3GPP TSG-RAN WG1 Meeting #117 R1-240nnnn

Fukuoka City, Fukuoka, Japan, May 20th – 24th, 2024

**Agenda Item: 9.6.3**

**Title: FL summary #1 on LP-WUS operation in CONNECTED mode**

**Source: Moderator (NTT DOCOMO)**

**Document for: Discussion, Decision**

# 1 Introduction

The core part of the Rel-19 LP-WUS/WUR WI [1] has the following objective:

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| The objectives of the work item are the following:   * To specify an LP-WUS design commonly applicable to both IDLE/INACTIVE and CONNECTED modes (RAN1, RAN4)   + Specify OOK (OOK-1 and/or OOK-4) based LP-WUS with overlaid OFDM sequence(s) over OOK symbol     - The LP-WUS design shall ensure that for IDLE/INACTIVE operation, the same information is delivered irrespective of LP-WUR type. The OFDM sequence can carry information.   + At least duty-cycled monitoring of LP-WUS is supported * For IDLE/INACTIVE modes   + Specify procedure and configuration of LP-WUS indicating paging monitoring triggered by LP-WUS, including at least configuration, sub-grouping and entry/exit condition for LP-WUS monitoring (RAN2, RAN1, RAN3, RAN4)   + Specify LP-SS with periodicity with Yms for LP-WUR, for synchronization and/or RRM for serving cell. (RAN1, RAN4)     - LP-SS is based on OOK-1 and/or OOK-4 waveform with or without overlaid OFDM sequences. Further down selection between with and without overlaid OFDM sequences is to be done within WI.     - Note: For LP-WUR that can receive existing PSS/SSS, existing PSS/SSS can be used for synchronization and RRM instead of LP-SS.     - Y will be decided within WI. 320ms is the start point.   + Specify further RRM relaxation of UE MR for both serving and neighbor cell measurements, and UE serving cell RRM measurement offloaded from MR to LP-WUR, including the necessary conditions (RAN4, RAN2) * For CONNECTED mode, specify procedures to allow UE MR PDCCH monitoring triggered by LP-WUS including activation and deactivation procedure of LP-WUS monitoring (RAN2, RAN1)   + Check in RAN#105 for potential TU adjustment in RAN2   + Note: In CONNECTED mode, UE MR ultra-deep sleep is not considered, and UE RRM/RLM/BFD/CSI measurements are performed by MR * Note: The target coverage of LP-WUS and LP-SS shall be the coverage of PUSCH for message3. * Note: The optimization of LP-WUS signal design for idle/inactive mode is prioritized over the optimization for connected mode. * Specify the necessary RAN4 core requirement(s) to support the feature (RAN4).   + Specify UE low-power wake-up receiver requirements, at least REFSENS, ACS and ASCS requirements with consideration of possible new methodology to assess the low-power wake-up receiver performance     - Define guard RBs for ACS and ASCS cases     - Study testability of above requirements     - Consider impacts of different architecture and impairments, and set requirements that enable all types of reasonable implementation   + Study and if necessary specify or support by declaration, the corresponding BS requirements, e.g., dynamic range for LP-WUS/LP-SS.     - Current NR BS requirements is baseline   + Specify necessary RRM requirements |

This document summarizes contributions [4] – [27] submitted to agenda item 9.6.3 (LP-WUS operation in CONNECTED mode).

# 2 Proposals for Online Sessions

### 2.1 Proposals for Tuesday Online

#### **Proposal 3.2-1a:**

* **For RRC CONNECTED mode, support UE capability report of the supported minimum time gap(s) between LP-WUS reception and MR to start PDCCH monitoring.**
  + **FFS exact values of the minimum time gap, [subject to UE capability discussion]**
  + **FFS for a LP-WUR type and/or given LP-WUS configuration based on UE capability report, only one minimum time gap is applied to a UE**
  + **FFS whether the reported value includes the duration for time/frequency synchronization of MR**

#### **Proposal 3.3-1a:**

* **LP-WUS occasions (LOs) are configured by RRC for LP-WUS monitoring in RRC CONNECTED mode.**
  + **Each LO has at least one LP-WUS monitoring occasion (MO), where UE can monitor for LP-WUS transmission.**
    - **FFS: Multiple LP-WUS MOs in a LO**
    - **FFS: Different LP-WUS MOs may correspond to different beams in multi-beam operation**
    - **FFS whether or not each LO is defined as a time window that covers the corresponding LP-WUS MOs**
    - **FFS details**
  + **FFS: It is at least supported that a UE monitors LOs with a configured periodicity.**

#### **Proposal 3.3-2a:**

* **For LP-WUS monitoring in RRC CONNECTED mode, a LP-WUS [monitoring occasion] is QCLed with existing NR signal(s)/channel(s) for the TCI state**
  + **FFS which existing NR signal(s)/channel(s) is the QCL source of LP-WUS**

#### **Proposal 4.1-1a:**

* **For RRC CONNECTED mode, when LP-WUS is enabled by gNB RRC signaling, UE [may/is expected to] monitor LP-WUS according to the LP-WUS monitoring configuration**
  + **When UE detects a LP-WUS indicating the UE to wake-up,**
    - **UE monitors PDCCH [for a given time duration]**
      * **[FFS the given time duration]**
    - **UE is not required to monitor LP-WUS [for the given time duration / when monitoring PDCCH]**
  + **~~Otherwise, UE is not required to monitor PDCCH by default~~**
    - **~~FFS: fallback mechanism to trigger PDCCH monitoring, if any~~**
  + **FFS: additional indication/condition for activation/deactivation of LP-WUS monitoring**

#### **Proposal 4.1-2a:**

* **For RRC CONNECTED mode, study fallback mechanism to trigger PDCCH monitoring when UE monitors LP-WUS**
  + **Option 1: when UE does not receive LP-WUS for a certain time**
  + **Option 2: when channel/beam quality is below a certain value**
  + **Option 3: UE actions that initiate it to wake up the MR regardless of the LP-WUS**
  + **Note: Other options are not precluded**

#### **Proposal 5-1a:**

* **Study whether/how LP-WUS supports CA in RRC CONNECTED mode**
  + **FFS: The cell(s) where LP-WUS is configured to monitor**
  + **FFS: The cell(s) where wake-up indication is applicable**
    - **Option 1: one or more serving cells based on gNB indication/configuration**
    - **Option 2: all activated serving cells**
    - **Note: other options are not precluded**

#### **Proposal 6-1:**

* **For RRC CONNECTED mode, LP-WUS can be configured without following existing features. Further study whether/how LP-WUS works with following existing features**
  + **Rel-16 DCP**
  + **Rel-17 PDCCH skipping**
  + **Rel-17 SSSG switching**
  + **Rel-18 cell DTX**

# 3 LP-WUS Procedures to trigger PDCCH monitoring

### 3.1 High-level procedures

As captured in TR38.869, four options of LP-WUS high-level procedures to trigger PDCCH monitoring have been discussed in Rel-18 SI.

