue or proposal in RAN1
  + This applies to issue or proposal that is not essential for WI
* **Decision 2**: This is a RAN2 issue, leave the study to RAN2.
  + This applies to issue (e.g., SFN wrap around mismatch) or proposal that is expected to have performance gain even without being evaluated by RAN1 and it only has RAN2 specification impact
* **Decision 3**: Further clarification, justification or evaluation for the issue or proposal is needed in RAN1
  + This applies to issue or proposal that should be evaluated but there is no consensus to accept it yet
* **Decision 4**: The proposed solution has performance gain, recommend RAN2 to identify the final solution **if necessary** (e.g., semi-static CDRX periodicity alignment)
  + This applies to issue or proposal that should be evaluated and evaluation has shown essential performance gain, but the solution only has upper layer specification impact
* **Decision 5**: Recommend for Rel-18 XR RAN1 WI (e.g., PDCCH skipping cancellation for retransmission)
  + This applies to issue or proposal that has been properly evaluated and is recommended to be specified in PHY specification

The following low priority issues are not captured in this document according to RAN1 #110 agreement/conclusion that they will not be further discussed in RAN1.

* Low priority Issue 1-6: SFN wraparound mismatch
* Low priority Issue 3-1: Misaligned UE transmission and reception.

Please note RAN2 has agreed on a new TR 38.835 in [R2-2208749](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_119-e/Inbox/R2-2208749.zip). This document will be used as baseline when text proposals are prepared to capture RAN1 evaluation results for TR 38.835. Please also note in R2-2208749, separate subclauses are created for Layer 2 enhancements and PHY enhancements.

For the 1st round email discussions, please check Questions and FL proposals labelled by [RD1] under each “Discussions” subsection. Please kindly provide feedback by Tuesday Oct. 11th, at UTC 9:00am if possible.

# CDRX Enhancements

Periodicity Alignment between CDRX and XR Traffic

### 2.1.1 Proposals and evaluations

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 | Table 2: Results for CDRX, for FR1, high load, Dense Urban scenario, and VR multi-stream traffic: DL video (60 fps, 30 Mbps, ±4 ms jitter, 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** | | R1-2208401 | Always On | - | - | - | H | 8 | 8 | 90.1% | - | - | | R1-2208401 | R15/16 DRX (Long DRX) | 10 | 8 | 4 | H | 8 | 7 | 82.6% | 4.2% | 4.1% | | R1-2208401 | R15/16 DRX (Short DRX) | 4 | 2 | 4 | H | 8 | 5 | 69.8% | 9.8% | 9.7% | | R1-2208401 | Matched CDRX (with our solution) | 16.6 (*drx\_offset*=3, *traffic\_time\_offset*=2 ms, *drx-LongCycle*=16 ms) | 10 | 4 | H | 8 | 7 | 82.5% | 9.1% | 9.0% | | R1-2208401 | Matched CDRX (solutions from other companies) | 16.6  (17-17-16 equivalent) | 10 | 4 | H | 8 | 7 | 83.7% | 9.5% | 9.4% |   Observation 2 Matching the DRX cycle with the non-integer video periodicity achieves 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.  Observation 3 The solution proposed in this section to match DRX with non-integer traffic periodicities achieves the same performance as other semi-static solutions and has several additional advantages.  Proposal 4 Enhance DRX formula to match non-integer (ms) XR traffic periodicities.  Proposal 5 RAN2 should decide the specifics of the DRX formula changes to align DRX with non-integer periodicities. |
| vivo | **Observation 2: DCI-based approach as solution to non-integer periodicity issue will introduce more control signalling overhead and spec impact.**  **Proposal 2: Support semi-static based DRX enhancements to accommodate the non-integer XR traffic periodicity.**  **Observation 3: The following potential semi-static solutions to align DRX cycle with XR traffic periodicity can be considered.**   * **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.**   **Table I. Power consumption results in FR1 DL Indoor Hotspot with 30Mbps traffic model**   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **Power saving scheme** | **DRX configuration**  **(Cycle\_ODT\_IAT 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 | 16.67\_8\_4 | 5 | 10 | 100% | 13.05% | Note1 | | R17 PDCCH monitoring adaptation | 16.67\_8\_4 | 5 | 10 | 100% | 23.36% | Note1,8 | | 16.67\_8\_4 | 5 | 10 | 100% | 18.73% | Note2,8 | | 16.67\_8\_4 | 5 | 10 | 100% | 14.64% | Note3,8 | | 16.67\_8\_4 | 5 | 10 | 100% | 11.44% | Note4,8 | | LP-WUS scheme | 16.67\_8\_4 | 5 | 10 | 100% | 30.21% | Note1,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 28.89% | Note2,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 28.29% | Note3,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 29.23% | Note4,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 43.84% | Note1,6,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 40.08% | Note3,6,9 | | Enhanced PDCCH skipping with HARQ interaction | 16.67\_8\_4 | 5 | 10 | 100% | 37.13% | Note1,7 | | 16.67\_8\_4 | 5 | 10 | 100% | 26.98% | Note3,7 | | AlwaysOn | - | 10 | 10 | 92.50% | - | Note1 | | - | 10 | 10 | 97.45% | - | Note1,12 | | - | 10 | 10 | 93.12% | - | Note1,11 | | - | 10 | 10 | 97.45% | - | Note1,11,12 | | 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 | 16.67\_8\_4 | 10 | 10 | 92.22% | 19.28% | Note1,8 | | 16.67\_8\_4 | 10 | 10 | 92.16% | 14.96% | Note2,8 | | 16.67\_8\_4 | 10 | 10 | 91.01% | 10.98% | Note3,8 | | 16.67\_8\_4 | 10 | 10 | 91.01% | 8.94% | Note4,8 | | 16.67\_8\_4 | 10 | 10 | 97.45% | 19.28% | Note1,8,12 | | 16.67\_8\_4 | 10 | 10 | 92.78% | 19.48% | Note1,8,11 | | 16.67\_8\_4 | 10 | 10 | 97.45% | 19.48% | Note1,8,11,12 | | 16.67\_8\_4 | 10 | 10 | 1.11% | 35.21% | Note1,10 | | 16.67\_8\_4 | 10 | 10 | 2.22% | 35.21% | Note1,10,12 | | 16.67\_8\_4 | 10 | 10 | 2.08% | 32.77% | Note1,10,11 | | 16.67\_8\_4 | 10 | 10 | 94.91% | 32.77% | Note1,10,11,12 | | LP-WUS scheme | 16.67\_8\_4 | 10 | 10 | 92.22% | 25.10% | Note1,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 92.20% | 24.08% | Note2,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 91.11% | 24.11% | Note3,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 91.11% | 25.93% | Note4,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 92.22% | 38.47% | Note1,6,9 | | 16.67\_8\_4 | 10 | 10 | 92.10% | 36.07% | Note3,6,9 | | Enhanced PDCCH skipping with HARQ interaction | 16.67\_8\_4 | 10 | 10 | 92.22% | 32.18% | Note1,7 | | 16.67\_8\_4 | 10 | 10 | 92.20% | 22.93% | Note3,7 | | 16.67\_8\_4 | 10 | 10 | 97.45% | 32.18% | Note1,7,12 | | 16.67\_8\_4 | 10 | 10 | 92.78% | 32.49% | Note1,7,11 | | 16.67\_8\_4 | 10 | 10 | 97.45% | 32.49% | Note1,7,11,12 | | Note1: jitter range = [-4, +4]ms  Note2: jitter range = [-6, +6]ms  Note3: jitter range = [-8, +8]ms  Note4: jitter range = [-10, +10]ms  Note5: with R17 PDCCH skipping indication  Note6: with R17 PDCCH skipping indication and interaction with HARQ retransmission  Note7: based on SSSG switching (doing PDCCH monitoring every 2 slots in sparse SSSG before data arrive) and R17 PDCCH skipping  Note 8: PDCCH skipping is indicated in the DCI that schedules a dummy PDSCH after all the HARQ-ACK processes of transmissions have been completed  Note 9: The total relative power for LP-WUS monitoring is 45  Note10: PDCCH skipping is indicated in the DCI scheduling the initial PDSCH transmission  Note11: initial BLER = 1%  Note12: X = 95 | | | | | | | |
| OPPO | ***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 {(traffic periodicity), (reference time in integer multiple of slot), e (traffic arrival offset in relative to referenced time)}. The -th DRX-ON duration for has the semi-static start at the -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 satisfy***  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 | 90.18% | / | | R15/16 CDRX | 16 | 14 | 2 | - | 5 | 88.77% | 5.11% | | Non-uniform CDRX cycle pattern | {17,17,16} | 10 | 2 | - | 5 | 88.77% | 18.72% | | Non-uniform CDRX cycle pattern with dynamic additional ODT | {17,17,16} | 4 | 2 | 4 | 5 | 90.18% | 30.86% |   ***Observation 4: In FR1 Dense Urban, AR/VR 30Mbps and 60fps, the following is observed:***   * ***For R15/16 C-DRX, the power saving gain can be 5.11% with loss of satisfied UE rate less than 1%;*** * ***For non-uniform CDRX cycle pattern, the power saving gain is 18.72% with loss of satisfied UE rate less than 1%;*** * ***For Non-uniform CDRX cycle pattern with dynamic additional on duration timer, the power saving gain is 30.86% with similar satisfied UE rate.*** |
| 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 recommends semi-static solution for CDRX alignment with 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*** * ***Details of the design can be up to RAN2***   *Table 1: Power consumption and capacity performance of enhanced DRX using semi-static CDRX alignment 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** | | | | | | **Jitter OFF** | | | | | | | Power consumption (PC) | | | | #satisfied UEs per cell/ #UEs per cell PDB 10ms | #satisfied UEs per cell/ #UEs per cell PDB 15ms | Power consumption (PC) | | | | #satisfied UEs per cell/ #UEs per cell PDB 10ms | #satisfied UEs per cell/ #UEs per cell PDB 15ms | | Baseline | Optional | | | 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 | 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 | 115.19 | 107.43 | 114.42 | 126.9 | 3.97/4 | 3.99/4 | | Legacy CDRX | DRX (8,6,6) | 111.36 | 98.98 | 109.41 | 127.46 | 3.72/4 | 3.81/4 | 109.67 | 98.19 | 107.4 | 126.03 | 3.80/4 | 3.89/4 | | DRX (16,4,14) | 112.99 | 102.69 | 111.63 | 126.18 | 3.82/4 | 3.89/4 | 111.58 | 101.94 | 109.78 | 125.95 | 3.84/4 | 3.93/4 | | w/ eDRX | DRX (8,6,6) | 108.36 | 98.04 | 107.36 | 121.26 | 3.83/4 | 3.9/4 | 103.05 | 93.34 | 102.26 | 116.97 | 3.97/4 | 3.99/4 | | DRX (16,4,14) | 111.43 | 102.32 | 110.63 | 123.13 | 3.89/4 | 3.93/4 | 105.55 | 97.76 | 104.77 | 117.26 | 3.97/4 | 3.99/4 | |
| ZTE, Sanechips | 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% | | 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% | | Enhanced multiple CDRX (3 CDRX configurations) | 50ms DRX cycle | 6 | 4 | 11 | 11 | 90.11% | 24% |   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% | | 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% | | Enhanced multiple CDRX (3 CDRX configurations) | 50ms DRX cycle | 6 | 4 | 11 | 11 | 90.1% | 34% |   Table 3 FR1 power consumption results in Dense Urban scenario (VR45M, fps=60, 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 (%)** | | Always On | - | - | - | 7 | 7 | 91.16% |  | | Aligned CDRX with XR traffic | Aligned  every 50ms | 8 | 5 | 7 | 7 | 89.8% | 23% | | Aligned CDRX with XR traffic | Aligned  every 50ms | 10 | 5 | 7 | 7 | 90.48% | 16% |   Observation 1: The CDRX alignment schemes including non-uniform CDRX cycle, uniform non-integer CDRX cycle, or enhanced multiple CDRX configurations can achieve periodicity alignment between enhanced CDRX and XR traffic.   * For FR1, Indoor Hotspot, [-4,4]ms jitter range, VR30M   + For DL+UL, the CDRX alignment schemes have 23.85%~24% power saving gain.   + For DL only, the CDRX alignment schemes have 33.8%~34% power saving gain. * For FR1, Dense Urban, [-4,4]ms jitter range, VR45M DL only, the CDRX alignment schemes have 16%~23% power saving gain.   **Proposal 1: Capture the above evaluation results of solutions of matching periodicities between XR traffic and CDRX into TR 38.835.**  **Proposal 2: RAN1 can recommend at least the studied RRC-based solutions for enhancement of CDRX to align with XR traffic periodicity for normative phase.** |
| 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 2: Support the semi-static configuration of enhanced DRX for the alignment between XR video periodicity and DRX cycle.***  ***Proposal 3: 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.***  ***Proposal 4: Adopt the text proposal in Section 3.1 to TR 38.835 v0.1.1 for CDRX cycle alignment with XR traffic periodicity.***  ***Observation 6: The main benefit of the dynamic alignment between the CDRX cycle and the XR traffic periodicity is that a single signaling can indicate the instantaneous jitter value and resolve the periodicity mismatch. Given that RAN1 has concluded the instantaneous jitter value is not assumed to be predictable, the dynamic alignment does not have the benefit anymore but will cause additional resource overhead and UE power consumption.***  ***Proposal 5: Rel-18 XR deprioritizes dynamic alignment between the CDRX cycle and the XR traffic periodicity.***  ***Observation 7: 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.***  ***Observation 8: By using SFN\_M instead of SFN in DRX formulas, the SFN wraparound issue can be resolved with the least spec impact for CDRX alignment with XR periodicities***   * ***SFN\_M is updated by 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*** * ***TP in Appendix in 8.1 can be adopted by RAN2***   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% | |

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

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Ericsson | Proposal 1 Do not study further any L1 and L2 solutions for which there are no evaluation results based on the agreed simulation methodology.  Proposal 2 Prioritize power saving enhancements based on semi-static configurations. |
| Huawei, HiSilicon | ***Proposal 1: To handle periodicity mismatch between C-DRX cycle and XR traffic,***   * ***Semi-static adjustment of C-DRX configuration is prioritized over dynamic adjustment.*** * ***RAN1 recommends the following semi-static solution to RAN2***    + ***Configuring multiple start offsets within one C-DRX cycle.*** |
| Spreadtrum | ***Proposal 1:*** ***In order to achieve an aligned periodicity between CDRX configuration and XR service, configure multiple periodicities of the three CDRX cycles within 50ms pattern can be considered.***  ***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.*** |
| 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.*** |
| TCL | **Proposal 1: *A fixed pattern for DRX within an integer periodicity for XR power saving can be considered.*** |
| Sony | **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.** |
| 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.** |
| 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.*** |
| CMCC | **Proposal 1. The following enhanced C-DRX schemes can be considered for alignment between C-DRX and XR traffic:**   * **Scheme #1: Configure a C-DRX cycle set or pattern that contains multiple C-DRX cycles and apply this pattern cyclically in the time domain;** * **Scheme #2: Configure multiple drx-StartOffset values in one C-DRX cycle.** |
| Panasonic | **Proposal 1: 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: The combination between DCI based (approach 3) and alternating periodicities (approach 2) should be taken.** |
| ETRI | **Proposal 1: To efficiently serve XR traffics with non-integer arrival rate, support non-uniform CDRX cycle patterns for a single DRX configuration.** |
| NEC | **Proposal 1: Study the mechanism to address the mismatch between DRX cycle and the non-integer periodicity of XR packet arrival time.** |
| LGE | ***Proposal 1: For resolving the mismatch between CDRX cycle and XR traffic periodicity, consider supporting a 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 caused by missing the dynamic signaling***  ***Proposal 6: Study enhancements to the secondary DRX group taking into account the XR traffic characteristics such as non-integer periodicity and jitter.*** |
| MediaTek | ***Proposal 3: RAN1 to recommend semi-static CDRX enhancement for XR. The remaining discussions and spec impact can be left to RAN2.*** |
| Rakuten Symphony | **Proposal 1: Support non-integer DRX cycle values for XR.**  **Proposal 4: Consider dynamic configuration of the DRX parameters.** |
| Google | **Proposal 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)**   **Proposal 2: Support the adjustment of drx-StartOffset to align C-DRX cycles and XR traffic periodicity. The adjustment can be autonomously applied by the UE.**  **Proposal 3: Re-use the 38.321 equation with some modification for the start of On-Duration timer.**  **Proposal 4: Adopt one of the two porposed formulas for the start of On-Duration timer:**   * **Solution 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;**   * **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:** * **Increment the counter:**   **m is increased by 1 every n drx-Cycles**   * **Start of On-Duration:**   **[(SFN × 10) + subframe number] modulo (drx-Cycle) = (drx-StartOffset + floor(m ×d)) modulo (drx-Cycle))** |
| DOCOMO | **Proposal 1: For CDRX enhancements to align with XR traffic periodicity, the following approaches can be further studied.**   * **Semi-static DRX configuration (e.g., predefined patterns of multiple CDRX cycles)** * **DCI based DRX enhancements (e.g., adjusting start-offset via DCI indication)** |

### 2.1.2 Summary of evaluation results

**Item 2.1-1: Enhanced CDRX for periodicity alignment with XR video**

[Ericsson] proposed to configure a new DRX cycle via (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 for FR1, Dense Urban, high load with VR DL+UL multi-stream traffic (60fps DL video, DL audio and UL pose) shows 4.9% higher power saving gain for all UEs in the cell in comparison to R15/16 long DRX cycle and ~83% satisfied UE rate. The performance is close to that for the {17, 17, 16}ms inter-DRX cycle solution.