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| **Table 7.3.2.3-1: LP-WUS operation methods in RRC\_CONNECTED**   |  |  |  |  | | --- | --- | --- | --- | | **LP-WUS application** | **Details** | **Start PDCCH monitoring condition** | **Stop PDCCH monitoring condition** | | **Direction 1: LP-WUS monitoring occasion is determined based on timer(s) related C-DRX** | Option 1: similar to Rel-16 DCP, i.e. the LP-WUS monitoring occasion is located before *drx-onDurationTimer*. | If LP-WUS addressed to UE or UE's subgroup is detected and the legacy *drx-onDurationTimer* is started | It could follow legacy, i.e. at expiration of a C-DRX timer, e.g. C-DRX *drx-OnDurationTimer* or when the UE receives Rel-17 PDCCH skipping indication (if supported and configured). | | Option 2: the LP-WUS monitoring occasion is located at any time outside DRX active time to indicate UE to enter into active time | If LP-WUS addressed to UE or UE's subgroup is detected | | **Direction 2: LP-WUS monitoring occasion is not determined based on timer(s) related C-DRX** | Option 4: the LP-WUS monitoring occasion is located at any time regardless of whether DRX is configured or not. | | **Direction 3: LP-WUS is transparent to current MAC operation** | The LP-WUS monitoring occasion should be determined based on physical layer design/restriction.  This direction may not have any impact on MAC. | N/A | N/A |   Note: The above directions/solutions are NOT Mutually Exclusive absolutely, e.g. some overlap may exist between direction 3 and direction 2, or between option 2 and option 4, based on the detailed design for each direction/option. The detailed design would be further determined in WI, if included.  In direction 1 above, LP-WUS is used in conjunction with C-DRX. LP-WUS could be configured outside the DRX active time with either of the following two options.  - Same function as Rel-16 DCP to indicate whether to start the next *drx-onDurationTimer* (i.e. option 1 above)  - To indicate UE to enters into active time for PDCCH monitoring (i.e. option 2 above)  Some examples for different options in direction 1 are shown as illustrated in the below figures.  For option 1: LP-WUS is used similar as Rel-16 DCP, an example is shown as below (note that a longer time offset may likely have to be applied to cover the MR transition time compared to DCP):    **Figure 7.3.2.3-1: Example for option 1**  For option 2: LP-WUS could be used at any time outside C-DRX active time to indicate UE to enter into active time, different examples for both 'duty-cycled' and 'continuous' mode are shown as below:    **Figure 7.3.2.3-2: Example for option 2 with 'duty-cycled' LP-WUS**    **Figure 7.3.2.3-3: Example for option 2 with 'continuous' LP-WUS**  In direction 2 above, LP-WUS is used in conjunction with C-DRX as the direction 1 or without C-DRX. In the latter case, the LP-WUS is used to indicate UE to activate/resume PDCCH monitoring. Some other solutions used to indicate UE to stop the PDCCH monitoring should be used in conjunction with LP-WUS, e.g. Rel-17 PDCCH monitoring adaptation.  For option 4: LP-WUS could be used at any time regardless of whether C-DRX is configured or not, different examples for both 'duty-cycled' and 'continuous' mode are shown as below:    **Figure 7.3.2.3-4: Example for option 4 with 'duty-cycled' LP-WUS**    **Figure 7.3.2.3-5: Example for option 4 with 'continuous' LP-WUS**  In direction 3, the detailed design should be determined based on physical layer design/restriction.  The corresponding pros/cons for the above options on LP-WUS using in RRC\_CONNECTED are summarized in the below table.  **Table 7.3.2.3-2: Pros and Cons of LP-WUS using options in RRC\_CONNECTED**   |  |  |  | | --- | --- | --- | | LP-WUS options | Pros | Cons | | Option 1: LP-WUS is used similar as Rel-16 DCP | More Power Saving gain is expected compared to legacy DCP due to the difference on power consumption between LP-WUS monitor and PDCCH monitor;  Less specification impact and complexity from reuse of DCP functionality compared to other solutions, e.g. option 2 option 3. | It would result in having redundant mechanism for the same purpose.  Artificially limiting WUR duty-cycle to the C-DRX cycle length (can easily be avoided using separate configuration parameters). | | Option 2: LP-WUS could be used at any time outside C-DRX active time to indicate UE to enter into active time | Power saving gain is excepted compared to current C-DRX mechanism.  LP-WUS configuration is more flexible than option 1 and option 3, e.g. since WUR duty-cycle is not locked to C-DRX cycle;  If a shorter WUR duty-cycle is compared to a longer C-DRX cycle, or continuous mode is used, DL data transmission latency could be reduced compared to C-DRX mechanism and option 1 by not limiting the DL data transmission to a C-DRX onDuration. | More complexity: how to coexist with current C-DRX mechanism;  More specification impacts: new PDCCH monitoring mechanism needs to be captured, e.g. separate WUR duty-cycle (different from C-DRX cycle), and WUR-specific on-duration timer for PDCCH monitoring must be introduced. | | [Option 3: LP-WUS could be used after the beginning of *drx-onDurationTimer*] | Power Saving gain is expected by reducing unnecessary PDCCH monitoring for XR traffic than legacy C-DRX if there is one-stream XR traffic with a non-changing fps which can be matched by the DRX cycle. | More specification impacts considering it may change the current PDCCH monitoring behaviour  Given the ramp-up time from micro/deep sleep, it may be useable in the limited cases, e.g., long *drx-onDurationTimer*. | | Option 4: LP-WUS could be used at any time regardless of whether C-DRX is configured or not | Power Saving gain is expected compared to current C-DRX mechanism and DCP since LP-WUS monitoring consumes less power than PDCCH monitoring;  LP-WUS configuration is more flexible than other options above;  DL data transmission latency could be reduced compared to current C-DRX mechanism. | More complexity: we need to discuss how to stop the PDCCH monitoring and how to configure the LP-WUS; | |

This issue has been discussed in RAN1#116bis and following agreement was made. As a result, RAN1 will not discuss Case 2 when C-DRX is not configured.

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| **Agreement**  Update the following agreement in RAN1#116 in red:  **Agreement**   * For RRC CONNECTED mode, from RAN1 perspective, further study following LP-WUS procedures to trigger PDCCH monitoring:   + Case 1: PDCCH monitoring is triggered by LP-WUS with C-DRX configuration     - Option 1-1: LP-WUS monitoring according to the LP-WUS monitoring configuration before drx-onDurationTimer to trigger the starting of the drx-onDurationTimer.       * This option may replace DCP functionality     - Option 1-2: LP-WUS monitoring outside at least legacy C-DRX active time according to the LP-WUS monitoring configuration to trigger PDCCH monitoring.       * PDCCH monitoring possibly irrespective of drx-onDurationTimer         + Option 1-2-1: PDCCH monitoring may be additionally triggered based on legacy C-DRX cycle and drx-onDurationTimer when monitoring LP-WUS   If this is adopted, it should be configured together with Option 1-1 to achieve power saving gain compared to legacy C-DRX   * + - * + Option 1-2-2: PDCCH monitoring is not triggered by legacy C-DRX cycle and drx-onDurationTimer when monitoring LP-WUS     - Option 1-3: LP-WUS monitoring inside at least legacy C-DRX active time according to the LP-WUS monitoring configuration to trigger PDCCH monitoring.   + ~~Case 2: PDCCH monitoring is triggered by LP-WUS without C-DRX configuration. LP-WUS can be monitored at any time according to the LP-WUS monitoring configuration~~     - ~~FFS duty-cycled and/or continuous LP-WUS monitoring~~ * Combination of options in Case 1 ~~and combination of options in Case 1 and Case 2 are not precluded~~ should be considered. * RAN1 does not discuss C-DRX related timers other than drx-onDurationTimer, this topic is up to RAN2 * Note: Above does not preclude to support fallback mechanism to trigger PDCCH monitoring, if any |

Many companies provided their view on the pros/cons of these options

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|  | | Pros | Cons |
| Case 1 | Option 1-1 | * Can be enabled in the same way as for Rel-16 DCP (TCL, vivo, CATT, Nokia, QC, E///, DCM) * Most parameters can follow legacy drx-config that provides a wide range of parameters, e.g., short duty cycle, short inactivity timer (E///) * Simple fallback behaviour to legacy C-DRX with some new LP-WUS exit criteria/trigger (Nokia) * significant power saving gain for FR2 (QC) | * no power saving gain brought by WUS during DRX active time (HW/HiSi, Nokia, vivo) * no traffic latency reduction outside DRX active time (HW/HiSi, Nokia, vivo) * shorter DRX cycle increases the MR power consumption for RLM/BM/BFD/RRM measurements (Nokia, vivo) |
| Option 1-2-1 (configured together with Option 1-1) | * Can enable more flexible triggering for PDCCH monitoring (IDC, Nokia, QC) * Simple fallback behaviour to legacy C-DRX with some new LP-WUS exit criteria/trigger (Nokia) * Lower latency than Option 1-1 (TCL) * Relax Legacy cDRX setting to reduce power consumption for ongoing MR measurements (Nokia) | * no power saving gain brought by WUS during DRX active time (HW/HiSi, vivo) * same as Option 1-1 with shorter DRX cycle length configuration (E///) * require new mechanisms to make the new ‘floating’ PDCCH monitoring windows work, e.g., PDCCH monitoring termination conditions such as timers/signalling, relevant MAC procedure and PDCCH monitoring procedure (HW/HiSi, TCL, SPRD, Samsung, Apple, QC) |
| Option 1-2-2 | * Can enable more flexible triggering for PDCCH monitoring and power saving (HW/HiSi, IDC, CATT, Nokia, QC, DCM) * Simple fallback behaviour to legacy C-DRX with some new LP-WUS exit criteria/trigger (Nokia) * keep the configurations of DRX cycle and DRX related timers and thus does not have impacts on the measurement (HW/HiSi, vivo, DCM) * The impact of legacy C-DRX can be minimized (TCL) * works standalone, can obtain more power saving and reduce latency (TCL, vivo) * Relax Legacy cDRX setting to reduce power consumption for ongoing MR measurements (Nokia) | * Cause significant complexity and impacts RAN2 aspects (E///, Nokia) * require new mechanisms to make the new ‘floating’ PDCCH monitoring windows work, e.g., PDCCH monitoring termination conditions such as timers/signalling, relevant MAC procedure and PDCCH monitoring procedure (SPRD, Samsung, CATT, Apple, QC, DCM) * Unclear measurement behaviors within the new PDCCH monitoring timer triggered by LP-WUS (Apple) * similar performance can be achieved with Option 1-1 by configuring a shorter C-DRX cycle-length (E///) * UEs monitoring LP-WUS have to completely depend on LP-WUS for DL scheduling without any fallback option (IDC) |
| Option 1-3 | * Can enable more flexible triggering for PDCCH monitoring starting from the middle of DRX Active Time for power saving (HW/HiSi, vivo, QC) * Relax Legacy cDRX setting to reduce power consumption for ongoing MR measurements (Nokia) | * Cannot reduce latency in case the traffic arrives outside the C-DRX active time (vivo) * use case is limited to traffic with jitter, e.g., XR traffic, where the power saving gain of WUS is minor (Nokia, E///) * Legacy cDRX sets upper bound on MR power consumption for ongoing measurements (Nokia) * Need to clarify the relationship between LP-WUS and C-DRX related timers (Samsung) * similar performance can be achieved with Option 1-1 by configuring a shorter C-DRX cycle-length (TCL, E///) |