[vivo] proposed to adopt semi-static solutions to align DRX cycle with XR traffic periodicity. Evaluation for FR1, DL Indoor Hotspot with 30Mbps traffic model shows the power saving gain is 7.33% to 9.38% and 4.98% to 6.62% higher than that of the R15/16 DRX (results with less than 80% satisfied UE rate is not counted) and 100% and 91.94% satisfied UE rates for low load and high load, respectively.

[OPPO] proposed a two-cycle DRX pattern to resolve mismatch between non-integer XR traffic arrival cycle and integer DRX cycle. Evaluation for FR1, DL, Dense Urban with 60fps and 30Mbps traffic shows the power saving gain is 13.61% higher than that of the R15/16 CDRX with the same 88.77% satisfied UE rate.

[Intel] proposed that RAN1 recommends the semi-static solution for CDRX alignment with XR traffic periodicity by configuring a periodic pattern of CDRX cycles such as consecutive DRX cycles with two DRX cycle values or start offset adjustments every N DRX cycles. Evaluation for VR and CG, Dense Urban scenario, DL shows a power saving gain 2.57% and 5.74% higher than that for the R15/16 CDRX as well as a 97.5% and 99.75% rate of satisfied UEs when jitter is on and off, respectively.

[ZTE] compared performance for various semi-static solutions including non-uniform CDRX cycle, uniform non-integer CDRX cycle, multiple CDRX configurations. Similar performance is observed for these solutions. For FR1, Indoor Hotspot, VR30M DL + UL, power saving gain of the proposed solutions is 17+% higher than that of R15/16 CDRX both having >90% satisfied UE rate. For FR1, Indoor Hotspot scenario, VR30M DL only, power saving gain of the proposed solutions is about 27% higher than that of R15/16 CDRX both having >90% satisfied UE rate. For FR1, Dense urban, VR45M DL only, the proposed solutions have 16%~23% power saving gain w.r.t. the AlwaysOn baseline with about 90% satisfied UE rate.

[Qualcomm] proposed semi-static configuration of enhanced DRX with non-integer rational numbers in DRX cycles and add floor operations in DRX formulas. Evaluation results for FR1, DL VR 30Mbps in Dense Urban environment show power saving gain of the proposed solution is -2.1% higher than the Rel-15/16 CDRX when UE satisfied rate is 90% for the proposed solution and is 79% for Rel-15/16 CDRX. With PDCCH skipping, power saving gain of the proposed solution is -1.2% higher than the Rel-15/16 CDRX when UE satisfied rate is 87% for the proposed solution and 38% for Rel-15/16 CDRX. With PDCCH skipping and SSSG switching, power saving gain of the proposed solution is -0.9% higher than the Rel-15/16 CDRX when UE satisfied rate is 83% for the proposed solution and 14% for Rel-15/16 CDRX. For FR2, DL VR 30Mbps in Indoor Hotspot environment, the proposed solution has 2.43% to 8.28% power saving gain with 84% to 88% UE satisfied rate when jitter is on. Maximum UE satisfied rate of Re1-15/16 CDRX is 65% when jitter is on.

### 2.1.3 Discussions

In RAN1 #110, the following agreement and conclusion were made related to the periodicity alignment between CDRX and XR traffic.

|  |
| --- |
| Agreement  RAN1 recommends identifying a solution for enhancement of CDRX to align with XR traffic periodicity  **Conclusion**  RAN1 does not assume instantaneous jitter value for a frame is predictable for Rel-18 XR SI power saving study before further input is provided by SA. |

Two types of solutions were proposed for the CDRX alignment including the semi-static solutions based on RRC configurations and dynamic solution based on L1 or L2 signaling. The main benefit for dynamic solution is that if a dynamic signaling is already designed for jitter handling, gNB can combine the CDRX periodicity alignment indication with jitter indication in the same signaling. If jitter is not assumed predictable, there is no need to define such a dynamic signaling for jitter handling anymore. Then the benefit of using the same signaling for periodicity alignment also does not hold. Based on this, the following proposal is made.

**[RD1]** **FL proposal 2.1-1**: deprioritize dynamic signaling based CDRX periodicity alignment for Issue 1-1 in RAN1.

Companies can also start to prepare TPs for capturing the evaluation results in TR.

**[RD1]** **FL proposal 2.1-2**: capture evaluation results for periodicity alignment for CDRX and XR traffic in TR 38.835.

Please provide your views.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | We support FL proposal 2.1-1 and FL proposal 2.1-2. According to the companies’ contributions summarized by moderator, most companies show semi-static enhancement of CDRX can achieve similar gain as dynamic enhancement of CDRX. At the same time, semi-static enhancement has less signaling overhead. |
| Nokia1 | *Firstly*, our results presented in R1-2209535 in Section 2.1.1, were relate to use of dynamic adaptation scheme for alignment of CDRX and XR, i.e. compensation of the drift. These were not against jitter, thus should not be placed to Section 2.2, but should be moved to this Section and accounted in discussion on the periodicity alignment.  *Secondly*, the reason why we feel that dynamic solution is better suited for the alignment/drift compensation, is that, while in simulations the conditions are static, in practical conditions they are not. There is no a-priori information on the absolute timing of the centre point of the packet arrival, hence, (while again in simulation this could be assumed), requiring that in practise the proper CDRX configuration (i.e. start offset and onDuration) need to be aligned over time. Thus before agreeing on proposal 2.1-1 it would be good to understand if companies assumed random offset between packet arrival (centre point) and initial CDRX configuration, or whether this was assumed to be ideally. known.  Thus, we don’t currently support the proposal 2.1-1 and feel that dynamic solution would have merits to address the drift issue. |
| ZTE, Sanechips | For proposal 2.1-1, we suggest to prioritize semi-static solutions, and not exclude dynamic approaches at this stage. In this way, the proposal can not only address companies’ concerns to semi-static methods, but also make dynamics solutions open for potentially beneficial cases, e.g., RAN awareness is enabled at CN side, the generation of video frame can be adjusted according to network situation. Therefore, we have following proposal:  [RD1] FL proposal 2.1-1 - v0: prioritize semi-static solutions based CDRX periodicity alignment for Issue 1-1 in RAN1.  Companies can also start to prepare TPs for capturing the evaluation results in TR.  We support proposal 2.1-2. |
| Samsung | Agree with FL proposal 2.1-1  For FL proposal 2.1-2, would there be any discussion of the results or would they be a copy-paste from Tdocs to the TR? In the latter case, a corresponding note should be captured. |
| InterDigital | We share similar understanding with Nokia on the benefits of dynamic adaptation scheme as it allows to address multiple issues that are typically present in practical scenarios including jitter, non-integer periodicity, variable payload sizes, etc.  As such, we do not see there is a strong need to deprioritize, at this stage, any dynamic signalling for CDRX periodicity alignment as indicated by proposal 2.1-1. |

Jitter Handling for CDRX

### 2.2.1 Proposals and evaluations

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 |
| Ericsson | Observation 4 Two-stage DRX is suitable for low network loads, where it saves up to ~17% power, while also achieving a high percentage of satisfied UEs (96.4%).  Proposal 6 Adopt the two-stage DRX solution to handle jitter for quasi-periodic XR traffic flows.  Proposal 7 RAN2 can address the details of the DRX specification changes for supporting two-stage DRX.    Figure 2. Illustration of two-stage DRX.  Table 3: Results for two-stage DRX, for FR1, high load, Dense Urban scenario, and VR multi-stream traffic: DL video (60 fps, 30 Mbps, ±4 ms jitter, 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** | | R1-2208401 | Always On | - | - | - | H | 8 | 8 | 90.1% | - | - | | R1-2208401 | R15/16 DRX (Long DRX) | 10 | 8 | 4 | H | 8 | 7 | 82.6% | 4.2% | 4.1% | | R1-2208401 | R15/16 DRX (Short DRX) | 4 | 2 | 4 | H | 8 | 5 | 69.8% | 9.8% | 9.7% | | R1-2208401 | Matched CDRX (with our solution) | 16.6 (*drx\_offset*=3, *traffic\_time\_offset*=2 ms, drx-LongCycle=16 ms) | 10 | 4 | H | 8 | 7 | 82.5% | 9.1% | 9.0% | | R1-2208401 | Matched CDRX (solutions from other companies) | 16.6  (17-17-16 equivalent) | 10 | 4 | H | 8 | 7 | 83.7% | 9.5% | 9.4% | | R1-2208401 | R17 PDCCH skipping & matched CDRX | 16.6  (matched with our solution) | 10 | 4 | H | 8 | 6 | 72.2% | 10.5% | 10.4% | | R1-2208401 | Two-stage DRX | outer DRX: 16.6 (matched with our solution);  inner DRX: 4 | outer ODT: 10; inner ODT: 2 | 4 | H | 8 | 5 | 71.7% | 14.2% | 14.1% |   Table 4 Results for two-stage DRX, for low load, FR1, Dense Urban scenario, and VR multi-stream traffic: DL video (60 fps, 30 Mbps, ±4 ms jitter, 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** | | R1-2208401 | Always On | - | - | - | L | 2 | 8 | 99.5% | - | - | | R1-2208401 | R15/16 DRX  (Long DRX) | 10 | 8 | 4 | L | 2 | - | 98.3% | 4.6% | 5.0% | | R1-2208401 | R15/16 DRX  (Short DRX) | 4 | 2 | 4 | L | 2 | - | 96.5% | 10.8% | 11.7% | | R1-2208401 | Matched CDRX (with our solution) | 16.6  (*drx\_offset*=3, *traffic\_time\_offset*=2 ms) | 10 | 4 | L | 2 | - | 97.0% | 10.2% | 10.9% | | R1-2208401 | R17 PDCCH skipping & matched CDRX | 16.6  (matched with our solution) | 10 | 4 | L | 2 | - | 96.6% | 11.2% | 11.9% | | R1-2208401 | Two-stage DRX | outer DRX: 16.6 (matched with our solution);  inner DRX: 4 | outer ODT: 10; inner ODT: 2 | 4 | L | 2 | - | 96.4% | 15.7% | 16.6% | |
| vivo | **Observation 1: With larger jitter range, there is negligible capacity loss.**  **Proposal 1: For R18 XR study, jitter model in accordance with the SA4’s inputs in TR 26.926 should be considered, e.g. jitter range of [-8ms, +8ms].**  **Observation 8: Compared to the existing R17 PDCCH monitoring adaptation scheme, two-stage CDRX scheme has slightly worse performance results in terms of power saving gain and capacity.**  **Table 3. Evaluation results in FR1 DL Indoor Hotspot with 30Mbps traffic model**   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **Power saving scheme** | **DRX configuration**  **(Cycle\_ODT\_IAT) ms** | **avg # UEs/ cell = N1** | **C1=floor**  **(Capacity)** | **% of satisfied UEs when #UEs/cell = N1** | **Power saving gain (%)** | **Notes** | | AlwaysOn | - | 5 | 10 | 100% | - |  | | R17 PDCCH monitoring adaptation | 16.67\_10\_4 | 5 | 10 | 100% | 23.36% | Note1 | | 16.67\_10\_4 | 5 | 10 | 100% | 25.39% | Note2 | | Two-stage CDRX | Outer CDRX:  16.67\_10\_4  Inner CDRX:  4\_2\_4 | 5 | 10 | 100% | 21.52% | Note3 | | AlwaysOn | - | 10 | 10 | 92.50% | - |  | | R17 PDCCH monitoring adaptation | 16.67\_10\_4 | 10 | 10 | 92.22% | 19.28% | Note1 | | 16.67\_10\_4 | 10 | 10 | 88.52% | 21.84% | Note2 | | Two-stage CDRX | Outer CDRX:  16.67\_10\_4  Inner CDRX:  4\_2\_4 | 10 | 10 | 86.89% | 16.36% | Note3 | | Note1: doing PDCCH monitoring every 2 slots in sparse SSSG before data arrive  Note2: doing PDCCH monitoring every 4 slots in sparse SSSG before data arrive  Note3: 4ms CDRX cycle and 2ms ODT for inner CDRX | | | | | | |   **Observation 9: Compared to the existing R17 PDCCH monitoring adaptation scheme, additional On-Duration scheme has slightly worse performance results in terms of power saving gain and capacity.**  **Table 4. Evaluation results in FR1 DL Indoor Hotspot with 30Mbps traffic model**   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **Power saving scheme** | **DRX configuration**  **(Cycle\_ODT\_IAT) ms** | **avg # UEs/ cell = N1** | **C1=floor**  **(Capacity)** | **% of satisfied UEs when #UEs/cell = N1** | **Power saving gain (%)** | **Notes** | | AlwaysOn | - | 5 | 10 | 100% | - |  | | R17 PDCCH monitoring adaptation | 16.67\_10\_4 | 5 | 10 | 100% | 23.36% | Note1 | | Additional On-Duration | 16.67\_4\_4 | 5 | 10 | 100% | 18.73% | Note2 | | AlwaysOn | - | 10 | 10 | 92.50% | - |  | | R17 PDCCH monitoring adaptation | 16.67\_10\_4 | 10 | 10 | 92.22% | 19.28% | Note1 | | Additional On-Duration (4ms) | 16.67\_4\_4 | 10 | 10 | 91.49% | 14.68% | Note2 | | Note1: doing PDCCH monitoring every 2 slots in sparse SSSG before data arrive  Note2: Additional onduration length is 4ms | | | | | | |   **Observation 4: R17 PDCCH monitoring adaptation can reduce unnecessary power consumption caused by jitter.**    **Figure 5. Jitter handling method based on LP-WUS**  **Observation 5: Due to the usage of sparse SSSG before data arrival, there are still some unnecessary PDCCH monitoring that cannot be completely avoided by R17 PDCCH monitoring adaptation.**  **Observation 6: The power saving gain by R17 PDCCH monitoring adaptation will decrease with the increase of jitter range.**  **Observation 7: Compared to R17 PDCCH monitoring adaptation scheme, LP-WUS based jitter handling scheme can provide up to 14% additional power saving gain with no capacity loss.**  **Proposal 3: Capture LP-WUS as one candidate solution for jitter handling solutions in TR 38.835.**  **Proposal 5: Capture the above text proposal into R18 XR TR 38.835.**  **Table I. Power consumption results in FR1 DL Indoor Hotspot with 30Mbps traffic model**   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **Power saving scheme** | **DRX configuration**  **(Cycle\_ODT\_IAT 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 | 16.67\_8\_4 | 5 | 10 | 100% | 13.05% | Note1 | | R17 PDCCH monitoring adaptation | 16.67\_8\_4 | 5 | 10 | 100% | 23.36% | Note1,8 | | 16.67\_8\_4 | 5 | 10 | 100% | 18.73% | Note2,8 | | 16.67\_8\_4 | 5 | 10 | 100% | 14.64% | Note3,8 | | 16.67\_8\_4 | 5 | 10 | 100% | 11.44% | Note4,8 | | LP-WUS scheme | 16.67\_8\_4 | 5 | 10 | 100% | 30.21% | Note1,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 28.89% | Note2,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 28.29% | Note3,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 29.23% | Note4,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 43.84% | Note1,6,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 40.08% | Note3,6,9 | | Interaction with HARQ retransmission | 16.67\_8\_4 | 5 | 10 | 100% | 37.13% | Note1,7 | | 16.67\_8\_4 | 5 | 10 | 100% | 26.98% | Note3,7 | | 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 | 16.67\_8\_4 | 10 | 10 | 92.22% | 19.28% | Note1,8 | | 16.67\_8\_4 | 10 | 10 | 92.16% | 14.96% | Note2,8 | | 16.67\_8\_4 | 10 | 10 | 91.01% | 10.98% | Note3,8 | | 16.67\_8\_4 | 10 | 10 | 91.01% | 8.94% | Note4,8 | | LP-WUS scheme | 16.67\_8\_4 | 10 | 10 | 92.22% | 25.10% | Note1,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 92.20% | 24.08% | Note2,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 91.11% | 24.11% | Note3,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 91.11% | 25.93% | Note4,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 92.22% | 38.47% | Note1,6,9 | | 16.67\_8\_4 | 10 | 10 | 92.10% | 36.07% | Note3,6,9 | | Interaction with HARQ retransmission | 16.67\_8\_4 | 10 | 10 | 92.22% | 32.18% | Note1,7 | | 16.67\_8\_4 | 10 | 10 | 92.20% | 22.93% | Note3,7 | | Note1: jitter range = [-4, +4]ms  Note2: jitter range = [-6, +6]ms  Note3: jitter range = [-8, +8]ms  Note4: jitter range = [-10, +10]ms  Note5: with R17 PDCCH skipping indication  Note6: with R17 PDCCH skipping indication and interaction with HARQ retransmission  Note7: based on SSSG switching (doing PDCCH monitoring every 2 slots in sparse SSSG before data arrive) and R17 PDCCH skipping  Note 8: PDCCH skipping is indicated in the DCI that schedules a dummy PDSCH after all the HARQ-ACK processes of transmissions have been completed  Note 9: The total relative power for LP-WUS monitoring is 45 | | | | | | | |
| Huawei, HiSilicon | Figure 1 Illustration of non-uniform PDCCH monitoring during C-DRX On Duration, where UE only monitors PDCCH in the colored occasions within On Duration  ***Observation 2: The proposed schemes, i.e., non-uniform PDCCH monitoring within C-DRX On Duration, can obtain ~18%, ~11%, ~6% power saving gain compared with Always-On scheme, and enhanced C-DRX, and R17 SSSG switching, respectively.***  ***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 2 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 compared with “Always On” | Power consumption reduction in terms of “PDCCH monitoring only” compared with “Always On” | | 1 | Always On | 93.42% | - | - | | 2 | Legacy C-DRX (DRX cycle=16, ODT=12w, IAT= 4) | 83.20% | 5.57% | 22.50% | | 3 | [1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1] | 91.43% | **7.64%** | **31.50%** | | 4 | [0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1] | 88.57% | 12.54% | 53.52% | | 5 | [0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1] | 88.83% | 12.98% | 53.61% | | 6 | [0, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 1, 0, 0] | 89.44% | 15.00% | 56.05% | | 7 | [0, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 0, 0] | 87.53% | **18.91%** | **62.89%** | | Case 1: Always On as in R17 XR  Case 2: Legacy C-DRX scheme with DRX cycle 16ms, On Duration Timer 12ms, and Inactivity Timer 4ms  Case 3: Enhanced C-DRX where the periodicity mismatch issue of C-DRX is solved  Case 4, 5: Rel-17 PDCCH monitoring adaptations, e.g., SSSG switching. In sparse SSSG, the search space periodicity is 2/4 slots and duration is 1/2 slots. In dense SSSG, the UE monitors PDCCH in every slot.  Case 6, 7: Proposed scheme, i.e., non-uniform PDCCH monitoring occasions within C-DRX On Duration  Note: Case 3-7 assumes the periodicity mismatch issue of C-DRX is already solved. For all C-DRX schemes, ODT=12ms, IAT=4ms. | | | | |     **Figure 3. Example to stop PDCCH monitoring in a DRX cycle after XR frame transmission finish**  Table 3 Simulation results of terminating OnDurationTimer by the expiration of InactivityTimer  (High Load Case, 11 UEs per cell on average where the capacity is 11.5 UEs/cell)   |  |  |  | | --- | --- | --- | | Scheme | Satisfied UE Ratio | Power Saving Gain compared with “Always On” | | Always On | 100% | - | | Enhanced C-DRX (Periodicity mismatch issue solved, ODT = 12ms, IAT = 4ms) | 91.43% | 7.64% | | Proposed Scheme (C-DRX with early stopping of ODT, periodicity mismatch issue solved, ODT = 12ms, IAT = 4ms) | 88.23% | 10.22% |   ***Proposal 3: To avoid unnecessary PDCCH monitoring after XR frame transmission finish, support stopping OnDurationTimer in a DRX cycle based on the expiration of InactivityTimer.*** |
| xiaomi | **Table 6: Summary of metrics**   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | Total  Energy | 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% |   ***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.*** |
| 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.***    Figure 4 Additional on duration time duration DRX off  ***Proposal 4: An additional DRX-on duration time can be dynamically indicated to UE to solve jitter issue.***  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 | 90.18% | / | | R15/16 CDRX | 16 | 14 | 2 | - | 5 | 88.77% | 5.11% | | Non-uniform CDRX cycle pattern | {17,17,16} | 10 | 2 | - | 5 | 88.77% | 18.72% | | Non-uniform CDRX cycle pattern with dynamic additional ODT | {17,17,16} | 4 | 2 | 4 | 5 | 90.18% | 30.86% |   ***Observation 4: In FR1 Dense Urban, AR/VR 30Mbps and 60fps, the following is observed:***   * ***For R15/16 C-DRX, the power saving gain can be 5.11% with loss of satisfied UE rate less than 1%;*** * ***For non-uniform CDRX cycle pattern, the power saving gain is 18.72% with loss of satisfied UE rate less than 1%;*** * ***For Non-uniform CDRX cycle pattern with dynamic additional on duration timer, the power saving gain is 30.86% with similar satisfied UE rate.*** |
| ZTE | Table 5 FR1 power consumption results in Indoor Hotspot scenario (VR30M, fps=60, DL + pose/control)  {Jitter= [-8,8]ms; additional active time = 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% | | Flexible additional active time + aligned CDRX | Aligned every 50ms | 5 | 4 | 11 | 11 | 90% | 14.18% |   Table 6 FR1 power consumption results in Indoor Hotspot scenario (VR30M, fps=60, DL only)  {Jitter=[-8,8]ms; additional active time = 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% | | Flexible additional active time + aligned CDRX | Aligned  every 50ms | 5 | 4 | 11 | 11 | 90% | 30% |   Table 7 FR1 power consumption results in Indoor Hotspot scenario (VR45M, fps=60, DL + pose/control)  {Jitter=[-8,8]ms; additional active time = 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 | 5 | 7 | 7 | 90% | 7.5% | | Flexible additional active time + aligned CDRX | Aligned every 50ms | 6 | 5 | 7 | 7 | 88.1% | 15.16% |   Table 8 FR1 power consumption results in Indoor Hotspot scenario (VR45M, fps=60, DL only)  {Jitter=[-8,8]ms; additional active time = 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 | 5 | 7 | 7 | 90% | 8.47% | | Flexible additional active time + aligned CDRX | Aligned  every 50ms | 6 | 5 | 7 | 7 | 88.1% | 20% |   Table 9 FR1 power consumption results in Indoor Hotspot scenario (CG30M + pose/control)  {Jitter=[-4,4]ms; additional active time = 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 (%)** | | CDRX alignment | 16 | 6 | 4 | 12 | 12 | 84% | 21.2% | | Flexible additional active time + aligned CDRX | 16 | 6 | 4 | 12 | 12 | 88.19% | 21.3% |   Table 10 FR1 power consumption results in Indoor Hotspot scenario (CG30M, DL only)  {Jitter=[-4,4]ms; additional active time = 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 (%)** | | CDRX alignment | 16 | 6 | 4 | 12 | 12 | 84% | 30.9% | | 16 | 8 | 6 | 12 | 12 | 88.89% | 20.6% | | Flexible additional active time + aligned CDRX | 16 | 6 | 4 | 12 | 12 | 88.19% | 32.4% |   Table 11 FR1 power consumption results in Dense Urban scenario (VR45M, fps=60, 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 (%)** | | Aligned CDRX with XR traffic | Aligned  every 50ms | 10 | 5 | 7 | 7 | 90.48% | 16% | | Flexible additional active time + aligned CDRX | Aligned  every 50ms | 2 | 5 | 7 | 7 | 91.84% | 26.24% |   Table 12 FR1 power consumption results in Dense Urban 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 | 14 | 5 | 7 | 7 | 87% | 4.86% | | Flexible additional active time + aligned CDRX | Aligned  every 50ms | 2 | 5 | 7 | 7 | 90.48% | 20.53% |   Observation 2:   * For FR1, Indoor Hotspot, [-4,4]ms jitter range, CG30M,   + For DL+UL, the flexible additional active time based on aligned CDRX has 21.3% power saving gain.   + For DL only, the flexible additional active time based on aligned CDRX has 32.4% power saving gain. * For FR1, Dense Urban, [-4,4]ms jitter range, VR45M,   + For DL only, the flexible additional active time based on aligned CDRX has 26.24% power saving gain.   Observation 3:   * For FR1, Indoor Hotspot, [-8,8]ms jitter range, VR30M   + For DL+UL, the flexible additional active time based on aligned CDRX has 14.18% power saving gain.   + For DL only, the flexible additional active time based on aligned CDRX has 30% power saving gain. * For FR1, Indoor Hotspot, [-8,8]ms jitter range, VR45M,   + For DL+UL, the flexible additional active time based on aligned CDRX has 15.16% power saving gain.   + For DL only, the flexible additional active time based on aligned CDRX has 20% power saving gain. * For FR1, Dense Urban, [-8,8]ms jitter range, VR45M,   + For DL only, the flexible additional active time based on aligned CDRX has 20.53% power saving gain.   **Proposal 3: Capture solutions of jitter handling and evaluation results into TR.38.835.**  Proposal 4: Support flexible additional active time based on current CDRX design, with minor specification change.  Table 13 FR1 power consumption results in Dense Urban scenario (VR45M, fps=60, 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 (%)** | | Aligned CDRX with XR traffic | Aligned  every 50ms | 10 | 5 | 7 | 7 | 90.48% | 16% | | Flexible additional active time + aligned CDRX | Aligned  every 50ms | 2 | 5 | 7 | 7 | 91.84% | 26.24% | | Flexible additional active time + aligned CDRX + PDCCH skipping(duration = 2ms) | Aligned  every 50ms | 2 | 5 | 7 | 7 | 91.16% | 33.5% | | PDCCH Skipping  (duration = 2ms,4ms) | Aligned  every 50ms | 10 | 5 | 7 | 7 | 84% | 24% |   Table 14 FR1 power consumption results in Dense Urban 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 | 14 | 5 | 7 | 7 | 87% | 4.86% | | Flexible additional active time + aligned CDRX | Aligned  every 50ms | 2 | 5 | 7 | 7 | 90.48% | 20.53% | | PDCCH skipping  (duration = 2ms,4ms) | Aligned  every 50ms | 14 | 5 | 7 | 7 | 82% | 9.2% |   Observation 4: For FR1, Dense Urban, [-4,4]ms jitter range, VR45M DL only,   * flexible additional active time has 26.24% PSG with 91.84% of satisfied UE * flexible additional active time with PDCCH skipping has 33.5% PSG with 91.16% of satisfied UE * PDCCH skipping has 24% PSG with 84% of satisfied UE   Observation 5: For FR1, Dense Urban, [-8,8]ms jitter range, VR45M DL only,   * flexible additional active time has 20.53% PSG with 90.48% of satisfied UE * PDCCH skipping has 9.2% PSG with 82% of satisfied UE   **Observation 6: The limitations of legacy PDCCH skipping should be accounted.**   * PDCCH skipping is indicated in a scheduling DCI * The PDCCH skipping duration may delay potential retransmission scheduling   Proposal 5: Dynamic CDRX enhancement deserves further study to at least address concerns about semi-static methods, in case of specific XR applications.   * Dynamic indication to adjust StarOffset of CDRX configuration to align the CDRX cycle with XR traffic * WUS/DCI indication of adjust of the startOffset of CDRX configuration   Table 16 FR1 power consumption results in Dense Urban scenario (VR45M, fps=60, 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 (%)** | | Aligned CDRX with XR traffic | Aligned  every 50ms | 10 | 5 | 7 | 7 | 90.48% | 16% | | WUS(start at the beginning of jitter range,  WUS is monitored  every 1 slot) | Aligned  every 50ms | 5 | 5 | 7 | 7 | 90.48% | 24.87% | | PDCCH Skipping  (duration = 2ms,4ms) | Aligned  every 50ms | 10 | 5 | 7 | 7 | 84% | 24% |   Table 17 FR1 power consumption results in Dense Urban 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 | 14 | 5 | 7 | 7 | 87% | 4.86% | | WUS(start at the beginning of jitter range,  WUS is monitored  every 1 slot) | Aligned  every 50ms | 5 | 5 | 7 | 7 | 86% | 20.84% | | PDCCH skipping  (duration = 2ms,4ms) | Aligned  every 50ms | 14 | 5 | 7 | 7 | 82% | 9.2% |   Observation 7: For FR1, Dense Urban, VR45M DL only,   * For [-4,4]ms jitter range, WUS enhancement has 24.87% PSG with 90.48% of satisfied UE * For [-8,8]ms jitter range, WUS enhancement has 20.84% PSG with 86% of satisfied UE   Proposal 6: Dynamic CDRX enhancement can study following aspects:   * For Dynamic indication to adjust StartOffset of CDRX configuration for addressing both issues. * Signalling indicates to start the additional DRX onDuration. |
| Nokia, NSB | **Observation 1**: *The non-integer and recurring decimal 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.*  **Observation 2**: *Static RRC configuration with periodic realignment does not fully solve the misalignment issue since the gap between the DRX cycle and the XR traffic cannot be fully cleared using a static reconfiguration*.  **Observation 3**: *Jitter makes hard to detect the expected arrival window of XR frames. Therefore, the realignment offset may be larger than the needed to account for potential errors*.  **Proposal 1**: To solve the misalignment issue, we propose to use a combination of static RRC configuration and dynamic L1/L2 signalling to perform both periodic and asynchronous realignment.  **Proposal 2**: *We propose to consider the adaptation of multiple parameters of the DRX configuration to solve the misalignment issue between the DRX cycle and XR traffic.*  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% |   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% |   **Observation 4**: *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 5:** *Dynamic adaptation of multiple parameters of the CDRX configuration like StartOffset and OnDuration minimizes capacity loss for XR services while improving the UE power saving gain in spite of jitter.*  **Proposal 3**: *We propose to consider L1/L2 signalling and new DRX parameters to dynamically change some of the parameters of the DRX cycle in order to handle the jitter of quasi-periodic application like XR.*    Figure 7 – Active time extension applied when packet arrival is after On Duration. We assumed that 1 packet is expected to arrive per DRX cycle.  **Observation 6**: *If the network can configure the UE with 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 Extension of Active Time 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 4**: *We propose to consider automatic extension of UE Active Time of CDRX based on the frame arrival to enable enhanced power saving.*   |  |  | | --- | --- | | (a) CDRX w/o Extension of Active Time | (b) CDRX w/ Extension of Active Time. |   Figure 9 – Capacity of CDRX configurations w/ and w/o Extension of Active Time (EAT) for CG traffic (Video Single-Stream) in Indoor Hotspot deployment (FR1) with X=99% of frames received within PDB and cells evenly loaded.    Figure 10 – Power saving gain of CDRX configurations w/ Extension of Active Time (EAT) in Indoor Hotspot deployment (FR1) with X=99% of frames received within PDB and cells evenly loaded. Power saving gain shall be ignored when there is no user that is satisfied (i.e., XR capacity is zero). |
| Qualcomm | ***Observation 9: Using fixed CDRX parameters may have negative impact on delays (PDB) and power consumption for XR traffic.***    **Figure 10: CDRX parameter adaptation**  ***Observation 10: For FR2, DL VR 30Mbps in Indoor Hotspot environment, dynamically adapting some of the (e)CDRX parameters can achieve considerable capacity gains over (e)CDRX***  ***Proposal 6: For XR, consider studying methods to dynamically adapt the CDRX parameters to the traffic bursts, specifically:***   * ***ON duration start*** * ***Inactivity timer early termination*** * ***PDCCH skipping/SSSG switching indication using a non-scheduling DCI***   **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% |   **Table 4**: **Summary of FR2 InH Power Consumption Results for 7UE per Cell, VR (30Mbps), PDB =10ms**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Power saving scheme | CDRX cycle (ms) | ODT (ms) | IAT (ms) | % of satisfied UE | Median PSG of all UEs (%) relative to baseline | | eCDRX + PDCCH skipping [note 1] + Adaptive ON Start  (*Baseline: eCDRX + PDCCH skipping [note 1]*) | 16 | 4 | 4 | 27% | 43.8% | | 16 | 8 | 8 | 84% | 38.6% | | 16 | 8 | 16 | 88% | 34.6% | | eCDRX + PDCCH skipping [note 2] + Adaptive ON Start  (*Baseline: eCDRX + PDCCH skipping [note 2]*) | 16 | 4 | 4 | 27% | 54.6% | | 16 | 8 | 8 | 84% | 55.6% | | 16 | 8 | 16 | 88% | 54.7% | | Note 1: PDCCH skipping inside ON duration only  Note 2: PDCCH skipping inside ON duration and for IAT (early IAT termination) | | | | | | |