Many companies also provided their view on the preference of these options as follows:

* Case 1
  + Option 1-1
    - [Apple], CATT, Samsung, Pana, Lenovo, Sony, MTK, ETRI, TCL, QC, E///, DCM, CMCC, NEC, LGE
  + Option 1-2-1 (configured together with Option 1-1)
    - IDC, Nokia, NEC, ETRI, LGE
    - Should be discussed in RAN2: Samsung
  + Option 1-2-2
    - HW/HiSi, TCL, Vivo, [Apple], CMCC, OPPO, DCM
    - Should be discussed in RAN2: Samsung
  + Option 1-3
    - HW/HiSi, SPRD, CMCC, ETRI, DCM, MTK
    - Should be discussed in RAN2: Samsung

Also, a number of companies provided their view on the combinations of these options

* Option 1-1 and Option 1-2-1
  + IDC, ZTE
* Option 1-1 and Option 1-2-2
  + Apple (unified design)
* Option 1-1 and Option 1-3
  + ETRI
* Option 1-2-2 and Option 1-3
  + HW/HiSi, DCM

In general, it can be said that,

* Case 1
  + Option 1-1: small power saving gain, no latency reduction, small spec impact
  + Option 1-2: tradeoff between large power saving gain and large latency reduction, large spec impact
    - Companies have different understanding which options 1-2-1 or 1-2-2 have larger spec impact, especially on C-DRX related timers aspect, which should be discussed in RAN2 according to the previous RAN1 agreement
  + Option 1-3: small power saving gain, useful for traffic with jitter, small/medium spec impact

As some companies also pointed out, there would be a number of interpretations on whether to reuse drx-onDurationTimer or introduce new timer(s) for PDCCH monitoring especially for Options 1-2-1/1-2-2 and Option 1-3, while this aspect should be discussed in RAN2 according to previous RAN1 agreement.

Since RAN2 starts the discussion on Procedures for LP-WUS in RRC\_CONNECTED from May RAN2 meeting, it would be better to wait for RAN2 progress before further down-selection among the options.

Hence, in this RAN1 meeting, moderator suggests discussing RAN1 specific aspects in high level, which are commonly applicable to all options, such as the LP-WUS monitoring occasions, timeline between LP-WUS reception/detection and PDCCH monitoring, activation/deactivation of LP-WUS monitoring, etc., to be discussed other (sub)sections.

### 3.2 Timeline between LP-WUS reception/detection and PDCCH monitoring

Regarding the timeline LP-WUS reception/detection and PDCCH monitoring, following agreement was made in RAN1#116

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| **Agreement**  For RRC CONNECTED mode, minimum time gap between LP-WUS reception and MR to start PDCCH monitoring is introduced considering at least following   * LP-WUS processing time * MR transition time for ramp up * Time/frequency synchronization of MR * FFS whether UE can report supported minimum time gap from candidate values   FFS: Whether the minimum time gap values can be more than one |

A number of companies provided their view on the FFS:

* Detail of the minimum time gap
  + can be discussed after LP-WUS design becomes clear: QC
  + several ms plus the time offset from the LP-WUS to [1~3] SSB burst before PDCCH MO: Pana
* FFS whether UE can report supported minimum time gap from candidate values
  + Support: HW/HiSi, TCL, vivo, Samsung, ZTE, Lenovo, xiaomi, ETRI, OPPO?, DCM
    - For different sleep states (e.g., deep sleep, light sleep, micro sleep)
  + FFS: CATT
  + Not support: Nokia

Majority companies propose to support UE capability report of the supported minimum time gap considering different sleep state, as captured in TR 38.869:

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| The MR sleep states considered for LP-WUS/WUR evaluation in RRC\_CONNECTED are the same as for baseline: deep sleep state with a 20 ms transition time, light sleep state with a 6 ms transition time, or micro sleep without any transition time, as described TR 38.840. Ultra-deep sleep state is not considered for LP-WUS/WUR in RRC\_CONNECTED state as a 400 ms transition time is too long to allow the MR to be ready for PDCCH monitoring from the ultra-deep sleep state considering the traffic requirements for NR. |

#### **[OLD]Proposal 3.2-1:**

* **For RRC CONNECTED mode, support UE capability report of the supported minimum time gap(s) between LP-WUS reception and MR to start PDCCH monitoring.**
  + **FFS exact values of the minimum time gap**

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| **Company** | **Y/N** | **Comments** |
| Lenovo | Y | Support the proposal in general. Please further clarify the clear time of “**LP-WUS reception**” if LO definition is supported (including multiple MOs in each LO) and the clear time for “**MR to start PDCCH monitoring**” |
| Qualcomm |  | We think the proposal is reasonable, while we also consider the decision can be after details of LP-WUS design are clearer. |
| vivo | Y | It is beneficial to allow the UE to report its minimum time gap values for MR wake up. And the network can accordingly configure UE with a time gap between LP-WUS reception and the time UE’s MR can start PDCCH monitoring. |
| CATT | Generally Y | We are OK with that UR can report the capability of the supported minimum time gap(s). But the reported minimum time gap should not be based on the different sleep mode similar as Rel-16, in where the value of the minimum time gap is a UE capability based on subcarrier spacing. |
| LGE | Y | Generally fine with the proposal.  We need to further discuss when the UE starts monitor PDCCH after LP-WUS reception and the minimum time gap. |
| Nokia1 |  | It would be good to understand weather this capability should in companies view restrict the possible offset configuration (between LP-WUS MO and the associated behavior) for the network. In our understanding there is in no principle problem for UE to support any offset, but the attainable power saving gain may depend on it. Thus, our preference would be to allow network configure the offset e.g. based on traffic KPIs. UE can optimize it’s applied power saving state accordingly to attain best possible power saving performance. |
| Spreadtrum | Y |  |
| MTK |  | Clarify whether we can let UE capability report on 1) single minimum time gap and 2) LPWUR type. If doable, then it is simple. |

#### **Proposal 3.2-1a:**

* **For RRC CONNECTED mode, support UE capability report of the supported minimum time gap(s) between LP-WUS reception and MR to start PDCCH monitoring.**
  + **FFS exact values of the minimum time gap, [subject to UE capability discussion]**
  + **FFS for a LP-WUR type and/or given LP-WUS configuration based on UE capability report, only one minimum time gap is applied to a UE**
  + **FFS whether the reported value includes the duration for time/frequency synchronization of MR**

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| **Company** | **Y/N** | **Comments** |
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### 3.3 LP-WUS monitoring occasions

As captured in TR38.869, both duty-cycled and continuous monitoring have been discussed for RRC CONNECTED mode in Rel-18 SI. Also, WID states that at least duty-cycled monitoring is suppoeted.