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

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| 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: Dynamic indication of DRX On Duration starting time can be applied to solve the jitter problem.***  ***Proposal 8: Support periodic XR-specific PDCCH monitoring in the On Duration and dormancy of DRX.***  ***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.*** |
| 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.*** |
| Sony | **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.** |
| 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.*** |
| CMCC | **Proposal 2. A new DCI can be used to indicate UE the extension of C-DRX ON at the end of C-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 C-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.** |
| 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.** |
| 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.*** |
| Rakuten Symphony | **Proposal 5: Consider early termination of Active Time.** |
| Google | **Proposal 5: Adopt the two stages C-DRX configurations to handle the jitter.**  **Proposal 6: 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.** |
| InterDigital | **Proposal 4:** Support adaptation (e.g. via DCI) for advancing/delaying the start offset time of the CDRX ON duration per cycle  **Proposal 5:** Study single indication (e.g. single DCI) for dynamically adapting the start offset time of CDRX ON duration for multiple cycles  **Proposal 6:** Support UE sending an indication to gNB to request dynamic adaptation to CDRX parameters (e.g. ON duration, start offset) for receiving DL traffic |
| DOCOMO | **Proposal 2: Further study the following directions for CDRX enhancements to handle jitter.**   * **Early termination of DRX On duration timer** * **Dynamic adjustment of CDRX starting time** |
| Qualcomm | ***Proposal 7: 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.*** |
| III | **Proposal#1:** **In order to handle jitter, we propose to utilize opportunistic or deterministic active-duration-minimization techniques to achieve better power saving gain with sufficiently high UE satisfaction.** |

### 2.2.2 Summary of evaluation results

**Item 2.2-1: Wider jitter range**

[vivo] pointed out that SA4 has added new XR video traces to TR 26.926 and sent the data to RAN1 in LS R1-2104023 in April 2021. Calculation shows that in the new XR video traces, jitter range has increased to [-8ms, +8ms] for the truncated Gaussian distribution. It is proposed that for R18 XR study, [-8ms, +8ms] jitter range should be considered.

**Item 2.2-2: Non-uniform PMOs within CDRX On Duration**

[Huawei, HiSilicon] proposed to configure non-uniform PDCCH monitoring occasions 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 tails of jitter distribution. Evaluation results show the proposed solution can obtain ~18%, ~11%, ~6% power saving gain compared with Always-On, periodicity aligned C-DRX and Rel-17 SSSG switching, respectively.

It is noticed that with the 12ms configured On Duration in the evaluation, the proposed non-uniform PMOs have a shorter effective On Duration (counted from the first to the last slots with PDCCH monitoring, e.g., 8ms for [0, 0, 0, 0, 0, 1, 1, 0, 0, 1, 1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 0, 0, 0]) than that of the sparse PMOs supported by existing specification (e.g., 11ms for [0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1]). This could be the main contributor of the power saving gain for the proposed solution.

**Item 2.2-3: Two-stage CDRX On-Duration**

[Ericsson] proposed to adopt the two-stage DRX solution to handle jitter for quasi-periodic XR traffic flows so that UE can monitor PDCCH sparsely before the data arrival for saving power. Simulation result shows 5.1% to 5.5% higher power saving gain and -10.8% and -0.6% higher UE satisfied rate than the periodicity aligned CDRX.

[Qualcomm] evaluated sparse PDCCH monitoring before the data arrival in the default SSSG followed by SSSG switching to per slot PDCCH monitoring. Results show a comparable additional power saving gain of 4.3% w.r.t. per slot PDCCH monitoring. [vivo] compared sparse PDCCH monitoring followed by Rel-17 SSSG switching and the two-stage On-Duration for FR1 DL Indoor Hotspot with 30Mbps traffic model. Rel-17 SSSG switching shows 1.5% to 5.5% higher saving gain than two-stage CDRX on duration and better UE satisfied rate.

**Item 2.2-4: Jitter handling by LP-WUS**

[vivo] and [Xiaomi] proposed the low power-wake up signal (LP-WUS) based jitter handling. Evaluation results show that compared to Rel-17 PDCCH monitoring adaptation, LP-WUS scheme can provide much higher power saving gain compared to Rel-17 PDCCH monitoring adaptation. The evaluations are based on companies’ own assumptions (e.g., power modelling, gap for the MR to wake up).

**Item 2.2-5: Early stopping of ODT based on expiration of IAT**

[Huawei, HiSilicon] proposed to stop OnDurationTimer in a DRX cycle when InactivityTimer expires. The proposed solution shows a 2.58% higher power saving gain and -3.2% higher satisfied UE ratio w.r.t. periodicity aligned CDRX. In RAN1 #100, companies argued that PDCCH skipping can achieve similar effect to early termination of DRX On Duration. Especially, PDCCH skipping with an explicit application delay equal to IAT is equivalent to the proposed solution. The proposed solution is good for XR DL single stream video service. For multi-stream service, a potential issue is if a non-video UE specific data is scheduled before the video frame (i.e., due to random jitter), UE stopping ODT after IAT expires may cause the UE to miss the video frame. In this case, using PDCCH skipping is more robust.

**Item 2.2-6: Additional DRX active time**

[ZTE] proposed flexible (UE autonomous) additional active time if UE does not receive data within current active time. Evaluations in various scenarios show better performance by the proposed solution than the periodicity aligned CDRX with PDCCH skipping. [Nokia, NSB] proposed the automatic Extension of Active Time (EAT) which works in a similar way. EAT extends DRX active time if XR frame does not arrive before the On Duration timer expires. EAT shows power saving gain over CDRX by using a relatively short On Duration w.r.t. jitter range. These proposed solutions are good for XR DL single stream video service. For multi-stream service, a potential issue is if a non-video UE specific data is scheduled before the video frame (i.e., due to random jitter), not extending the ODT may cause the UE to miss the video frame.

[OPPO] proposed to use dynamic signaling such as a DCI to trigger additional On Duration if the data packet arrives after the On Duration expires. Evaluation results show 12.14% higher power saving gain and 1.41% higher satisfied UE rate than the periodicity aligned CDRX. Compared with [ZTE] and [Nokia]’s autonomous extension of DRX active time, [OPPO]’s solution has additional signaling overhead. In the meanwhile, the dynamic signaling can be more robust if a non-video UE specific data is scheduled before the video frame in the same DRX cycle.

[vivo] compared the additional On-Duration scheme with existing R17 PDCCH monitoring adaptation scheme by simulations. It shows additional On-Duration has slightly worse performance results in terms of power saving gain and capacity.

PDCCH skipping is apparently the alternative solution for the additional DRX active time technique. If DRX On Duration timer is configured long enough to cover jitter range, Rel-17 PDCCH skipping can avoid unnecessary power consumption ([OPPO]). [ZTE] pointed out that to avoid delay to potential retransmission scheduling, PDCCH skipping duration needs to be short (e.g., 2, 4ms in the evaluations) which limits the achievable power saving gain. In the meanwhile, companies have proposed to resolve the retransmission interaction with PDCCH skipping issue by cancelling the PDCCH skipping if UE has reported a NACK to gNB. In this sense, additional DRX active time and cancellation of PDCCH skipping for retransmission become two competing solutions.

**Item 2.2-7: Dynamic indication of StartOffset and On Duration**

[Nokia, NSB] proposed to consider L1/L2 signalling and new configurations such as [MinStartOffset, MaxStartOffset], [MinOnDuration, MaxOnDuration] to dynamically change the corresponding DRX parameters to handle the jitter. For Dense Urban, CG, DL Only, 30Mbps, FR1, power saving gain of the proposed technique is -4.3% higher and UE satisfied rate is 7% to 15% higher than CDRX. For Dense Urban, AR/VR, DL Only, 30Mbps, FR1, the proposed technique has 13% power saving gain compared to AlwaysOn with 83% satisfied UE rate (Note: only results with 80% or higher satisfied UE rate are counted) when CDRX has 0% UE satisfied rate.

[ZTE] proposed dynamic indication in WUS to adjust StartOffset to align the CDRX cycle with XR traffic and handle the jitter. For FR1, Dense Urban, VR45M DL only, with [-4,4]ms jitter range, the proposed enhancement has 24.87% PSG with 90.48% satisfied UE rate. With [-8,8]ms jitter range, the proposed enhancement has 20.84% PSG with 86% satisfied UE rate.

[Qualcomm] proposed dynamic adaptation of On Duration start and PDCCH skipping over remaining DRX active time within On Duration or Inactivity Timer. For FR2, DL VR 30Mbps in Indoor Hotspot environment, the proposed solution shows ~30% to ~52% higher power saving gain than periodicity aligned CDRX with >80% satisfied UE rate.

For jitter handling, these proposals assumed that instantaneous jitter value is known by the gNB. Note that in RAN1 #110, a conclusion was made that RAN1 does not assume instantaneous jitter value for a frame is predictable for Rel-18 XR SI power saving study before further input is provided by SA.

### 2.2.3 Discussions

As mentioned in the introduction section, for every proposal or open issue, one of the following decisions is to be made in this meeting

|  |
| --- |
| * **Decision 1**: Deprioritize the issue or proposal in RAN1   + This applies to issue or proposal that is not essential for WI * **Decision 2**: This is a RAN2 issue, leave the study to RAN2.   + This applies to issue (e.g., SFN wrap around mismatch) or proposal that is expected to have performance gain even without being evaluated by RAN1 and it only has RAN2 specification impact * **Decision 3**: Further clarification, justification or evaluation for the issue or proposal is needed in RAN1   + This applies to issue or proposal that should be evaluated but there is no consensus to accept it yet * **Decision 4**: The proposed solution has performance gain, recommend RAN2 to identify the final solution **if necessary** (e.g., semi-static CDRX periodicity alignment)   + This applies to issue or proposal that should be evaluated and evaluation has shown essential performance gain, but the solution only has upper layer specification impact * **Decision 5**: Recommend for Rel-18 XR RAN1 WI (e.g., PDCCH skipping cancellation for retransmission)   + This applies to issue or proposal that has been properly evaluated and is recommended to be specified in PHY specification |

**[RD1]** **Question 2.2-1:** For each Item 2.2-1 to 2.2-7, which decision above do you suggest?

* If there is more than one solution to the Item, please suggest the decision for yourss most preferred solution.

Please provide your views.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | **Item 2.2-1: Wider jitter range**   * **Decision 3** (RAN1 agreed to reuse R17 evaluation assumption; this can be set to be optional if companies see the need to include it)   **Item 2.2-2: Non-uniform PMOs within CDRX On Duration**   * **Decision 3** (How much power saving gain can be achieved compared to R17 PDCCH adaptation?)   **Item 2.2-3: Two-stage CDRX On-Duration**   * **Decision 2** (Seem like a RAN2 mechanism)   **Item 2.2-4: Jitter handling by LP-WUS**   * **Decision 3** (R18 LP-WUS study just kicked off)   **Item 2.2-5: Early stopping of ODT based on expiration of IAT**   * **Decision 2** (Seem like a RAN2 mechanism)   **Item 2.2-6: Additional DRX active time**   * **Decision 2** (Seem like a RAN2 mechanism)   **Item 2.2-7: Dynamic indication of StartOffset and On Duration**   * **Decision 3** (How much power saving gain can be achieved compared to R17 PDCCH adaptation?) |
| Nokia1 | *Item 2.2-1: Wider jitter range*: **Decision 1**: It is not clear whether this is really needed. With the current assumptions for the jitter distribution, the probability of jitter exceeding e.g. 6ms is less than 0.5%, thus it is not clear that it has any significant meaning for the outcome of the evaluations. In any case like already agreed in RAN1#109e, evaluation of other values is not precluded.  *Item 2.2-2: Non-uniform PMOs within CDRX On Duration*: **Decision 1 & 3**; accounting the Rel-17 PDCCH monitoring adaptation, currently supporting max 3 SSSGs, 2 SSSGs and {1,2} skipping durations, and the possibility to dynamically switch the applied SSSGs or skipping via DCI based on actual traffic arrival, it is not clear whether more power saving can be achieved.  *Item 2.2-3: Two-stage CDRX On-Duration*: **Decision 1 & 3**: In terms of power saving, it would seem that Rel-17 PDCCH monitoring adaptation can be used to approximate the same behaviour, thus it is not clear if significantly higher power saving gain can be achieved.  *Item 2.2-4: Jitter handling by LP-WUS*: **Decision 1** (under XR study item): The related study item just started in RAN1, and it is expected that it will take some time before the necessary aspects of LP-WUS (and WUR) are concluded, thus it would seem appropriate to leave this for the corresponding study item.  *Item 2.2-5: Early stopping of ODT based on expiration of IAT*: **Decision 1 & 3**: Based on the agreements made in RAN1#110 under Rel-17 NR UE power saving, the PDCCH skipping will be terminated at the end of Active time. Thus via Rel-17 PDCCH monitoring adaptation, similar behaviour can be achieved from PDCCH monitoring perspective and it is not clear if significantly higher power saving gain can be attained.  *Item 2.2-6: Additional DRX active time*: **Decision 5**: we see that Extending the Active Time (EAT), which allows the network to use shorter onDuration configuration enabling more power efficient operation in most cases.  *Item 2.2-7: Dynamic indication of StartOffset and On Duration*: As noted earlier (in Section 2.1.3 above), our intent was to apply the dynamic adaptation of offset and onDuration to address the drift due to misalignment with CDRX and XR traffic. Hence this was not to address the instantaneous jitter, and as noted earlier, we see that our results should be accounted in afore discussion for CDRX and XR alignment. We did not assume a-priori knowledge of the instantaneous traffic arrival time (or the centre point of jitter range), but a ML algorithm was used to adapt the applied configuration with the help of the dynamic indication. That being said, we also see that there can be also other benefits and use cases for dynamic DRX configuration adaptation e.g. to adjust to/track changes e.g. in long term jitter statistics, thus **Decision 3 & 5** could be considered |
| ZTE, Sanechips | For Item 2.2-1, we suggest to adopt **Decision 3**, to highlight the realistic jitter range can be larger than the ones used in RAN1’s evaluation model.  For Item 2.2-2 , item 2.2-4, item 2.2-7, adopt **Decision 3**,  For Item 2.2-3 ~ item 2.2-5, item 2.2-6, adopt **Decision 4 or Decision 5**.  Moreover, the evaluations and solutions can be informed to RAN2, which can facilitate the ongoing discussion on jitter handling in RAN2. |
| Samsung | **2.2-1: Decision 2** - RAN2 may address through interaction with SA  **2.2-2: Decision 1** - Stop discussion, no need to consider  **2.2-3: Decision 1** – Stop discussion  a) There are simpler equivalent solutions for a 2-stage C-DRX. In any case, RAN2 may further consider and RAN1 can skip discussion.  b) No need to consider SSSG – gNB can do anything based on Rel-17 and sparse-to-dense monitoring will increase latency.  **2.2-4: Decision 1** - Stop discussion. Not in scope - XR is proposed as a use case for evaluation in the LP-WUS SI.  **2.2-5: Decision 1** – Stop discussion. PDCCH skipping can achieve the proposed functionality.  **2.2-6: Decision 1** – Stop discussion. PDCCH skipping can achieve the proposed functionality.  **2.2-7: Decision 1** – Stop discussion. PDCCH skipping together with RRC settings of parameters can achieve the proposed functionality. |
| InterDigital | Item 2.2-1 [Wider jitter range]: **Decision 1**   * Prefer to retain Rel-17 baseline assumption for jitter. Furthermore, the power saving gains expected from considering wider jitter range are not clear.   Item 2.2-2 [Non-uniform PMOs within CDRX On Duration]: **Decision 1**  Item 2.2-3 [Two-stage CDRX On-Duration] **Decision 2**   * Can be left to RAN2 to decide on whether/how to support 2 stage CDRX   Item 2.2-4: Jitter handling by LP-WUS: **Decision 1**   * Can be left to R18 LP-WUS SI and deprioritize discussion in Rel-18 XR SI   Item 2.2-5: Early stopping of ODT based on expiration of IAT: **Decision 3**   * Further clarification in terms of PSG are needed in comparison to Rel-17 PDCCH monitoring adaptation schemes.   Item 2.2-6: Additional DRX active time: **Decision 5 or 2**   * Extension of active time via dynamic signalling can be beneficial for realizing power saving gains in scenarios with variable XR traffic patterns.   Item 2.2-7: Dynamic indication of StartOffset and On Duration: **Decision 5 or 2**   * Dynamic indication to change the StartOffset and OnDuration are useful for addressing issues related to variable XR traffic patterns, where semi-static CDRX configurations/parameters may not align well with the dynamic XR traffic. |