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| Table 7.3.2.2-1: Pros and Cons of 'duty-cycled' and 'continuous' mode for LP-WUS in RRC\_CONNECTED mode   |  |  |  | | --- | --- | --- | |  | 'Duty-cycled' mode for LP-WUS | 'Continuous' mode for LP-WUS | | Pros | More UE power saving gain than continuous mode LP-WUS. | Potentially shorter DL latency than 'Duty-cycled' mode.  LP-WUR does not need to keep track of slot or radio frame numbering (i.e., DRX timing). | | Cons | LP-WUR must keep track of slot and/or radio frame numbering (i.e., DRX timing).  Potentially longer DL latency. | Higher power consumption than duty-cycled LP-WUS. |   Two examples for UE operations for 'duty-cycled' mode and 'continuous' mode are shown in the below two Figures.  A screen shot of a computer  Description automatically generated  Figure 7.3.2.2-1: Example for 'Duty-cycled WUR' operation  A screen shot of a computer  Description automatically generated  Figure 7.3.2.2-2: Example for 'Continuous WUR' operation |

A number of companies provided their view on the preference of the monitoring mode, roughly categorized as follows:

* Duty-cycled monitoring
  + SPRD, Samsung, E///, Sony, ETRI, Sharp
* Continuous monitoring
  + Sony

In addition to the monitoring mode, following views are provided related to LP-WUS monitoring occasions:

* Vivo
  + LP-WUS occasion(s) is determined by a WUS monitoring Periodicity, Offset, WUS monitoring Window and WUS monitoring pattern within the window where multiple LP-WUS monitoring occasions can be configured in the LP-WUS monitoring window within each period.
* Xiaomi
  + Support periodical transmission occasions of LP WUS shared by multiple UEs.
  + Required monitoring occasions at UE side depends on the application cases.

For LP-WUS monitoring in idle/inactive mode, following agreements were made in previous RAN1 meetings:

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| **Agreement**  LP-WUS occasions (LOs) are defined for LP-WUS monitoring.   * Each LO has one or more LP-WUS monitoring occasions (MOs), where UE can monitor for LP-WUS transmission in each of the LP-WUS MOs.   + Different LP-WUS MOs may correspond to different beams in multi-beam operation   + FFS whether or not each LO is defined as a time window that covers the corresponding LP-WUS MOs   + FFS details * It is at least supported that a UE monitors LOs with a configured periodicity. * FFS eDRX, if supported   **Agreement**  Each LO consists of N \* K LP-WUS MOs, where N is the number of beams corresponding to LP-WUS, and K is the number of LP-WUS MOs for each beam.   * Option 1: K = 1 * Option 2: K can be larger than or equal to 1   + FFS if more than 1 LP-WUS is transmitted from the same beam, whether the information in these multiple LP-WUS is always the same or can be different |

Based on the agreements for idle/inactive mode, following high level proposal on LP-WUS monitoring occasions can be considered, which is commonly applicable to the options in Section 3.1 (High-level procedures), while it is FFS whether multi-beam operation is applied to connected mode, since UE dedicated LO configuration is possible for connected mode.

#### **[OLD]Proposal 3.3-1:**

* **LP-WUS occasions (LOs) are defined for LP-WUS monitoring in RRC CONNECTED mode.**
  + **Each LO has at least one LP-WUS monitoring occasion (MO), where UE can monitor for LP-WUS transmission.**
    - **FFS: Multiple LP-WUS MOs in a LO**
    - **FFS: Different LP-WUS MOs may correspond to different beams in multi-beam operation**
    - **FFS whether or not each LO is defined as a time window that covers the corresponding LP-WUS MOs**
    - **FFS details**
  + **It is at least supported that a UE monitors LOs with a configured periodicity.**

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| **Company** | **Y/N** | **Comments** |
| Lenovo | Y | Suggest adding: “FFS: LO is configured UE-specific/UE-group specific.” |
| OPPO | Y | We think multiple MO may not be needed for CONNECTED mode. But, it is OK for FFS. |
| Qualcomm |  | We suggest to revise the main bullet as follows:   * **LP-WUS occasions (LOs) are configured by RRC ~~defined~~ for LP-WUS monitoring in RRC CONNECTED mode.**   We also do not fully understand why multiple MOs have to be in a LO. |
| vivo | Y | Maybe we can follow the LO definition already agreed in 9.6.2 and to see if there is anything need to be specifically studied. |
| CATT |  | Not sure whether this proposal is needed or not since we already have the definition of LO and no need beam sweeping for CONNECTED mode. |
| LGE | N | We are not sure that the concept of LO should be applied for CONNECTED mode. We think the concept of LO is valid only when LO consists of multiple LP-WUS MOs. If LO has only one LP-WUS MO, the concept of LO is not necessary. In CONNECTED mode, LP-WUS MOs are configured for the UE, so we don’t see the necessity for the concept combining multiple LP-WUS MOs into one LO. |
| Nokia1 |  | The use of LO was justified in IDLE/Inactive where the beam sweep would need to be supported (i.e. binding these together). As in CONNECTED mode operation UE would be expected to monitor LP-WUS based on configured TCI states, thus not sure if there is fundamental need to have LO specified in CONNECTED mode operation. Hence we could agree the definition for the discussion and later consider if we need the definition in CONNECTED mode.  “In the scope of LP-WUS monitoring discussions in RRC CONNECTED mode **LP-WUS occasions (LOs) are defined as follows~~for LP-WUS monitoring in RRC CONNECTED mode~~**”  .  Depending on the scheme, the applicability or need of defining LO periodicity does not seem fully clear. While not proponent of Option 1-1, it would also appear that for it there is no need to configure LO periodicity, but an offset would suffice. |
| Spreadtrum |  | We share the similar views with LGE. |
| MTK | Y | It is beneficial to support duty-cycle based monitoring in RRC CONNECTED. |

#### **Proposal 3.3-1a:**

* **LP-WUS occasions (LOs) are configured by RRC for LP-WUS monitoring in RRC CONNECTED mode.**
  + **Each LO has at least one LP-WUS monitoring occasion (MO), where UE can monitor for LP-WUS transmission.**
    - **FFS: Multiple LP-WUS MOs in a LO**
    - **FFS: Different LP-WUS MOs may correspond to different beams in multi-beam operation**
    - **FFS whether or not each LO is defined as a time window that covers the corresponding LP-WUS MOs**
    - **FFS details**
  + **FFS: It is at least supported that a UE monitors LOs with a configured periodicity.**

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| **Company** | **Y/N** | **Comments** |
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Regarding the multi-beam operation for CONNECTED mode, following views are provided:

* QC
  + Support TCI state for LP-WUS in CONNECTED mode
    - A LP-WUS is QCLed with the SSB/CSI-RS for the TCI state
    - Re-use TCI-state framework for CORESET/PDCCH
* DCM
  + Study the beam property of LP-WUS of following
    - Option A: Multiple beam transmissions of LP-WUS
    - Option B: Single beam transmission of LP-WUS

#### **[OLD]Proposal 3.3-2:**

* **For LP-WUS monitoring in RRC CONNECTED mode, a LP-WUS is QCLed with existing NR signal(s)/channel(s) for the TCI state**
  + **FFS which existing NR signal(s)/channel(s) is the QCL source of LP-WUS**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Lenovo | Y | Support the proposal |
| OPPO | Y | Agree in general. Regarding the meaning of LP-WUS, would that QCL is associated with a LP-WUS monitoring occasion? What is A LP-WUS? |
| Qualcomm | Y |  |
| vivo |  | OK to study the QCL relationship between LP-WUS and existing NR signal(s)/channel(s). |
| CATT |  | Agree with OPPO, more clarification is needed. |
| LGE |  | Need to further study which benefits can be provided when multi-beam operation is supported for CONNECTED mode. |
| Nokia1 |  | Typically in CONNECTED mode UE monitors the configured TCI states e.g. for the CORESET for PDCCH. Hence we agree that the TCI state association should be defined for the LP-WUS channel in the CONNECTED mode. |
| Spreadtrum |  | We share the similar views with OPPO. |
| MTK |  | Not clear what is the intention. Better to define MO only. |

#### **Proposal 3.3-2a:**

* **For LP-WUS monitoring in RRC CONNECTED mode, a LP-WUS [monitoring occasion] is QCLed with existing NR signal(s)/channel(s) for the TCI state**
  + **FFS which existing NR signal(s)/channel(s) is the QCL source of LP-WUS**

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| **Company** | **Y/N** | **Comments** |
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# 4 Activation/deactivation of LP-WUS monitoring

### 4.1 Activation/deactivation mechanism

As captured in TR38.869, following options of activation/deactivation of LP-WUS monitoring have been discussed in Rel-18 SI.

|  |
| --- |
| - In RRC CONNECTED mode, LP-WUS monitoring can be activated/deactivated by at least one or more of  - by gNB RRC signaling, with or without UE assistance.  - by gNB L1/L2 LP-WUS activation/deactivation signaling, with or without UE assistance.  - based on pre-configured condition(s), such as timer.  - LP-WUS monitoring by UE is known to gNB, study whether it could be transparent to gNB.  - other options are not precluded. |