Multiple CDRXs for Multiple Flows

### 2.3.1 Proposals and evaluations

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 5 A single DRX configuration matched to one traffic flow may not fulfill the PDBs of other traffic flows, resulting in a capacity of zero UEs/cell.  Observation 6 Multiple simultaneous DRX configurations, each matching a traffic flow, achieves 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 7 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 8 Adopt multiple simultaneous DRX configurations.  Proposal 9 RAN2 can address the details of the DRX specification changes for supporting multiple DRX configurations.    Figure 2. Illustration of multi-flow DRX with two configurations, each matching a DL traffic flow: the cycle and *drx-onDurationTimer* in green follow the video flow (16.66 ms periodicity) and the DRX configuration in magenta follows the audio flow (10 ms periodicity). The video traffic experiences a random jitter in the range of ±4 ms with a truncated Gaussian distribution around the mean traffic periodicity.  Table 5 Results for multi-flow DRX, for FR1, high load, Dense Urban scenario, and VR multi-stream traffic: DL video (30 fps, 30 Mbps, ±4 ms jitter, 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** | | R1-2208401 | Always On | - | - | - | H | 5 | 5 | 94.0% | - | - | | R1-2208401 | R15/16 DRX  (Long DRX) | 10 | 8 | 4 | H | 5 | 5 | 90.7% | 3.0% | 3.3% | | R1-2208401 | R15/16 DRX  (Short DRX) | 4 | 2 | 4 | H | 5 | 4 | 85.9% | 6.9% | 7.2% | | R1-2208401 | Matched CDRX (with our solution) | 33.3  (*drx\_offset*=3, *traffic\_time\_offset*=1 ms, *drx-LongCycle*=33 ms) | 10 | 4 | H | 5 | 0 | 0% | 18.4% | - | | R1-2208401 | Multi-flow DRX | 33.3 (matched with our solution) | 10 | 4 | H | 5 | 4 | 88.4% | 13.4% | 13.6% | | 10 | 2 | 0 | | R1-2208401 | Multi-flow and two-stage DRX | outer DRX: 33.3 (matched with our solution);  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.*** |
| Intel | ***Proposal 2: RAN1 studies multiple active DRX configurations to support XE media with multiple flows.*** |
| Sony | **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.** |
| 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.*** |
| ETRI | **Proposal 3: To handle multi-flow XR traffic, support multiple DRX configurations within a serving cell (or a DRX group).** |
| NEC | **Proposal 3: Study the enhancement of multiple DRX configurations to better support XR services with multiple traffic flows.** |
| LGE | ***Proposal 7: Study CDRX enhancements for power efficient support of multiple XR traffic flows, including multiple DRX configuration and multi carrier operation.*** |
| Apple | **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.**   **Proposal 1A: *drx-SlotOffset*, *drx-RetransmissionTimerDL*, *drx-RetransmissionTimerUL*, *drx-LongCycleStartOffset*, *drx-HARQ-RTT-TimerDL*, and *drx-HARQ-RTT-TimerUL* are configured commonly among multiple DRX configurations.** |
| Rakuten Symphony | **Proposal 2: Support multiple DRX cycles and independent operation of DRXs.** |
| 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 sending an indication to gNB to request activation of preconfigured CDRX configurations |
| DOCOMO | **Proposal 3: Multiple active CDRX configurations for multiple traffic flows should be further studied in comparing with existing schemes (e.g., WUS, PDCCH skipping and/or SSSG switching).** |

### 2.3.2 Summary of evaluation results

**Item 2.3-1: 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 with cycle aligned with DL video periodicity and the other DRX is configured for the DL audio. As pointed out in the contribution, the proposed solution is mainly helpful when periodicity of the DL video (e.g., 33.33ms at 30fps) is longer than the PDB of the other DL audio traffic flow, for which a single DRX configuration matched to DL video peiodicity cannot meet the PDB requirement for the DL audio. For 60fps DL video, one DRX configuration can serve both DL video and audio well.

For FR1, high load, Dense Urban scenario, and VR multi-stream traffic, power saving gain of the proposed solution is 6.5% to 10.4% higher than that of the Rel-15/16 CDRX with long and short cycles. The proposed solution has a 88.4% satisfied UE rate. Together with two-stage DRX, it has 10% to 13.9% higher power saving gain than the Rel-15/16 CDRX at a 81.8% satisfied UE rate.

In RAN1 #110, some alternative solutions were discussed, such as the following

* One active CDRX for DL video and SPS for DL audio
* CDRX periodicity is set to 16.66ms even when 30fps video is transmitted, use WUS (DCI 2\_6) to skip CDRX On Durations without either video or audio traffic
* gNB configures long On Duration and uses PDCCH skipping to skip PDCCH monitoring between video and audio packets.

### 2.3.3 Discussions

As mentioned in the introduction section, for every proposal or open issue, one of the following decisions is to be made in this meeting.

|  |
| --- |
| * **Decision 1**: Deprioritize the issue or proposal in RAN1   + This applies to issue or proposal that is not essential for WI * **Decision 2**: This is a RAN2 issue, leave the study to RAN2.   + This applies to issue (e.g., SFN wrap around mismatch) or proposal that is expected to have performance gain even without being evaluated by RAN1 and it only has RAN2 specification impact * **Decision 3**: Further clarification, justification or evaluation for the issue or proposal is needed in RAN1   + This applies to issue or proposal that should be evaluated but there is no consensus to accept it yet * **Decision 4**: The proposed solution has performance gain, recommend RAN2 to identify the final solution **if necessary** (e.g., semi-static CDRX periodicity alignment)   + This applies to issue or proposal that should be evaluated and evaluation has shown essential performance gain, but the solution only has upper layer specification impact * **Decision 5**: Recommend for Rel-18 XR RAN1 WI (e.g., PDCCH skipping cancellation for retransmission)   + This applies to issue or proposal that has been properly evaluated and is recommended to be specified in PHY specification |

In RAN1 #110, the main debating point was whether there is existing alternative solution that can serve the multi-flow XR traffic. In this meeting, the discussion will continue along this line for multiple CDRX configurations.

**[RD1]** **Question 2.3-1:** For the proposed multiple CDRX configurations, which decision above do you suggest?

Please provide your views.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | **Decision 2** (Seem like a RAN2 mechanism) |
| Nokia1 | **Decision 2 & 3**: From UE power saving perspective it is not clear if further benefit can be attained on top of aligned CRDX and XR together with Rel-16/17 PDCCH monitoring enhancements. |
| ZTE, Sanechips | For multiple CDRX configurations, it looks like a RAN2 issue, but as an alternative for serving multiple flows, the solution in this case was discussed and evaluated in RAN1. Thus we think **Decision 3** is proper, and companies can justify the power saving gain against other alternatives if any. |
| Samsung | **Decision 2** – RAN2 issue. |
| InterDigital | **Decision 5**  Our contribution in [27] R1-2209657 provides evaluation results on multiple active CDRX configurations. In [27] mean power saving gains of 12.52% are shown when using 2 CDRX configurations for video and audio traffic flows compared to using a single CDRX configuration. We would like to suggest to the moderator to capture our results in the discussion. |

Dynamic Adjustment of CDRX to Data or Frame Rate

### 2.4.1 Proposals

Proposals in this subsection correspond to the low priority Issue 1-4 identified in RAN1 #109-e meeting. No evaluation result was provided by any company for these proposals.

* 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 without evaluation results for dynamic adjustment of CDRX**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Ericsson | Proposal 1 Do not study further any L1 and L2 solutions for which there are no evaluation results based on the agreed simulation methodology.  Proposal 2 Prioritize power saving enhancements based on semi-static configurations.  Proposal 3 Deprioritize issues 1-4, 2-1, 2-2 from power saving study of Rel-18 XR SI. |
| InterDigital | **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  **Proposal 6:** Support UE sending an indication to gNB to request dynamic adaptation to CDRX parameters (e.g. ON duration, start offset) for receiving DL traffic |
| III | **Proposal#2:** **We should wait for SA’s further explanation about the variable frame rate. Without this explanation, there is no need of further discussion about this issue.** |

Low Latency Handling

### 2.5.1 Proposals

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 8: Proposals without evaluation results on low latency handling**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Apple | **Proposal 3: to achieve UE power saving:**   * **The following DRX timers can be configured in a SPS configuration specific fashion:**   + **drx-HARQ-RTT-TimerDL/drx-RetransmissionTimerDL .** * **The following DRX timers can be configured in a CG configuration specific fashion:**   + **specific drx-HARQ-RTT-TimerU/drx-RetransmissionTimerUL.** * **DRX timer initial values can be different for different HARQ processes.**    + **For DL, the DRX timer initial values can be dynamically signaled:**     - **drx-HARQ-RTT-TimerDL**     - **drx-RetransmissionTimerDL**   + **For UL, the DRX timer initial values can be dynamically signaled:**     - **drx-HARQ-RTT-TimerUL**     - **drx-RetransmissionTimerUL** * **Except for cases with SPS configuration specific/CG configuration specific/dynamically indicated initial timer values, the initial timer values provided in DRX-Config are used.** |

Other CDRX Enhancements

### 2.6.1 Proposals

This subsection captures new proposals submitted in this meeting. No evaluation was provided by companies.

**Table 9: Proposals on the other CDRX enhancements without evaluation results**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Huawei, HiSilicon | ***Observation 3: When UE is configured to transmit multiple PUSCHs within a CG period, the existing C-DRX mechanism for handling UL retransmission is not efficient in terms of power saving, because UE will start*** ***drx-RetransmissionTimerUL after each PUSCH transmission and will be in active time for a long time.***  ***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.***  ***Proposal 5: Further study C-DRX enhancements to save power when UE is configured to transmit multiple PUSCHs, e.g., only start the drx-RetransmissionTimerUL for the last PUSCH.*** |
| 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.*** |
| Qualcomm | ***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

### 3.1.1 Proposals

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.

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

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Ericsson | Proposal 1 Do not study further any L1 and L2 solutions for which there are no evaluation results based on the agreed simulation methodology.  Proposal 2 Prioritize power saving enhancements based on semi-static configurations.  Proposal 3 Deprioritize issues 1-4, 2-1, 2-2 from power saving study of Rel-18 XR SI. |
| 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.*** |
| Lenovo | **Proposal 6: For DCI format 2\_6, study if PDCCH monitoring can be aligned with XR traffic/DRX pattern.**   * **If PDCCH is to be monitored according to periodic search spaces, discuss if any enhancement to determine the PDCCH monitoring window is needed.** |
| NEC | **Proposal 7: Specify XR specific PDCCH monitoring offset parameters such as k(µ) in Search Space Set configuration.**  **Proposal 8: Specify a higher layer parameter of ‘frame per second’ for the frame rate of XR traffic.** |
| LGE | ***Proposal 8: Alignment between PDCCH monitoring and XR traffic should be discussed under CDRX enhancements.*** |

XR-dedicated PDCCH Monitoring Window

### 3.2.1 Proposals and evaluations

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 11: 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.**  **Proposal 7：The dynamic XR-dedicated PDCCH monitoring scheme customized the PDCCH monitoring control matching XR traffic generation and disassociate the PDCCH monitoring control by C-DRX is the feasible solution for C-DRX enhancement and does not have impact to the delay insensitive traffic arrival compared to the pre-configured non-uniform DRX cycles.**  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 non-scheduling DCI for persistent PDCCH skipping indication)** | 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. UE can be indicated by non-scheduling DCI to skip the indicated interval of PDCCH monitoring occasions; | | **XR-PMW scheme 3**  **(XR-PMW with go-to-sleep):** | UE is configured with the XR-PMW. When traffic transmission is completed, UE would be indicated to go to sleep until the next XR-PMW cycle. | | **XR-PMW scheme 4**  **(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 and MU-MIMO scheduling   |  |  |  |  | | --- | --- | --- | --- | | Evaluation Schemes | #satisfied UEs per cell | % of satisfied UEs | Power Saving Gain (PSG) | | Baseline: DG scheduling and UE always-on | 11.5 | 95.8% | 0.0% | | DG scheduling with C-DRX(16,12,4) | 10.8 | 90.0% | 8.0% | | XR-PMW scheme 1:  XR-PMW (16,12) | 10.8 | 90.0% | 11.7% | | XR-PWM scheme 2:  XR-PMW with non-scheduling PDCCH skipping indication | 10.7 | 89.7% | 22.4% | | XR-PMW scheme 3:  XR-PMW (16,12) with go-to-sleep | 10.8 | 90.0% | 24.0% | | XR-PMW scheme 4:  XR-PMW (16,12)  with PDCCH skipping and go-to-sleep | 10.7 | 89.7% | 29.4% |   Table 6: The performance comparison between and C-DRX (16, 12, 4) XR-PMW with PDCCH skipping and go-to-sleep and MU-MIMO scheduling   |  |  |  |  | | --- | --- | --- | --- | | Evaluation Schemes | #satisfied UEs per cell | % of satisfied UEs | Power Saving Gain (PSG) | | DG scheduling with C-DRX(16,12,4) and Rel-17 PDCCH skipping scheme | 10.8 | 90.0% | 0.0% | | XR-PWM scheme 1:  XR-PMW with (16,12) | 10.8 | 90.0% | 3.8% | | XR-PWM scheme 2:  XR-PMW with non-scheduling PDCCH skipping indication | 10.7 | 89.7% | 15.7% | | XR-PWM scheme 3:  XR-PMW with go-to-sleep | 10.8 | 90.0% | 17.4% | | XR-PWM scheme 4:  XR-PMW  with PDCCH skipping and go-to-sleep | 10.7 | 89.7% | 23.3% |   **Observation 3: 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 11.7%~29.4% PSG compared to that of the UE always-on for DG scheduling.**  **Observation 4: Under the similar capacity performance, he XR-PMW could obtain the less than 10% capacity performance gap than that of the UE always-on for DG scheduling and obtain 15.7%~223.3% PSG compared to that of DG scheduling with C-DRX(16,12,4) and Rel-17 PDCCH skipping scheme.**  **Proposal 8: The XR-dedicated PDCCH monitoring window should be supported for XR UE power saving due to the advantages that it doesn't affect other data services and is achievable.**    Figure 4: Illustration of enhanced SPS with PDCCH skipping and go-to-sleep.  **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 multiple 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 12: Proposals without evaluation results on XR-dedicated PDCCH monitoring Window**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Ericsson | Proposal 1 Do not study further any L1 and L2 solutions for which there are no evaluation results based on the agreed simulation methodology.  Proposal 2 Prioritize power saving enhancements based on semi-static configurations.  Proposal 3 Deprioritize issues 1-4, 2-1, 2-2 from power saving study of Rel-18 XR SI. |
| Qualcomm | ***Proposal 12: For XR, consider studying a configuration of multiple time windows that have different configurations for messages, signals, and/or operations, where switching between windows can be configured, dynamic, or implicit.*** |

### 3.2.2 Summary of evaluation results

**Item 3.2-1: XR-dedicated PDCCH monitoring window**

[CATT] proposed to introduce the XR-dedicated PDCCH monitoring window when DRX is configured. Network configures the XR-dedicated PDCCH monitoring windows for XR service and CDRX for the other services. The UE monitors PDCCH in the XR-dedicated PDCCH monitoring window both within and outside the DRX active time. This solution and the multiple DRX configurations are two competing solutions with similar design purpose.