This issue has been discussed in RAN1#116 and following agreement was made:

|  |
| --- |
| **Agreement**  For RRC CONNECTED mode, from RAN1 perspective,   * PDCCH monitoring triggered by LP-WUS is enabled/disabled by gNB RRC signaling   + FFS whether to support UE assistance. * LP-WUS monitoring by UE is known to gNB.   + FFS whether implicit/explicit indication from UE is necessary * In case LP-WUS monitoring is enabled, following options are further studied   + Option 1: No additional indication/condition are introduced for activation/deactivation of LP-WUS monitoring   + Option 2: Activation/deactivation of LP-WUS monitoring by gNB L1/L2 signaling with or without UE assistance.   + Option 3: Activation/deactivation of LP-WUS monitoring based on condition(s), such as timer.   + Option 4: Activation/deactivation of LP-WUS monitoring based on implicit indication/condition, e.g. UL transmission. |

Many companies provided their view on these options for each of the options/cases in Section 3.1

* Option 1-1 in Section 3.1
  + Option 1: Apple, CATT, CMCC, Xiaomi, Sony, QC (while autonomous fallback is necessary), E///, ZTE
  + Option 2: Samsung, ZTE (deactivation), Sharp, TCL, LGE
  + Option 3: Samsung, TCL, Lenovo, LGE
  + Option 4: TCL, LGE
* Option 1-2-1 in Section 3.1
  + Option 1: ZTE, Nokia
  + Option 2: ZTE (deactivation), Xiaomi (activation), Nokia, LGE, Sharp
  + Option 3: IDC, Xiaomi (activation), Nokia, LGE
  + Option 4: LGE, Nokia
* Option 1-2-2 in Section 3.1
  + Option 1: Apple, CMCC, ZTE
  + Option 2: HW/HiSi, TCL, ZTE (deactivation), vivo, Sharp
  + Option 3: TCL, OPPO
  + Option 4: HW/HiSi, TCL
* Option 1-3 in Section 3.1
  + Option 1: CMCC, ZTE, Xiaomi
  + Option 2: HW/HiSi, SPRD, ZTE (deactivation), Apple, Sharp
  + Option 3: Apple (Activation)
  + Option 4: HW/HiSi, Apple (deactivation)

Also, some companies provide views on the FFS in the last agreement:

* FFS whether to support UE assistance.
  + Yes: CMCC, IDC, Nokia, OPPO
  + No: CATT
* FFS whether implicit/explicit indication from UE is necessary
  + Yes: Nokia
  + No: vivo, ETRI

As mentioned above, some companies also propose autonomous fallback to PDCCH monitoring when UE monitors LP-WUS

* autonomous fallback to PDCCH monitoring when UE monitors LP-WUS
  + When UE does not received LP-WUS for a long time: ZTE, Nokia
  + when the channel/beam quality is not satisfactory for successful LP-WUS reception: QC, Pana, ETRI

As the preferred options of the additional indication/condition for activation/deactivation of LP-WUS monitoring are different among the options in Section 3.1 (high-level procedures), following high level proposal on UE LP-WUS/PDCCH monitoring behavior can be considered, which is commonly applicable to the options in Section 3.1.

#### **[OLD]Proposal 4.1-1:**

* **For RRC CONNECTED mode, when LP-WUS is enabled by gNB RRC signaling, UE is expected to monitor LP-WUS according to the LP-WUS monitoring configuration**
  + **When UE detects a LP-WUS indicating the UE to wake-up,**
    - **UE monitors PDCCH for a given time duration**
      * **FFS the given time duration**
    - **UE is not required to monitor LP-WUS for the given time duration**
  + **Otherwise, UE is not required to monitor PDCCH by default**
    - **FFS: fallback mechanism to trigger PDCCH monitoring, if any**
  + **FFS: additional indication/condition for activation/deactivation of LP-WUS monitoring**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Moderator |  | The fallback mechanism is to be discussed in Proposal 4.1-2 |
| Lenovo | Y | Suggest combining the two sub-bullet as   * + - **UE monitors PDCCH and may not be required to monitor LP-WUS for a given time duration.** |
| OPPO |  | We are fine for the case for detected wake-up. We may not need to define Otherwise now. Could put that in FFS. |
| Qualcomm |  | Tend to agree with OPPO – otherwise bullet may cause some confusion.  On the main bullet, following maybe more appropriate:   * **For RRC CONNECTED mode, when LP-WUS is enabled by gNB RRC signaling, UE may ~~is expected to~~ monitor LP-WUS according to the LP-WUS monitoring configuration** |
| vivo |  | To keep it more open, we suggest one description for the first sub-bullet can be that when UE detects a LP-WUS indicating the UE to wake-up, UE monitors PDCCH. And UE is not required to monitor LP-WUS during PDCCH monitoring.  Besides, regarding the give time duration, we are not sure if it is needs to be mentioned explicitly. For example, when will a UE return to LP-WUS monitoring after finishing PDCCH monitoring depends on the certain exit condition of PDCCH monitoring such as via PDCCH skipping indication or by the expiry of PDCCH monitoring related timer. Hence, the PDCCH monitoring duration triggered by a LP-WUS will be implicitly figured out. |
| CATT |  | When LP-WUS monitoring is enabled, the LP-WUS monitoring should be active all the time for the UE power saving. The LP-WUS is used for the low power consumption of LP-WUR in detecting LP-WUS to achieve further UE power saving. Thus, the benefit of deactivation of LP-WUS monitoring is not clear. In other words, the use case for dynamic activation and deactivation of LP-WUS monitoring shows no benefit in achieving UE power saving. Thus, the activation/deactivation of LP-WUS is based on the LP-WUS’s configuration. |
| LGE | Y | Fine with the proposal. |
| Nokia1 |  | This proposal seems to make some assumptions on the schemes to be supported? Would it be best to defer this until the scheme is decided? E.g. “a given time duration” definition will vary depending on 1-1 (onDuration) an 1-2 (new time) and may not even be a specific time (some companies have more elaborate proposals).  Hence would it be better to consider this on higher level e.g. whether UE monitors LP-WUS or not, rather than the behavior upon detecting LP-WUS? |
| MTK |  | We are not sure about “Otherwise, UE is not required to monitor PDCCH by default”. |

#### **Proposal 4.1-1a:**

* **For RRC CONNECTED mode, when LP-WUS is enabled by gNB RRC signaling, UE [may/is expected to] monitor LP-WUS according to the LP-WUS monitoring configuration**
  + **When UE detects a LP-WUS indicating the UE to wake-up,**
    - **UE monitors PDCCH [for a given time duration]**
      * **[FFS the given time duration]**
    - **UE is not required to monitor LP-WUS [for the given time duration / when monitoring PDCCH]**
  + **~~Otherwise, UE is not required to monitor PDCCH by default~~**
    - **~~FFS: fallback mechanism to trigger PDCCH monitoring, if any~~**
  + **FFS: additional indication/condition for activation/deactivation of LP-WUS monitoring**

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| **Company** | **Y/N** | **Comments** |
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#### **[OLD]Proposal 4.1-2:**

* **For RRC CONNECTED mode, study fallback mechanism to trigger PDCCH monitoring when UE monitors LP-WUS**
  + **Option 1: when UE does not receive LP-WUS for a certain time**
  + **Option 2: when channel/beam quality is below a certain value**
  + **Note: Other options are not precluded**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Lenovo | Y | Support Option 2 |
| OPPO | N | For Option 1, we think the UE fall back can simply following timer without considering if the LP-WUS received. |
| Qualcomm |  | We are not sure if it is really necessary to specify required (or non-transparent) fallback mechanism from LP-WUS monitoring to PDCCH monitoring. gNB will anyway transmit PDCCH to the UE. Specifying particular fallback mechanism may just be an unnecessary burden for UE implementation. |
| vivo | N | The measurement is still ongoing by UE MR during LP-WUS monitoring. So, the network can be aware of when the channel quality becomes bad, and it can accordingly send LP-WUS to trigger the resume of PDCCH monitoring or gNB can directly disable the LP-WUS operation by RRC signalling before UE loses the control. Hence, we think no additional fallback mechanism is needed. |
| CATT |  | Per our understanding, the fallback mechanism will lead additional power consumption, which is against the power saving target. |
| LGE |  | We are generally fine with both options.  Regarding option 2, we can consider channel quality based on multiple times of measurements not one-shot measurement. So, we suggest an update as follows:  Option 2: when channel/beam quality is below a certain value for a certain number of times or a certain time |
| Nokia1 | Y | Other options could include UE actions that initiate it to wake up the MR regardless of the LP-WUS (option 4) |
| Spreadtrum | N | Fallback mechanism to trigger PDCCH monitoring when UE monitors LP-WUS is not needed. |
| MTK |  | ok |

#### **Proposal 4.1-2a:**

* **For RRC CONNECTED mode, study fallback mechanism to trigger PDCCH monitoring when UE monitors LP-WUS**
  + **Option 1: when UE does not receive LP-WUS for a certain time**
  + **Option 2: when channel/beam quality is below a certain value**
  + **Option 3: UE actions that initiate it to wake up the MR regardless of the LP-WUS**
  + **Note: Other options are not precluded**

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| **Company** | **Y/N** | **Comments** |
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In addition, following views are provided related to activation/deactivation of LP-WUS monitoring, which can be discussed after high-level design of activation/deactivation of LP-WUS monitoring is decided.