It is noticed that only DL traffic with a single stream is evaluated (see attached Excel sheet) though the proposed solution intends to serve multiple traffic flows. Evaluation results show that with negligible capacity loss, the XR-dedicated window with non-scheduling DCI based PDCCH skipping, go-to-sleep and go-to-sleep can obtain 15.7%~23.3% power saving gain w.r.t. CDRX (16,12,4) with Rel-17 PDCCH skipping. As mentioned in the paper, periodicity of the XR-dedicated search space is aligned with the mean XR traffic inter-arrival time, e.g., 16.67ms. While the CDRX (16,12,4) performance reference has a periodicity misalignment with XR video traffic. This could be the main contributor to the power saving gain of the proposed solution.

**Item 3.2-2: Wakeup timing based on SPS occasions**

[CATT] proposed to use the enhanced SPS to determine the wakeup timeline for XR-dedicated PDCCH monitoring window in both DRX ON and OFF. This is an alternative (i.e., via indirect configuration) solution to configure the periodicity and start offset of the XR-dedicated PDCCH monitoring window. Evaluation results showed that the SPS enhancement obtains 9.9% to 38.1% power saving gain compared to that of DG scheduling with CDRX (16,12,4). It is unclear why this solution can obtain higher power saving (i.e., up to 38.1%) than the basic XR-dedicated PDCCH monitoring window solution (i.e., up to 23.3%) given that the UE always consumes extra power for SPS PDSCH monitoring (and may end up without decoding a PDSCH due to jitter) before every XR traffic data arrival.

### 3.2.3 Discussions

As mentioned in the introduction section, for every proposal or open issue, one of the following decisions is to be made in this meeting.

|  |
| --- |
| * **Decision 1**: Deprioritize the issue or proposal in RAN1   + This applies to issue or proposal that is not essential for WI * **Decision 2**: This is a RAN2 issue, leave the study to RAN2.   + This applies to issue (e.g., SFN wrap around mismatch) or proposal that is expected to have performance gain even without being evaluated by RAN1 and it only has RAN2 specification impact * **Decision 3**: Further clarification, justification or evaluation for the issue or proposal is needed in RAN1   + This applies to issue or proposal that should be evaluated but there is no consensus to accept it yet * **Decision 4**: The proposed solution has performance gain, recommend RAN2 to identify the final solution **if necessary** (e.g., semi-static CDRX periodicity alignment)   + This applies to issue or proposal that should be evaluated and evaluation has shown essential performance gain, but the solution only has upper layer specification impact * **Decision 5**: Recommend for Rel-18 XR RAN1 WI (e.g., PDCCH skipping cancellation for retransmission)   + This applies to issue or proposal that has been properly evaluated and is recommended to be specified in PHY specification |

**[RD1]** **Question 3.2-1:** For the proposed solutions under Item 3.2-1 and 3.2.-2, which decision above do you suggest?

Please provide your views if necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | **Item 3.2-1: XR-dedicated PDCCH monitoring window**   * **Decision 3** (The mechanism seems orchestrated but also a little complicated; may need more input from more than one company)   **Item 3.2-2: Wakeup timing based on SPS occasions**   * **Decision 3** (The mechanism seems orchestrated but also a little complicated; may need more input from more than one company) |
| Nokia1 | *Item 3.2-1/2*: **Decision 1& 3**: This would appear similar as multiple (concurrent) CDRX configurations together with XR specific RNTI. Also it is not clear what part of the gain is due to multiple windows and which part due to CRDX and XR alignment. |
| ZTE,  Sanechips | For item 3.2-1, we suggest to adopt **Decision 3**, it should be clarified whether or not this solution is intented to multiple traffic flows; if the answer is yes, we can consider it as another alternative in section 2.3.  For item 3.2-2, we think it should be clarified whether item 3.2-2 refers to some details of configuration of XR-dedicated PDCCH monitoring window. And the SPS occasions in this case should be clarified to further address the moderator’s question. |
| Samsung | **Decision 1** |
| InterDigital | **Decision 1** |

Enhancements to PDCCH Monitoring Adaptation

### 3.3.1 Proposals and evaluations

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

|  |  |
| --- | --- |
| **Company** | **Proposals and evaluation results** |
| vivo | **Observation 10: The existing R17 PDCCH skipping indication will cause either capacity loss or unnecessary PDCCH monitoring.**    **Figure 8. Potential network implementation of PDCCH skipping indication using Rel-17 specification**    **Figure 9. Example of PDCCH skipping and interaction with HARQ retransmission**    **Figure 10. Power saving gain of VR/AR 30Mbps in InH scenario**    **Figure 11. System capacity of VR/AR 30Mbps in InH scenario**    **Figure 12. System capacity of VR/AR 30Mbps in InH scenario**  **Observation 11: Compared with the existing R17 PDCCH skipping indication, the enhanced PDCCH skipping with HARQ interaction provides good balance between power saving gain and system capacity.**  **Proposal 4: Support the PDCCH skipping with HARQ retransmission interaction by the following solutions:**   * **Solution 1: If there is any NACK feedback during the skipping duration, UE is required to resume the PDCCH monitoring for corresponding retransmission within the *drx-retransmissiontimer*.** * **Solution 1-1: On top of solution 1, the network can dynamically enable or disable the HARQ interaction for the indicated PDCCH skipping, according to the remaining PDB, the importance of the transmission or the probability of decoding failure (e.g. link quality).**   **Observation 12: By adopting the schemes of both PDCCH skipping interaction with HARQ retransmission and LP-WUS jitter handling, 40.08%~43.84% and 36.07%~38.47% total power saving gains can be obtained in low load and high load, respectively, and without capacity loss.**  **Proposal 5: Capture the above text proposal into R18 XR TR 38.835.**  **Table I. Power consumption results in FR1 DL Indoor Hotspot with 30Mbps traffic model**   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **Power saving scheme** | **DRX configuration**  **(Cycle\_ODT\_IAT 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 | 16.67\_8\_4 | 5 | 10 | 100% | 13.05% | Note1 | | R17 PDCCH monitoring adaptation | 16.67\_8\_4 | 5 | 10 | 100% | 23.36% | Note1,8 | | 16.67\_8\_4 | 5 | 10 | 100% | 18.73% | Note2,8 | | 16.67\_8\_4 | 5 | 10 | 100% | 14.64% | Note3,8 | | 16.67\_8\_4 | 5 | 10 | 100% | 11.44% | Note4,8 | | LP-WUS scheme | 16.67\_8\_4 | 5 | 10 | 100% | 30.21% | Note1,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 28.89% | Note2,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 28.29% | Note3,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 29.23% | Note4,5,8,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 43.84% | Note1,6,9 | | 16.67\_8\_4 | 5 | 10 | 100% | 40.08% | Note3,6,9 | | Enhanced PDCCH skipping with HARQ interaction | 16.67\_8\_4 | 5 | 10 | 100% | 37.13% | Note1,7 | | 16.67\_8\_4 | 5 | 10 | 100% | 26.98% | Note3,7 | | AlwaysOn | - | 10 | 10 | 92.50% | - | Note1 | | - | 10 | 10 | 97.45% | - | Note1,12 | | - | 10 | 10 | 93.12% | - | Note1,11 | | - | 10 | 10 | 97.45% | - | Note1,11,12 | | 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 | 16.67\_8\_4 | 10 | 10 | 92.22% | 19.28% | Note1,8 | | 16.67\_8\_4 | 10 | 10 | 92.16% | 14.96% | Note2,8 | | 16.67\_8\_4 | 10 | 10 | 91.01% | 10.98% | Note3,8 | | 16.67\_8\_4 | 10 | 10 | 91.01% | 8.94% | Note4,8 | | 16.67\_8\_4 | 10 | 10 | 97.45% | 19.28% | Note1,8,12 | | 16.67\_8\_4 | 10 | 10 | 92.78% | 19.48% | Note1,8,11 | | 16.67\_8\_4 | 10 | 10 | 97.45% | 19.48% | Note1,8,11,12 | | 16.67\_8\_4 | 10 | 10 | 1.11% | 35.21% | Note1,10 | | 16.67\_8\_4 | 10 | 10 | 2.22% | 35.21% | Note1,10,12 | | 16.67\_8\_4 | 10 | 10 | 2.08% | 32.77% | Note1,10,11 | | 16.67\_8\_4 | 10 | 10 | 94.91% | 32.77% | Note1,10,11,12 | | LP-WUS scheme | 16.67\_8\_4 | 10 | 10 | 92.22% | 25.10% | Note1,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 92.20% | 24.08% | Note2,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 91.11% | 24.11% | Note3,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 91.11% | 25.93% | Note4,5,8,9 | | 16.67\_8\_4 | 10 | 10 | 92.22% | 38.47% | Note1,6,9 | | 16.67\_8\_4 | 10 | 10 | 92.10% | 36.07% | Note3,6,9 | | Enhanced PDCCH skipping with HARQ interaction | 16.67\_8\_4 | 10 | 10 | 92.22% | 32.18% | Note1,7 | | 16.67\_8\_4 | 10 | 10 | 92.20% | 22.93% | Note3,7 | | 16.67\_8\_4 | 10 | 10 | 97.45% | 32.18% | Note1,7,12 | | 16.67\_8\_4 | 10 | 10 | 92.78% | 32.49% | Note1,7,11 | | 16.67\_8\_4 | 10 | 10 | 97.45% | 32.49% | Note1,7,11,12 | | Note1: jitter range = [-4, +4]ms  Note2: jitter range = [-6, +6]ms  Note3: jitter range = [-8, +8]ms  Note4: jitter range = [-10, +10]ms  Note5: with R17 PDCCH skipping indication  Note6: with R17 PDCCH skipping indication and interaction with HARQ retransmission  Note7: based on SSSG switching (doing PDCCH monitoring every 2 slots in sparse SSSG before data arrive) and R17 PDCCH skipping  Note 8: PDCCH skipping is indicated in the DCI that schedules a dummy PDSCH after all the HARQ-ACK processes of transmissions have been completed  Note 9: The total relative power for LP-WUS monitoring is 45  Note10: PDCCH skipping is indicated in the DCI scheduling the initial PDSCH transmission  Note11: initial BLER = 1%  Note12: X = 95 | | | | | | | |
| 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.***    Figure 1 Power saving gain results by SLS for retransmission aware PDCCH skipping  ***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.***  ***Observation 5: In one way, NW can handle the retransmission issue by applying a low MCS for last data scheduling to ensure a correct decoding while this comes with resource efficiency cost as the network needs to aim for a very low BLER target using a single shot transmission.***    **Figure 3 Resource impact of robust MCS for last data scheduling to ensure a correct decoding**  ***Observation 6: Figure 3 (using Formula (1) below) shows that the robust MCS scheme for last data scheduling to ensure a correct decoding can consume 1.72 times to 7.31 times of resources with MCS 0 to MCS 5, which is a large overhead for XR application.***  **The resource impact is modelled by the following formula:**  **where**   * **𝑠: number of scheduled data transmissions (segments) for one frame, s = 1, 2, 3, ….** * **: probability of one frame is transmitted by 𝑠 scheduled data transmissions (segments)**   + **The value of 𝑠 and are derived from SLS results as shown in Figure 2** * **: The spectral efficiency (SE) from MCS index table 5.1.3.1-1 and 5.1.3.1-2 in 38.214 [3], using the MCS calculated by gNB channel based on link adaptation algorithm in SLS** * **: The SE from MCS index table 5.1.3.1-1 and 5.1.3.1-2 in 38.214 [3], using a low MCS 0 to 5** |
| Huawei, HiSilicon | Figure 8 Illustration of the flexible duration of PDCCH skipping  ***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 4 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% | |
| xiaomi | **Table 3: Summary of metrics**   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | Total  Energy | 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% |   ***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.*** |
| Ericsson | Table 6 Results for enhanced PDCCH skipping, for FR1, high and low load, Dense Urban scenario, and VR multi-stream traffic: DL video (60 fps, 30 Mbps, ±4 ms jitter, 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** | | R1-2208401 | Always On | - | - | - | H | 8 | 8 | 90.1% | - | - | | R1-2208401 | R17 PDCCH skipping & matched CDRX | 16.6 (matched with our solution) | 10 | 4 | H | 8 | 6 | 72.2% | 10.5% | 10.4% | | R1-2208401 | Enhanced PDCCH skipping & matched CDRX | 16.6 (matched with our solution) | 10 | 4 | H | 8 | 6 | 72.4% | 10.5% | 10.5% | | R1-2208401 | R17 PDCCH skipping & matched CDRX | 16.6 (matched with our solution) | 10 | 4 | L | 2 | - | 96.6% | 11.2% | 11.9% | | R1-2208401 | Enhanced PDCCH skipping & matched CDRX | 16.6 (matched with our solution) | 10 | 4 | L | 2 | - | 97.3% | 11.2% | 12.0% |   Observation 8 Enhancing PDCCH skipping to support more skipping durations does not outperform R17 PDCCH skipping with two skipping values.  Proposal 11 Do not introduce larger duration sets that PDCCH skipping indication selects from.  Proposal 12 Do not prioritize further enhancements of PDCCH skipping beyond those in R17. |
| 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.**    Figure 1: The procedure of the PDCCH skipping with 2 bits indication in non-scheduling DCI  **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.**  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) with Rel-17 PDCCH skipping scheme** | When the XR packet transmission is completed, UE would be indicated by scheduling DCI to skip an interval of PDCCH skipping and return to normal PDCCH monitoring afterward. | | **PDCCH skipping enhancement scheme 1**  **(non-scheduling and scheduling DCI with persistent skipping indication)** | UE can be indicated by both scheduling and non-scheduling DCI to skip the indicated interval of PDCCH monitoring occasions persistently. The skipping duration is persistent without termination of PDCCH skipping until a new skipping indication is received. | | **PDCCH skipping enhancement scheme 2**  **(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 3**  **(**C**ontinuous PDCCH skipping and dynamic go-to-sleep indication)** | 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 sleep state. |   **Proposal 4: The go-to-sleep indication should be enhanced to be jointly configured with PDCCH skipping indication in the XR-specific DCI for fast transition to the sleep state PDCCH skipping enhancement schemes.**  Table 2: Evaluation results of PDCCH skipping schemes compared to always-on with MU-MIMO scheduling   |  |  |  |  | | --- | --- | --- | --- | | PDCCH monitoring Schemes | Considered UE set | Mean PSG compared to always-on | #satisfied UEs per cell | | Baseline 1: Always-on | - | - | 11.5 | | PDCCH skipping enhancement scheme 1  (non-scheduling and scheduling DCI with persistent skipping indication) | All UEs | 22.4% | 10.7 | | Satisfied UEs | 22.4% | | PDCCH skipping enhancement scheme 2  (go-to-sleep) | All UEs | 24.0% | 10.8 | | Satisfied UEs | 24.4% | | PDCCH skipping enhancement scheme 3  (Continuous PDCCH skipping and dynamic go-to-sleep indication) | All UEs | 29.4% | 10.7 | | Satisfied UEs | 29.9% |   Table 3: Evaluation results of PDCCH skipping schemes compared to C-DRX(16,12,4) with Rel-17 PDCCH skipping scheme and MU-MIMO scheduling   |  |  |  |  | | --- | --- | --- | --- | | Schemes | Considered UE set | Mean PSG compared to C-DRX(16,12,4) | #satisfied UEs per cell | | Baseline: C-DRX(16,12,4) with Rel-17 PDCCH skipping scheme | - | - | 10.8 | | PDCCH skipping enhancement scheme 1  (non-scheduling and scheduling DCI with persistent skipping indication) | All UEs | 15.7% | 10.7 | | Satisfied UEs | 15.7% | | PDCCH skipping enhancement scheme 1  (go-to-sleep) | All UEs | 17.4% | 10.8 | | Satisfied UEs | 17.8% | | PDCCH skipping enhancement scheme 2  (Continuous PDCCH skipping and dynamic go-to-sleep indication) | All UEs | 23.3% | 10.7 | | Satisfied UEs | 23.8% |   **Observation 1: The enhanced PDCCH schemes including: non-scheduling DCI based PDCCH skipping, go-to-sleep indication and continuous PDCCH skipping and go-to-sleep indication can obtain 22.4%~29.9% power saving gain with negligible capacity degradation compared with Always-on.**  **Observation 2: The enhanced PDCCH schemes including: non-scheduling DCI based PDCCH skipping, go-to-sleep indication and continuous PDCCH skipping and go-to-sleep indication can obtain 15.7%~23.8% power saving gain with negligible capacity degradation compared with C-DRX(16,12,4) with Rel-17 PDCCH skipping scheme.** |
| Nokia, NSB | **Observation 10**: *PDCCH monitoring adaptation via SSSG switching allows for significant power saving at the expenses of a capacity decrease.*  **Observation 11:** *Using DCI 2\_6 outside the C\_DRX active time to adapt the SSSG monitoring has the potential to mitigate the capacity loss without heavily compromising the power saving.*  **Observation 12:** *When using PDCCH monitoring adaptation via SSSG switching, the best capacity and power saving tradeoff was observed when configuring SSSG0 with ks=2 and SSSG1 with ks=1.*  **Proposal 5**: Adopt *DCI 2\_6 outside the C\_DRX active time* to trigger SSSG switching for PDCCH monitoring adaptation.   |  |  | | --- | --- | | *(a)* | *(b)* |   Figure 11 – Capacity and power saving gain evaluation of C-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, 4}, and SSSG1 with ks=1. |
| Qualcomm | Graphical user interface, text, application  Description automatically generated  Figure 13: CG transmission triggers PDCCH monitoring for potential retransmission.  ***Observation 16: 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.***  ***Observation 17: 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.***  ***Observation 18: The retransmission-less CG can be realized if***   * ***extend the Rel-17 NTN uplink HARQ Mode feature to TN and redefine “uplink-Harq-ModeB” in the way that no retransmission is expected from network after the first CG PUSCH transmission from the UE, or*** * ***configure zero value for the configuredGrantTimer or omit the configuredGrantTimer to indicate the retransmission-less CG***   ***Proposal 9: Support the transmission-less CG for XR UL pose/control information transmission so that UE is not required to monitor PDCCH for scheduling retransmission. Recommend RAN2 to specify a solution.***  ***Proposal 10: Adopt the text proposal in Section 4.1 to TR 38.835 v0.1.1 for retransmission-less CG.***  Table 8 Retransmission-less CG, 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 | | | | | | | | | |