* IDC
  + Support a mechanism to report UE decision of LP-WUS monitoring deactivation potentially with reason for the decision.
* OPPO
  + The LP-WUS LR and MR switching behavior is not specified in the operation for LP-WUS RRC CONNECTED mode.

### 4.2 Miss/False-detection of LP-WUS activation/deactivation and fallback mechanism of LP-WUS monitoring

Following companies mentioned Miss/False-detection of LP-WUS activation/deactivation.

* HW/HiSi
  + The impact due to miss-detection/falsely-detection of LP-WUS activation/deactivation signaling should be minimized/avoided for CONNECTED mode UE.
* Samsung
  + For activation/deactivation of LP-WUS monitoring, prioritize Option 2 and Option 3, and support explicit confirmation message(s) from the UE to the gNB for handshake in Option 2.

This issue has been discussed in previous RAN1 meetings but as commented by some companies, this proposal can be low priority and discussed after high-level LP-WUS activation/deactivation procedure in connected mode becomes clear.

#### **[TBD]Proposal 4.2-1:**

* **TBD**

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| **Company** | **Y/N** | **Comments** |
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# 5 LP-WUS payload

As captured in TR38.869, following candidates of LP-WUS contents have been discussed in Rel-18 SI.

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| --- |
| - For CONNECTED mode, study at least following candidates for content of LP-WUS  - information on which user(s) is/are targeted by the LP-WUS  - e.g UE-group, -subgroup or -ID  - indication to wake-up to PDCCH monitoring. |

This issue has been discussed in RAN1#116 and RAN1#116bis, and following agreements were made:

|  |
| --- |
| **Agreement**  For RRC CONNECTED mode, maximum number of LP-WUS information bits is up to X bits   * FFS value X, which is no more than [8 or 16]   **Agreement**  Regarding the LP-WUS information to trigger PDCCH monitoring of RRC connected UEs, at least consider the following:   * Option 1: A bitmap with each bit corresponding to [one or more] UEs * Option 2: A codepoint value corresponding to one or part of UE identity, e.g., C-RNTI * Option 3: A codepoint value corresponding to [one or more] UEs * Option 4: Multiple codepoint values with each corresponding to [one or more] UE(s) * Option 5: Multiple bit blocks with each corresponding to [one or more] UE(s) * Combination of above options are not precluded. * FFS how to carry LP-WUS information, e.g, by encoded bits (with/without CRC) and/or by OOK sequence selection for ‘ON-OFF’ pattern for OOK symbols of LP-WUS. * FFS how to carry LP-WUS information by overlaid OFDM sequences.   + It doesn’t preclude considering the configuration where a single candidate overlaid OFDM sequence is used * FFS details of LP-WUS information to trigger PDCCH monitoring (e.g. whether above is applicable to one or more serving cells) |

* Value X (to be further discussed in AI 9.6.1)
  + 8: Sony, QC (as WA), Nokia E/// (FFS how to support LP-WUS operation with up to 8 bits)
  + 16: HW/HiSi, vivo, Lenovo,
  + 24: ZTE
* Sequence vs encoded bits (to be discussed in AI 9.6.1)
  + Option 1: vivo, Nokia, OPPO, Sharp, DCM
  + Option 2:
  + Option 3: vivo, QC, Sony
    - Maximum number of sequence(s) that the UE can monitor for a LP-WUS is per UE capability: QC
  + Option 4: vivo, QC, Sony, Sharp, DCM
  + Option 5: ZTE, Sharp, DCM (merged with Option 4)
* Granularity of wake-up indication (PDCCH triggering)
  + subgroup-based: ZTE, TCL
  + UE specific: ZTE, CMCC, Sony, IDC
* FFS how to carry LP-WUS information by overlaid OFDM sequences.
  + To be discussed in AI 9.6.1: vivo
* Other contents
  + Scell dormancy: IDC, Sharp
    - No: vivo, OPPO
  + SSSG switching: Xiaomi
  + BWP switching: Xiaomi
  + Cell information: TCL
* FFS details of LP-WUS information to trigger PDCCH monitoring (e.g. whether wake-up indication is applicable to one or more serving cells): SPRD
  + Vivo
    - Option 1-1 in Section 3.1: LP-WUS information should be applicable to all the activated serving cells
    - Option 1-2 in Section 3.1: LP-WUS information can be applicable to one or more scheduling cells based on NW configuration
    - Option 1-3 in Section 3.1: LP-WUS information can be applicable to one or more scheduling cells based on NW configuration
  + Xiaomi
    - LP WUS can be configured in the same or different carrier/band from where MR operates
    - UE is only required to monitor LP WUS on one carrier.
  + ZTE
    - LP-WUS supports CA in connected mode
    - For CA support, discuss whether LP-WUS is appliedfor all serving cells or for a group of SCells for triggering PDCCH monitoring.
      * With or without C-DRX, a uniform design is preferred.
    - Deprioritize LP-WUS used for SCell dormancy and prioritize LP-WUS used for SCell wake-up for PDCCH monitoring.
  + OPPO
    - When multi-carrier operation enabled, the LP-WUS indication applied to multiple carriers. It may indicate multiple carriers wake-up for those activated carriers.

Regarding the value X, since the above agreement was made in RAN1#116 meeting as a great compromise among companies, moderator assumes we don’t need to further down select the value in this agenda, but it can be further discussed in AI 9.6.1 considering performance, system overhead, etc.

Regarding Sequence vs encoded bits, Granularity of wake-up indication, and how to carry LP-WUS information by overlaid OFDM sequences, those are highly related to LP-WUS structure and hence, those can be further discussed in AI 9.6.1.

Regarding the other contents than wake-up indication (PDCCH triggering), this may depend on the overall LP-WUS procedure to trigger PDCCH discussed in Section 3.1, and can be discussed once further progress is made there.

For example, for Option 1-1 (replace Rel-16 DCP) in Section 3.1, Rel-16 DCP supports group common PDCCH monitoring and UE specific wake-up indication (up to 140 bits) as specified in TS38.212, and hence, same mechanism can be considered while payload size is much smaller.

|  |
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| 7.3.1.3.7 Format 2\_6  DCI format 2\_6 is used for notifying the power saving information outside DRX Active Time for one or more UEs.  The following information is transmitted by means of the DCI format 2\_6 with CRC scrambled by PS-RNTI:  - block number 1, block number 2,…, block number *N*  where the starting position of a block is determined by the parameter *ps-PositionDCI-2-6* provided by higher layers for the UE configured with the block.  If the UE is configured with higher layer parameter *ps-RNTI* and *dci-Format2-6*, one block is configured for the UE by higher layers, with the following fields defined for the block:  - Wake-up indication - 1 bit  - SCell dormancy indication – 0 bit if higher layer parameter *dormancyGroupOutsideActiveTime* is not configured; otherwise 1, 2, 3, 4 or 5 bits bitmap determined according to the number of different *DormancyGroupID(s)* provided by higher layer parameter *dormancyGroupOutsideActiveTime,* where each bit corresponds to one of the SCell group(s) configured by higher layers parameter *dormancyGroupOutsideActiveTime,* with MSB to LSB of the bitmap corresponding to the first to last configured SCell group in ascending order of *DormancyGroupID*.  The size of DCI format 2\_6 is indicated by the higher layer parameter *sizeDCI-2-6*, according to Clause 10.3 of [5, TS 38.213]. |

It would be better to discuss whether wake-up indication is applicable to one or more serving cells. Based on companies contribution, following proposal can be considered

### **[OLD]Proposal 5-1:**

* **LP-WUS supports CA in RRC CONNECTED mode**
  + **FFS: The cell(s) where LP-WUS is configured to monitor**
  + **FFS: The cell(s) where wake-up indication is applicable**
    - **Option 1: one or more serving cells based on gNB indication/configuration**
    - **Option 2: all activated serving cells**
    - **Note: other options are not precluded**