**Table 14: Proposals without evaluation results on PDCCH monitoring adaptation**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Ericsson | Proposal 10 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. |
| Huawei, HiSilicon | ***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.***  ***Proposal 8: For DL retransmission handling during PDCCH skipping, UE terminates PDCCH skipping if UE sends NACK.***  ***Proposal 9: For UL retransmission handling during PDCCH skipping, no special enhancement is needed, i.e., leave it to gNB implementation.*** |
| 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.*** |
| CATT | **Proposal 5: The adaptation indication for PDCCH skipping should be separately between XR and other indicated to avoid different services latency requirements.** |
| TCL | ***Proposal 2: Whether to skip the DRX re-transmission timer of UL data or not can be studied.***  ***Proposal 3: An additional PDCCH monitor occasions can be configured for XR on DRX-OFF state.***  ***Proposal 5: PDCCH monitoring adaptation can be considered for XR power saving.*** |
| 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.*** |
| Sony | **Proposal 5 – For DCI candidates with scheduling or common format to be monitored at the beginning of DRX ON, explicit indication by WUS DCI can be considered for power saving.**  **Proposal 6 - Adding DCI linkage information in DCI can provide significant power saving gain and no impact to other XR performance metric.** |
| Lenovo | **Proposal 4: Study impact of PDUs/PDU set dropping on DRX timers (including drx-InactivityTimer, drx-RetransmissionTimerDL, drx-RetransmissionTimerUL).**  **Proposal 5: If PDCCH monitoring can be skipped while *drx-RetransmissionTimerDL/UL* is running, study if overhead and power saving degradation due to sending multiple PDCCH skipping commands within an on-duration of a DRX cycle duration can be of concern.**   * **If such overhead and power saving degradation are of concern, study benefits of selecting a skipping duration from a larger set of RRC configured skipping durations to accommodate XR traffic jitter or varying video frame size.** |
| Xiaomi | ***Proposal 6: The feature that multiple PDSCH/PUSCH scheduling by a single DCI should also be allowed to apply in FR1.*** |
| CMCC | **Proposal 4. PDCCH skipping can be considered to be applied when C-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., repurposing some fields in DL/UL grant.** |
| ETRI | **Proposal 4: Further study the PDCCH monitoring enhancement for DL/UL retransmission during the Rel-17 PDCCH skipping duration.** |
| 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.** |
| LGE | ***Proposal 9: XR-dedicated PDCCH monitoring window should be considered under CDRX enhancement for multiple XR flows.***  ***Proposal 10: Consider WUS outside DRX Active Time as well as the DCI inside DRX Active Time as a candidate for indicating the PDCCH monitoring adaptation.***  ***Proposal 11: Consider SPS enhancement within DRX Active Time for XR UE power saving.***  ***Proposal 12: Consider that a UE monitor PDCCH for retransmission scheduling even if a UE is in skipping duration.***  ***Proposal 13: Consider more PDCCH skipping durations with CDRX enhancement for XR.***  ***Proposal 14: Consider enhancements on PDCCH monitoring adaptation in connected mode to mimic the CDRX function for a UE not being configured with the CDRX.***  ***Proposal 15: 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.*** |
| Rakuten Symphony | **Proposal 3: Study extending the Rel-17 PDCCH skipping mechanism to support multiple DRX cycles.**  **Proposal 5: Study varying search space sparsity in ON duration.** |
| Google | **Proposal 7: Support the use of non-scheduling DCI format to trigger the PDCCH skipping.**  **Proposal 8: Define new configurable PDCCH skipping durations in the range xr\_periodicity +/- jitter\_range.**  **Proposal 9: PDCCH skipping should operate efficiently when the UE is configured or not with C-DRX**  **Proposal 10: Define new configurable SSSG switching timers in the range xr\_periodicity +/- jitter\_range.**  **Proposal 11: Support Single DCI scheduling multi-PDSCHs/PUSCHs in TDD mode for DCI monitoring power saving.** |
| 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 |
| Samsung | **Proposal 1: Support canceling PDCCH skipping when a UE provides NACK for a TB scheduled by a DCI format that indicates PDCCH skipping.**  **Proposal 2: Support canceling P/SP SRS/CSI transmissions during slots of PDCCH skipping.**  **Proposal 3: Enable disabling of HARQ retransmissions for a CG-PUSCH configuration.** |
| DOCOMO | **Proposal 4: Rel-17 PDCCH monitoring adaptation can be baseline for Rel-18 PDCCH monitoring enhancements.**  **Proposal 5: Study PDCCH skipping enhancements triggered by non-scheduling DCI.** |
| Qualcomm | **Proposal 11: 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)** |
| III | **Proposal#3: Any NACK transmission which occurs within a PDCCH Skipping duration should result in the termination of this skipping. In addition, PDCCH monitoring with a predefined duration should restart right away.** |

### 3.3.2 Summary of evaluation results

**Item 3.3-1: PDCCH skipping and interaction with HARQ retransmission**

Please note RAN1 #110 concluded that this issue will not be further discussed for Rel-17 power saving maintenance.

[vivo] proposed that if there is NACK feedback during the skipping duration, UE resumes PDCCH monitoring to receive corresponding retransmission scheduling within the *drx-retransmissiontimer*. Additionally, network can dynamically enable or disable this mechanism for the indicated PDCCH skipping, e.g., according to the remaining PDB etc. The proposed solution is compared with Rel-17 PDCCH skipping, PDCCH skipping indicated by non-scheduling DCI and AlwaysOn for different combinations of target BLER (1%, 10%) and required percentage of successful packets (99%, 95%). Evaluation shows the proposed solution has a power saving gain close to that of Rel-17 PDCCH skipping which is higher than the non-scheduling DCI and capacity close to the AlwaysOn scheme.

[MediaTek] proposed that after the UE is indicated to skip PDCCH monitoring, if any NACK is transmitted or if UL data is transmitted, the UE resumes PDCCH monitoring for a configured duration. As a result, longer PDCCH skipping duration can be indicated without impacting the potential retransmission and higher overall power saving gain can be achieved. It shows 20.78%~27.97% power saving gain with higher UE satisfied rate w.r.t Rel-17 PDCCH skipping.

As discussed under “Item 2.2-6: Additional DRX active time” for CDRX jitter handling, the resuming PDCCH monitoring during PDCCH skipping solution and the additional CDRX active time solution are two competing solutions when CDRX is configured. (Resuming PDCCH monitoring after PDCCH skipping starts also applies when CDRX is not configured.)

**Item 3.3-2: Enhancements to PDCCH skipping duration**

Note that in RAN1 #100, it was agreed that UE terminates PDCCH skipping outside DRX active time. According to this agreement, UE does not monitor PDCCH until next On Duration start if the PDCCH skipping duration covers remaining DRX active time.

[Huawei, HiSilicon] proposed the adaptive PDCCH skipping duration until the earliest possible arrival time of the next frame to maximize the seamless PDCCH skipping duration. When CDRX is not configured, power saving gain of the proposed solution is 6.23% to 7.2% higher than that of the Rel-17 PDCCH skipping with three PDCCH skipping durations with both having similar UE satisfied ratio.

[Xiaomi] proposed to adopt four PDCCH skipping durations (e.g., 6/8/10/12ms). Compared with two durations (e.g., 8/10ms), when CDRX is not configured, four durations have 6% more power saving gain and 1.5% more satisfied UE rate.

Regarding [Huawei] and [Xiaomi]’s proposals, PDCCH skipping should be supported when CDRX is not configured. The question is – is there a need to further enhance PDCCH skipping when CDRX is not configured?

[Ericsson] compared two cases when CDRX is configured: i) Rel-17 PDCCH skipping with two durations only; ii) enhanced PDCCH skipping with arbitrary skipping duration covering the remaining DRX active time. The arbitrary skipping duration is used as a genie performance reference. Evaluation results show the genie reference has negligible power saving or capacity gain compared with PDCCH skipping with two durations. This implies two durations are nearly optimal. As a result, there is no need to introduce larger duration sets that PDCCH skipping indication selects from.

[CATT] proposed to enhance PDCCH skipping by introducing the go-to-sleep indication for fast transition to the sleep state. Similar to the DRX Command MAC CE,the go-to-sleep PDCCH terminates UE DRX active time immediately. This corresponds to the “arbitrary skipping duration” used by [Ericsson] as genie reference and the “adaptive PDCCH skipping duration” by [Huawei] if DRX is configured. Evaluation results show that the go-to-sleep indication has a 17.4% higher power saving gain than CDRX with Rel-17 PDCCH skipping with both having the same UE satisfied rate. This is different than the observation from [Ericsson] that Rel-17 PDCCH skipping has almost same power saving gain as that of genie performance.

**Item 3.3-3: Non-scheduling DCI based PDCCH skipping and continuous PDCCH skipping**

[CATT] proposed the non-scheduling DCI to reduce unnecessary PDCCH monitoring (due to the variation of inter-arrival time caused by delay jitter from network transport) when no XR data could be scheduled for transmission due to late arrival of XR traffic at the beginning of traffic. Note that in RAN1 #110, a conclusion was made that RAN1 does not assume instantaneous jitter value for a frame is predictable for Rel-18 XR SI power saving study before further input is provided by SA.

[CATT] also proposed the continuous PDCCH skipping. gNB configures a short skipping duration and UE continuously skips the PDCCH MOs until the DCI is successfully decoded at the time of packet arrival. This seems to have same effect as sparse PDCCH monitoring with the SS periodicity equal to the short skipping duration followed by SSSG switching triggered by the data scheduling DCI.

Evaluation results show that these two solution together have a 15.7% higher power saving gain than CDRX with Rel-17 PDCCH skipping without loss of UE satisfied rate.

**Item 3.3-4: DCP indicated SSSG switching**

[Nokia, NSB] proposed to use DCP (DCI 2\_6) to indicate the SSSG to begin with at the start of On Duration as an enhancement to Rel-17 SSSG switching. For CG 30Mbps, Indoor Hotspot and PDB of 15ms, evaluation results show that the proposed solution can mitigate the capacity loss by SSSG switching without heavily compromising the power saving. To properly select the SSSG at the start of On Duration, gNB needs to know information of the instantaneous jitter value (not necessarily the full information). Note that in RAN1 #110, it was concluded that RAN1 does not assume instantaneous jitter value for a frame is predictable for Rel-18 XR SI power saving study before further input is provided by SA.

**Item 3.3-5: Retransmission-less CG for UL pose retransmission**

[Qualcomm] proposed to disable the retransmission for CG for UL pose information. Due to the small packet size and throughput contribution of UL pose, conservative MCS can be configured to successfully transmit the UL pose by first transmission at no cost of overall capacity loss. For FR1, high load, joint DL and UL VR 30Mbps in Dense Urban environment, disabling the retransmission avoids PDCCH monitoring for retransmission 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 without capacity loss. Only upper layer design is involved for retransmission-less CG.

### 3.3.3 Discussions

As mentioned in the introduction section, for every proposal or open issue, one of the following decisions is to be made in this meeting

|  |
| --- |
| * **Decision 1**: Deprioritize the issue or proposal in RAN1   + This applies to issue or proposal that is not essential for WI * **Decision 2**: This is a RAN2 issue, leave the study to RAN2.   + This applies to issue (e.g., SFN wrap around mismatch) or proposal that is expected to have performance gain even without being evaluated by RAN1 and it only has RAN2 specification impact * **Decision 3**: Further clarification, justification or evaluation for the issue or proposal is needed in RAN1   + This applies to issue or proposal that should be evaluated but there is no consensus to accept it yet * **Decision 4**: The proposed solution has performance gain, recommend RAN2 to identify the final solution **if necessary** (e.g., semi-static CDRX periodicity alignment)   + This applies to issue or proposal that should be evaluated and evaluation has shown essential performance gain, but the solution only has upper layer specification impact * **Decision 5**: Recommend for Rel-18 XR RAN1 WI (e.g., PDCCH skipping cancellation for retransmission)   + This applies to issue or proposal that has been properly evaluated and is recommended to be specified in PHY specification |

**[RD1]** **Question 3.3-1:** For proposed solutions for Item 3.3-1 to 3.3-5, which decision above do you suggest?

* If there are more than proposal or solution for an Item, please suggest the decision for you most preferred one.