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| **Company** | **Y/N** | **Comments** |
| Lenovo |  | Need further study for CA scnearios |
| OPPO |  | We don’t consider CA for LP-WUS. The power saving benefit is not applicable for CA. |
| Qualcomm | Y | CA is a typical RRC connected operation. Further, R16 DCP already supported CA scenarios. We do not see a reason to exclude CA operation from LP-WUS feature. |
| vivo |  | It really depends on the LP-WUS monitoring mechanism, so we can study the need of LP-WUS for CA case, but not directly support CA based LP-WUS. |
| CATT | Y | When Option 1-1 is applied, the DCP functionality e.g. wake-up indication and Scell dormancy indication should be replaced. |
| LGE |  | There has been not sufficient discussion yet. We need to further study CA for LP-WUS for example, which CA scenario can provide power saving gain. |
| Nokia1 |  | Would prefer the word “support” be modified to “study”. At this meeting, only a few companies explicitly raised this. Also, how this proposal may impacted by payload size and support of similar multiple cell features, e.g. if the wake-up needs to be cell specific (explicitly). |
| Spreadtrum | Y | LP-WUS operation with CA in RRC CONNECTED mode should be considered. |
| MTK |  | No benefit has been shown to support CA |

### **Proposal 5-1a:**

* **Study whether/how LP-WUS supports CA in RRC CONNECTED mode**
  + **FFS: The cell(s) where LP-WUS is configured to monitor**
  + **FFS: The cell(s) where wake-up indication is applicable**
    - **Option 1: one or more serving cells based on gNB indication/configuration**
    - **Option 2: all activated serving cells**
    - **Note: other options are not precluded**

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| **Company** | **Y/N** | **Comments** |
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In addition, following views are provided related to how to inform LP-WUS information in addition to the LP-WUS payload, which can be discussed after high-level design of LP-WUS payload is decided in AI 9.6.1.

* IDC
  + A portion of LP-WUS information can be informed to UE implicitly using LP-WUS monitoring resource association (e.g., LO and MO) and structure of LP-WUS.
* LGE
  + To overcome limited maximum number of LP-WUS information bits, consider the combination of time/frequency resources and LP-WUS payload for UE identification.

# 6 Coexistence with existing UE power saving features

In addition to C-DRX discussed in Section 3, many companies provided their view on the coexistence with existing UE power saving features, roughly categorized as follows:

* Rel-16 DCP
  + Can coexist
    - HW/HiSi: If DCP is configured, after LP-WUS monitoring is activated, the UE should not monitor DCP in MR.
    - OPPO: The DCP should be able to indicate wake-up with LP-WUS. Thus, rules should be discussed on how duplicated indications applied, especially if the DRX-based indication is adopted for LP-WUS
    - CATT: For LP-WUS trigger MR monitor DCP, the LP-WUS can be designed to indicate more than one UE with capacity up to 12 UEs.
    - LGE: The UE does not need to monitor DCP and LP-WUS simultaneously to trigger PDCCH monitoring.
      * Further study that the UE switches between DCP monitoring and LP-WUS monitoring.
  + Cannot coexist
    - ZTE: LP-WUS and group specific DCP does not need to be configured at the same time
    - CMCC: LP-WUS procedure Option 1-1 and Rel-16 DCP can not be configured or activated to one UE simultaneously
    - E///: benefit of using DCP and LP-WUS in a 2-step or tandem approach is not clear and in contrast, it would only increase the latency, create unwanted interdependencies of different features, and additional cost/complexity to implement the feature
* Rel-17 PDCCH skipping
  + Can coexist
    - HW/HiSi: After LP-WUS monitoring is activated, the UE should stop/suspend the Rel-17 PDCCH adaption mechanism, if configured
    - ZTE: If LP-WUS is monitored outside active time, no spec impacts are foreseen for PDCCH skipping and LP-WUS coexistence.
    - Nokia: Once PDCCH skipping is triggered by DCI UE would start to monitor LP-WUS. If the LP-WUS is detected within PDCCH skipping period, it could trigger the termination of skipping and UE would resume PDCCH monitoring
    - CMCC: LP-WUS procedure Option 1-2-2/Option 1-3 and Rel-17 PDCCH skipping/SSSG switching can be configured or activated to one UE simultaneously
    - OPPO: The LP-WUS should be interworking with legacy power saving schemes in CONNECTED mode, which are PDCCH-based WUS (DCP, Format 2\_6), Cross-slot scheduling & PDCCH Skipping.
    - E///: since legacy onDurationTimer is triggered by LP-WUS, there is no issue on the coexistence with existing power saving techniques used during Active Time of C-DRX
    - QC: PDCCH monitoring in the DRX Active Time, even if it is triggered by LP-WUS, can be skipped/reduced by Rel-17 PDCCH skipping or SSSG switching indication. This will be quite beneficial for power saving, especially if the value(s) of *drx-onDurationTimer* and/or *drx-InactivityTimer* is/are relatively large. Use of Rel-17 PDCCH skipping or SSSG switching does not require additional specification impact.
  + Cannot coexist
* Rel-17 SSSG switching
  + Can coexist
    - ZTE: No much power saving is observed if LP-WUS is used for SSS switching and no issue is observed when LP-WUS coexist with SSSG switching
    - CMCC: LP-WUS procedure Option 1-2-2/Option 1-3 and Rel-17 PDCCH skipping/SSSG switching can be configured or activated to one UE simultaneously
    - E///: since legacy onDurationTimer is triggered by LP-WUS, there is no issue on the coexistence with existing power saving techniques used during Active Time of C-DRX
    - QC: PDCCH monitoring in the DRX Active Time, even if it is triggered by LP-WUS, can be skipped/reduced by Rel-17 PDCCH skipping or SSSG switching indication. This will be quite beneficial for power saving, especially if the value(s) of *drx-onDurationTimer* and/or *drx-InactivityTimer* is/are relatively large. Use of Rel-17 PDCCH skipping or SSSG switching does not require additional specification impact.
* Rel-18 Cell DTX
  + Can coexist
    - HW/HiSi, TCL, LGE: The co-existence of LP-WUS and cell DTX should be considered in Rel-19

Given divergent view on whether LP-WUS can work with existing UE power saving features, following proposal is made for further study

### **Proposal 6-1:**

* **For RRC CONNECTED mode, LP-WUS can be configured without following existing features. Further study whether/how LP-WUS works with following existing features**
  + **Rel-16 DCP**
  + **Rel-17 PDCCH skipping**
  + **Rel-17 SSSG switching**
  + **Rel-18 cell DTX**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Lenovo | Yes | OK to study |
| OPPO | Y |  |
| Qualcomm |  | It is not clear whether R16 DCP can be used together with LP-WUS, especially if LP-WUS monitoring is based on option 1-1 (replacing R16 DCP). Suggest to delete the first sub-bullet for now.  Simultaneous configuration of R17 PDCCH skipping (or SSSG switching) is important to achieve power saving gain in connected mode. We prefer to design LP-WUS such that it can work with these features. |
| vivo | Y |  |
| LGE | Y |  |
| Nokia1 | Y |  |
| Spreadtrum | Y |  |
| MTK |  | No benefit has been shown to support CA |

# 7 Other aspects

The submitted contributions bring up the following other aspects which are not covered in any other sections in this summary.

**L1 measurement/report**

* QC
  + Introduce RRC configuration enabling/disabling skipping of CSI/BM measurement reporting during the time that the UE does not monitor PDCCH
    - At least for periodic CSI, periodic L1-RSRP, and periodic L1-SINR reporting
* Xiaomi
  + Support CSI report enhancement during the MR’s non-active period.
    - CSI report can be skipped or relaxed to a larger periodicity during the MR’s non-active period so that more power saving gain can be expected from MR
* TCL
  + At least support transmitting HARQ-ACK when LP-WUS indicates no PDCCH monitoring. Study whether or not transmitting CSI reporting and SRS when the UE MR is in light/micro sleep state

**Frequency location of LP-WUS**

* QC
  + As baseline, LP-WUS on a serving cell is configured within active DL BWP of the serving cell
    - FFS: outside active DL BWP of the serving cell (as optional UE capability)

**Dual DRX-group**

* QC
  + Support LP-WUS monitoring with dual DRX groups
    - Opt.1: LP-WUS is configured to be monitored per DRX group
      * For dual DRX groups, LP-WUS monitoring is configured per DRX group
      * LP-WUS monitored on a cell within a DRX group triggers PDCCH monitoring on the cell of the DRX group
    - Opt.2: LP-WUS carries an indication for which DRX group(s) it triggers PDCCH monitoring



**LP-WUS monitoring parameters**

* HW/HiSi: In CONNECTED mode, monitoring parameters of LP-WUS can be adjusted by MR signaling and/or pre-defined rules at least for different coverage requirement.