Please provide your views.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | **Item 3.3-1: PDCCH skipping and interaction with** **HARQ retransmission**   * **Decision 5**    + XR capacity can be evidently degraded with large skipping duration, or large resource for last transmission with low MCS, as shown in our contribution R1-2209517. To us, taking care of HARQ retransmission for PDCCH skipping only requires small spec impact but can result in large power saving gain (20.78%~27.97% with sustained UE satisfied rate) w.r.t Rel-17 PDCCH skipping   **Item 3.3-2: Enhancements to PDCCH skipping duration**   * **Decision 3** (We are open to this enhancement since the spec impact may be small, but it is is not very clear to us how many new PDCCH skipping durations are needed)   **Item 3.3-3: Non-scheduling DCI based PDCCH skipping and continuous PDCCH skipping**   * **Decision 3** (We are open to this enhancement. Also want to see the views from other companies)   **Item 3.3-4: DCP indicated SSSG switching**   * **Decision 3** (We are open to this enhancement. Also want to see the views from other companies)   **Item 3.3-5: Retransmission-less CG for UL pose retransmission**   * **Decision 5**    + Since the pose transmission period is very small, say 4ms, this enhancement seems intuitive to assist UE power saving |
| Nokia1 | *Item 3.3-1*: **Decision 1**. As discussed in Section 3.1.2 of our contribution R1-2209535, the length of the skipping duration is restricted due to various reasons, thus, limiting the duration so that it does not prohibit/hinder PDCCH monitoring for re-transmissions can be achieved by network configuration.  *Item 3.3-2*: **Decision 1 & 3**. It would indeed appear based on some results that further changes for PDCCH skipping durations does not provide any significant benefits, while others suggest some benefits. Overall does not appear necessary.  *Item 3.3-3*:  **Decision 3 for non scheduling DCI:**  Could be further considered covering the rel-17 PDCCH monitoring adaptation; skipping and SSSG switching, to determine whether it facilitates the network operation e.g. via ‘late’ or ‘early’ indication of PDCCH monitoring adaptation without scheduling.  **Decision 1 & 3 for continuous skipping:**  It is not clear whether this can provide benefit over the SSSG switching.  *Item 3.3-4:* Firstly, to clarify that the proposed scheme in our contribution (R1-2209535) does not require knowledge about the instantaneous jitter but can be operated by the network e.g. based on packet arrival prior onDuration. As this would be rather low hanging fruit that would also enable network to take somewhat more aggressive approach in CDRX and SSSG configuration, we would propose **Decision 5**. |
| ZTE,  Sanechips | For item 3.3-1, we think the latency impact of PDCCH skipping on retransmission can be solved by NW implementation. And short PDCCH skipping duration indicated in legacy scheduling DCI may be applied for improving power saving gain, and it may cause performance deterioration.  For the evaluation of proposed solutions, the addition enhancement of non-scheduling DCI for PDCCH skipping indication should be clarified as one of the assumption. Thus we suggest to adopt **Decision 3**.  For other items, basically further clarification is needed to address the concerns raised from the moderator. Thus we suggest to adopt **Decision 3** for these items. |
| Samsung | **3.3-1-3.3-5: Decision 3** |
| InterDigital | Item 3.3-1 [PDCCH skipping and interaction with HARQ retransmission]: **Decision 3**  Item 3.3-2 [Enhancements to PDCCH skipping duration]: **Decision 3**  Item 3.3-3 [Non-scheduling DCI based PDCCH skipping and continuous PDCCH skipping: **Decision 3**  Item 3.3-4 [DCP indicated SSSG switching]: **Decision 3**  Item 3.3-5 [Retransmission-less CG for UL pose retransmission]: **Decision 5** |

# 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.

Power Saving by XR-Aware Scheduling

### 4.1.1 Proposals and evaluations

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 15: Proposals and evaluation results on XR-awareness scheduling**

|  |  |
| --- | --- |
| **Company** | **Proposals and evaluation results** |
| CATT | Table 10: The evaluation results of the gNB scheduling awareness schemes  with XR-specific playoutDelayForMediaStartup   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Evaluation Schemes | Capacity | | | Power saving | | #satisfied UEs per cell | % of satisfied UEs | Capacity performance gain | PSG | | DG scheduling with UE always on (Baseline) | 11.5 | 95.83% | - | - | | XR-specific *playoutDelayForMediaStartup* scheme with go-to-sleep  (3 frames playout delay) | 20 | 94.17% | 67% | 26.43%\* | | XR-specific *playoutDelayForMediaStartup* scheme with PDCCH skipping and go-to-sleep  (3 frames playout delay) | 20 | 93.3% | 67% | 28.51%\* | | \*Note: The power saving gain is based on the same capacity as that of the baseline scheme (DG scheduling with UE always on). | | | | |   **Observation 7: Large power saving gain and capacity gain can be obtained by the awareness of UE XR-specific *playoutDelayForMediaStartup*.**  **Proposal 11: gNB awareness of UE playout buffer should be studied and supported for XR UE power saving.** |

**Table 16: Proposals without evaluation results on XR-aware scheduling**

|  |  |
| --- | --- |
| **Company** | **Proposals** |
| Google | **Proposal 12: Issue 3-2 of power saving by XR-aware scheduling should be studied in RAN2 and deprioritized in RAN1.** |

### 4.1.2 Summary of evaluation results

**Item 4.1-1: UE playout buffer for XR**

[CATT] proposed to introduce XR-application awareness of UE playout buffer size at the gNB scheduler to schedule the XR traffic in better favour of UE power saving with relaxed PDB requirements. The proposed solution allows for relaxed PDB (i.e., “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 the relaxed PDB can reduce power consumption by enabling more aggressive sleep.

XR-awareness belongs to RAN2 XR SI scope. In RAN1 #110, companies showed concerns on the PHY impact of the proposed solution and suggested to leave it to RAN2 without further RAN1 discussions. In this meeting, RAN1 will further discuss the PHY impact and decide whether further study in RAN1 is necessary.

### 4.1.3 Discussions

As mentioned in the introduction section, the goal is for every pending proposal or open issue, one of the following decisions is made in this meeting.

|  |
| --- |
| * **Decision 1**: Deprioritize the issue or proposal in RAN1   + This applies to issue or proposal that is not essential for WI * **Decision 2**: This is a RAN2 issue, leave the study to RAN2.   + This applies to issue (e.g., SFN wrap around mismatch) or proposal that is expected to have performance gain even without being evaluated by RAN1 and it only has RAN2 specification impact * **Decision 3**: Further clarification, justification or evaluation for the issue or proposal is needed in RAN1   + This applies to issue or proposal that should be evaluated but there is no consensus to accept it yet * **Decision 4**: The proposed solution has performance gain, recommend RAN2 to identify the final solution **if necessary** (e.g., semi-static CDRX periodicity alignment)   + This applies to issue or proposal that should be evaluated and evaluation has shown essential performance gain, but the solution only has upper layer specification impact * **Decision 5**: Recommend for Rel-18 XR RAN1 WI (e.g., PDCCH skipping cancellation for retransmission)   + This applies to issue or proposal that has been properly evaluated and is recommended to be specified in PHY specification |

In RAN1 #110, the main debating point was whether the proposed playout buffer for UE has PHY impact. In this meeting, discussion will continue along this line.

**[RD1]** **Question 4.1-1:** For the proposed XR-application awareness of UE playout buffer size, which decision above do you suggest?

Please provide your views.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | **Decision 3** (The mechanism seems orchestrated but also a little complicated; may need more input from more than one company) |
| Nokia1 | **Decision 1 & 3**: It is not clear whether it is possible to assume buffering of 3 video frames without impact to the user experience. |
| ZTE,  Sanechips | We suggest to adopt **Decision 2**. |
| Samsung | **Decision 2** |

Unnecessary Data Transmission in Allocated Resources

### 4.2.1 Proposals and evaluations

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 17: 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.***    **Figure 19: An overallocation of PUSCH is partially utilized for transmission of TB with UL data only and no padding**  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 and the gains depend on the initial oversized allocation***  ***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 13: To reduce power consumption, study partial uplink transmission and investigate necessary signaling to enable it.***  ***Proposal 14: 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 18: Proposals without evaluation results on unnecessary data transmission**

|  |  |
| --- | --- |
| **Company** | **Proposals and evaluation results** |
| China Telecom | ***Proposal 15: C-DRX enhancements for SPS PDSCHs of different priorities should be studied.*** |
| 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.** |
| Google | **Proposal 13: Issue 3-3 of unnecessary data transmission in allocated resources can be studied in RAN1.**  **Proposal 14: 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.** |

### 4.2.2 Summary of evaluation results

**Item 4.2-1: Partial uplink transmission**

[Qualcomm] proposed enhancements to Rel-15 Uplink Skipping to allows a UE to transmit over a resource among the allocated resource that is just enough to transmit the UL data. For VR with uplink pose/control, a 12.73% power saving gain is observed assuming pose/control flow in UL assuming same capacity with baseline scheme assuming transmission over the UL BW. For proper demodulation in the UL at gNB, it is proposed to use UCI to indicate the resources utilized/skipped in the PUSCH or the MCS selected by the UE.

### 4.2.3 Discussions

As mentioned in the introduction section, for every proposal or open issue, one of the following decisions is to be made in this meeting.

|  |
| --- |
| * **Decision 1**: Deprioritize the issue or proposal in RAN1   + This applies to issue or proposal that is not essential for WI * **Decision 2**: This is a RAN2 issue, leave the study to RAN2.   + This applies to issue (e.g., SFN wrap around mismatch) or proposal that is expected to have performance gain even without being evaluated by RAN1 and it only has RAN2 specification impact * **Decision 3**: Further clarification, justification or evaluation for the issue or proposal is needed in RAN1   + This applies to issue or proposal that should be evaluated but there is no consensus to accept it yet * **Decision 4**: The proposed solution has performance gain, recommend RAN2 to identify the final solution **if necessary** (e.g., semi-static CDRX periodicity alignment)   + This applies to issue or proposal that should be evaluated and evaluation has shown essential performance gain, but the solution only has upper layer specification impact * **Decision 5**: Recommend for Rel-18 XR RAN1 WI (e.g., PDCCH skipping cancellation for retransmission)   + This applies to issue or proposal that has been properly evaluated and is recommended to be specified in PHY specification |

**[RD1]** **Question 4.2-1:** For proposed partial uplink transmission and indication signaling, which decision above do you suggest?

Please provide your views.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | **Decision 3**   * The baseline (always use 272 RBs) used in the contribution R1-2210002 seems a little pessimistic to us. Besides, to our understanding, it may be also possible that UE just informs NW the required UL resource and leaves the remaining to NW implementation. |
| Nokia1 | **Decision 2**: In section 4 of our contribution (R1-2209535) we also considered that that the existing mechanism (NW configured multiple CG’s) could offers similar adaptation mechanism without need of an additional UCI. Thus it might be appropriate to consider in RAN2 whether any further enhancements to CG are needed. |
| ZTE,  Sanechips | We suggest to adopt **Decision2 or** **Decision 3**. |
| Samsung | **Decision 1** - Also, the issue does not relate to UE power savings and there cannot be power savings considering the PUSCH power control formula as power increases when SE becomes lower and exponentially offsets a linear reduction in the number of RBs. |

# Low Priority Issues without Evaluation Result

The following issues were considered as low priority issues in RAN1 #109-e. Since then, there has been no evaluation results submitted by any company for these issues. Moderator proposes to deprioritize these issues for Rel-18 XR SI so that discussions can be focused on the proposals with evaluation results.

* Low priority Issue 1-4: CDRX enhancements to adjust to variable burst sizes and frame rate
* Low priority Issue 1-5: low latency handling
* Low priority Issue 2-1: Alignment between PDCCH monitoring and XR traffic to resolve the mismatch between PDCCH monitoring periodicity and XR traffic periodicity

**[RD1]** **FL proposal 5-1**: The following low priority issues without evaluation results from any company are deprioritized in RAN1 for Rel-18 XR SI power saving study.

* Low priority Issue 1-4: CDRX enhancements to adjust to variable burst sizes and frame rate
* Low priority Issue 1-5: low latency handling
* Low priority Issue 2-1: Alignment between PDCCH monitoring and XR traffic to resolve the mismatch between PDCCH monitoring periodicity and XR traffic periodicity

Please provide your views.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MTK | Support FL proposal 5-1 |
| ZTE,  Sanechips | We agree to deprioritize these low priority issues |
| Samsung | Support the FL proposal |
|  |  |

# Online Discussion Proposals

# RAN1 #110-bis-e Meeting Outcome

In this meeting, the following agreement and conclusions were made for power saving techniques for Rel-18 XR SI.

# References

1. RAN1 #109-e Chairman’s Notes, May 2022
2. RAN1 #110 Chairman’s Notes, August 2022
3. R1-2207833, Final Moderator Summary on XR specific power saving techniques, Moderator (Qualcomm Incorporated)
4. R1-2208401, Discussion on power saving enhancements for XR, Ericsson
5. R1-2208420, Discussion on XR-specific power saving techniques, Huawei, HiSilicon
6. R1-2208566, Discussion on XR specific power saving techniques, Spreadtrum Communications
7. R1-2210273, Discussion on XR specific power saving enhancements (revision of R1-2208660), vivo
8. R1-2208781, Discussion on XR specific power saving enhancement for NR, China Telecom
9. R1-2208862, Discussion on XR specific power saving techniques, OPPO
10. R1-2208952, UE Power saving techniques for XR, CATT
11. R1-2208999, XR specific power saving techniques, TCL Communication Ltd.
12. R1-2209069, Discussion on XR specific power saving techniques, Intel Corporation
13. R1-2209112, Considerations on XR specific power saving techniques, Sony
14. R1-2209128, XR-specific power saving techniques, Lenovo
15. R1-2209197, Evaluation on XR specific power saving techniques, ZTE, Sanechips
16. R1-2209263, Discussions on techniques for XR Power Saving, xiaomi
17. R1-2209354, Discussion on XR-specific power saving techniques, CMCC
18. R1-2209387, Discussion on XR specific power saving techniques, Panasonic
19. R1-2209410, Discussion on power saving techniques for XR, ETRI
20. R1-2209427, Discussion on XR specific power saving techniques, NEC
21. R1-2209456, Discussion on XR-specific power saving techniques, LG Electronics
22. R1-2209517, On XR specific power saving techniques, MediaTek Inc.
23. R1-2209535, XR-specific power saving enhancements, Nokia, Nokia Shanghai Bell
24. R1-2209597, XR specific power saving techniques, Apple
25. R1-2209619, Power saving techniques for XR Rakuten, Symphony
26. R1-2209636, On XR-specific power saving techniques, Google Inc.
27. R1-2209657, Discussion on XR specific power saving techniques, InterDigital, Inc.
28. R1-2209748, Considerations on Power Savings for XR, Samsung
29. R1-2209919, Discussion on XR specific power saving techniques, NTT DOCOMO, INC.
30. R1-2210002, Power saving techniques for XR, Qualcomm Incorporated
31. R1-2210084, Further Discussion on XR power saving, III

# 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 precluded  Note 2: It can also be adopted for addressing issue 1-1  Note 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 precluded  Note 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 study  Note 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. |

RAN1 #110 Agreements

|  |
| --- |
| **R1-2207831** Moderator Summary #1 on XR specific power saving technique Moderator (Qualcomm Incorporated)  **Conclusion**  Conclude that “SFN wraparound mismatch” is a RAN2 issue. It can be left to RAN2 to address. RAN1 does not further study it.  **Agreement**  RAN1 recommends identifying a solution for enhancement of CDRX to align with XR traffic periodicity  **Conclusion**  RAN1 does not assume instantaneous jitter value for a frame is predictable for Rel-18 XR SI power saving study before further input is provided by SA.  **R1-2207832** Moderator Summary #2 on XR specific power saving techniques Moderator (Qualcomm Incorporated)  **Conclusion**  All the proposed PDCCH monitoring adaptation/reduction schemes including those for jitter handling need to be compared against the Rel-17 PDCCH monitoring adaptation which is to be used as performance reference.  **Conclusion**  UE transmission and reception alignment for Issue 3-1 is deprioritized for power saving in Rel-18 XR SI.  **Conclusion**  RAN1 does not assume dynamic switch of different XR video data rates or frame rates for Rel-18 XR power saving study before further input is provided by SA.  **R1-2207833** Final Moderator Summary on XR specific power saving techniques Moderator (Qualcomm Incorporated)  **For future meetings**  Companies are encouraged to account the enhancement of CDRX to align with XR traffic periodicity in their further evaluations for XR power saving enhancements.  **Conclusion**:   * Companies are requested to use the Excel sheet attached with TR 38.838 in [RP-213652](https://www.3gpp.org/ftp/TSG_RAN/TSG_RAN/TSGR_94e/Docs/RP-213652.zip)  for recording the simulation results that are provided in their contributions. |