### **Question 7-1:**

* **Is there a need to treat any of the issues listed above in this meeting?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Qualcomm |  | We think these are important aspects that should be discussed. Given the current progress, not sure if we can make conclusion on these aspects in this meeting. |
| Nokia1 | . | We would suggest to focus first on other aspects. |
|  |  |  |

# 8 Conclusions

To be updated

# References

|  |  |  |  |
| --- | --- | --- | --- |
| [1] | [**RP-240801**](https://www.3gpp.org/ftp/TSG_RAN/TSG_RAN/TSGR_103/Docs/RP-240801.zip) | Revised WID: Low-power wake-up signal and receiver for NR (LP-WUS/WUR) | vivo, NTT DOCOMO, Ericsson, MediaTek, Samsung, Sony |
| [2] | [**R1-2400640**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_116/Docs/R1-2400640.zip) | Work plan for Low-power wake-up signal and receiver for NR | vivo, NTT DOCOMO |
| [3] | [**R1-2403714**](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_116b/Docs/R1-2403714.zip) | FL summary #3 on LP-WUS operation in CONNECTED mode | Moderator (NTT DOCOMO) |
| [4] | [**R1-2403950**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2403950.zip) | Procedures and functionalities of LP-WUS in CONNECTED mode | Huawei, HiSilicon |
| [5] | [**R1-2404001**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404001.zip) | Discussion on LP-WUS procedures in Connected mode | TCL |
| [6] | [**R1-2404037**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404037.zip) | Discussion on LP-WUS operation in CONNECTED modes | Spreadtrum Communications |
| [7] | [**R1-2404126**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404126.zip) | Discussion on LP-WUS operation in CONNECTED modes | Samsung |
| [8] | [**R1-2404188**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404188.zip) | Discussion on LP-WUS operation in CONNECTED modes | vivo |
| [9] | [**R1-2404298**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404298.zip) | LP-WUS operation in CONNECTED modes | Apple |
| [10] | [**R1-2404314**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404314.zip) | Discussion on RRC CONNECTED mode LP-WUS monitoring | InterDigital, Inc. |
| [11] | [**R1-2404412**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404412.zip) | System design and procedure of LP-WUS operation for UE in CONNECTED Modes | CATT |
| [12] | [**R1-2404440**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404440.zip) | Discussion on LP-WUS operation in CONNECTED modes | Lenovo |
| [13] | [**R1-2404467**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404467.zip) | Discussion on LP-WUS operation in CONNECTED mode | CMCC |
| [14] | [**R1-2404511**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404511.zip) | LP-WUS operation in CONNECTED mode | Sony |
| [15] | [**R1-2404565**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404565.zip) | Discussion on LP-WUS operation in CONNECTED mode | ZTE, Sanechips |
| [16] | [**R1-2404629**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404629.zip) | Discussion on LP-WUS operation in Connected mode | Xiaomi |
| [17] | [**R1-2404666**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404666.zip) | Discussion on LP-WUS operation in RRC CONNECTED mode | NEC |
| [18] | [**R1-2404707**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404707.zip) | LP-WUS operation in CONNECTED mode | Nokia |
| [19] | [**R1-2404762**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404762.zip) | Discussion on LP-WUS operation in CONNECTED mode | Panasonic |
| [20] | [**R1-2404783**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404783.zip) | Discussion on LP-WUS operation in CONNECTED modes | ETRI |
| [21] | [**R1-2404854**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404854.zip) | Consideration on wake-up procedure in connected mode | OPPO |
| [22] | [**R1-2404899**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404899.zip) | Discussion on LP-WUS operation in CONNECTED modes | LG Electronics |
| [23] | [**R1-2404968**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404968.zip) | Discussion on LP-WUS operation in CONNECTED modes | Sharp |
| [24] | [**R1-2405053**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405053.zip) | Discussion on LP-WUS operation in CONNECTED mode | NTT DOCOMO, INC. |
| [25] | [**R1-2405075**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405075.zip) | LP-WUS operation in CONNECTED modes | MediaTek Inc. |
| [26] | [**R1-2405110**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405110.zip) | LP-WUS operation in CONNECTED mode | Ericsson |
| [27] | [**R1-2405166**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405166.zip) | LP-WUR operation in connected mode | Qualcomm Incorporated |

# RAN1 agreements

### **RAN1#116**

**Agreement**

* For RRC CONNECTED mode, from RAN1 perspective, further study following LP-WUS procedures to trigger PDCCH monitoring:
  + Case 1: PDCCH monitoring is triggered by LP-WUS with C-DRX configuration
    - Option 1-1: LP-WUS monitoring according to the LP-WUS monitoring configuration before drx-onDurationTimer to trigger the starting of the drx-onDurationTimer.
      * This option may replace DCP functionality
    - Option 1-2: LP-WUS monitoring outside C-DRX active time according to the LP-WUS monitoring configuration to trigger PDCCH monitoring.
      * PDCCH monitoring possibly irrespective of drx-onDurationTimer
    - Option 1-3: LP-WUS monitoring inside C-DRX active time according to the LP-WUS monitoring configuration to trigger PDCCH monitoring.
  + Case 2: PDCCH monitoring is triggered by LP-WUS without C-DRX configuration. LP-WUS can be monitored at any time according to the LP-WUS monitoring configuration
    - FFS duty-cycled and/or continuous LP-WUS monitoring
* Combination of options in Case 1 and combination of options in Case 1 and Case 2 are not precluded.

**Agreement**

For RRC CONNECTED mode, maximum number of LP-WUS information bits is up to X bits

* FFS value X, which is no more than [8 or 16]

**Agreement**

For RRC CONNECTED mode, minimum time gap between LP-WUS reception and MR to start PDCCH monitoring is introduced considering at least following

* LP-WUS processing time
* MR transition time for ramp up
* Time/frequency synchronization of MR
* FFS whether UE can report supported minimum time gap from candidate values

FFS: Whether the minimum time gap values can be more than one

**Agreement**

For RRC CONNECTED mode, from RAN1 perspective,

* PDCCH monitoring triggered by LP-WUS is enabled/disabled by gNB RRC signaling
  + FFS whether to support UE assistance.
* LP-WUS monitoring by UE is known to gNB.
  + FFS whether implicit/explicit indication from UE is necessary
* In case LP-WUS monitoring is enabled, following options are further studied
  + Option 1: No additional indication/condition are introduced for activation/deactivation of LP-WUS monitoring
  + Option 2: Activation/deactivation of LP-WUS monitoring by gNB L1/L2 signaling with or without UE assistance.
  + Option 3: Activation/deactivation of LP-WUS monitoring based on condition(s), such as timer.
  + Option 4: Activation/deactivation of LP-WUS monitoring based on implicit indication/condition, e.g. UL transmission.

### **RAN1#116bis**

**Agreement**

Update the following agreement in RAN1#116 in red:

**Agreement**

* For RRC CONNECTED mode, from RAN1 perspective, further study following LP-WUS procedures to trigger PDCCH monitoring:
  + Case 1: PDCCH monitoring is triggered by LP-WUS with C-DRX configuration
    - Option 1-1: LP-WUS monitoring according to the LP-WUS monitoring configuration before drx-onDurationTimer to trigger the starting of the drx-onDurationTimer.
      * This option may replace DCP functionality
    - Option 1-2: LP-WUS monitoring outside at least legacy C-DRX active time according to the LP-WUS monitoring configuration to trigger PDCCH monitoring.
      * PDCCH monitoring possibly irrespective of drx-onDurationTimer
        + Option 1-2-1: PDCCH monitoring may be additionally triggered based on legacy C-DRX cycle and drx-onDurationTimer when monitoring LP-WUS

If this is adopted, it should be configured together with Option 1-1 to achieve power saving gain compared to legacy C-DRX

* + - * + Option 1-2-2: PDCCH monitoring is not triggered by legacy C-DRX cycle and drx-onDurationTimer when monitoring LP-WUS
    - Option 1-3: LP-WUS monitoring inside at least legacy C-DRX active time according to the LP-WUS monitoring configuration to trigger PDCCH monitoring.
  + ~~Case 2: PDCCH monitoring is triggered by LP-WUS without C-DRX configuration. LP-WUS can be monitored at any time according to the LP-WUS monitoring configuration~~
    - ~~FFS duty-cycled and/or continuous LP-WUS monitoring~~
* Combination of options in Case 1 ~~and combination of options in Case 1 and Case 2 are not precluded~~ should be considered.
* RAN1 does not discuss C-DRX related timers other than drx-onDurationTimer, this topic is up to RAN2
* Note: Above does not preclude to support fallback mechanism to trigger PDCCH monitoring, if any