**3GPP TSG RAN Meeting #100 RP-231021**

**Taipei, June 12-14, 2023**

## Status Report to TSG

**Agenda item:** 9.2.6

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **WI / SI Name** | Study on low-power Wake-up Signal and Receiver for NR | | | | |
| included in this status report | Study Item:  Yes | Core part:  No | Performance part:  No | | Testing part:  No |
| **Acronym** | FS\_NR\_LPWUS | | | | |
| **Unique ID** | 940085 | | | | |
| **TSG Tdoc of latest approved WI/SI description (if any)** | RP-222644 | | | | |
| **Target Completion Date**  **(indicate if changed)** | Study Item:  12/2023 |  |  |  | |
| **Overall Completion level** | Study Item:  65 % |  |  |  | |

Note: Overall completion level percentage numbers should use one of the colors below:

* xx%: Normal progress, no RAN plenary action needed
* xx%: Progress behind schedule, may need RAN plenary intervention. If so, SR should clearly define requested action
* xx%: Progress critically behind, RAN plenary shall intervene. SR should define requested action

**Source:**

|  |  |  |
| --- | --- | --- |
| **Leading WG** | | RAN 1 |
| **Rapporteur** | **Name** | Xiaodong Shen |
| **Company** | vivo Communication Technology |
| **Email** | shenxiaodong@vivo.com |

## 1 Work plan related evaluation

|  |  |
| --- | --- |
| **Do you want to modify the time budget for this WI/SI compared to what was endorsed at the last RAN meeting?** | No |

*If you answered No: Then please remove the Excel file from the zip file of this status report.*

*If you answered Yes: Then please fill out the attached Excel template to request a modification of the time budgets for your WI /SI. The Excel table has to be filled out for all affected RAN WGs and up to the target date of the WI/SI. The basis are the endorsed time budgets of the last RAN meeting. Please highlight all changes of the values.  
 One time unit (TU) corresponds to ~ 2 hours in the meeting.  
 If this status report covers a WI with Core and Performance part, then please have one line for each in the attached Excel table.  
 Note: If no Excel table is attached, then this means no time budget change.*

**Additional explanations/motivations for the time budget changes in the attached Excel table:**

## 2. Detailed progress in RAN WGs since last TSG meeting (for all involved WGs)

NOTE: Agreements and Open issues impacted cross-TSG aspects shall be explicitly highlighted

## 2.1 RAN1

#### 2.1.1 Agreements

**RAN1 #112-bis**

Evaluation on low power WUS

Agreement

Update as followings for the e-DRX paging probability

Note:

* For i-DRX with cycle duration Y second,
  + Per UE paging probability RE = 1 – (1 – RE, REF)Y/YREF
* For e-DRX with K i-DRX cycles duration, PTW duration of L i-DRX cycles, and an i-DRX cycle duration Y second
  + Per UE paging probability is
    - RE = 1 – (1 – RE, REF)(K-L+1)Y/YREF for the first i-DRX cycle within the PTW
    - RE = 1 – (1 – RE, REF)Y/YREF for each of the remaining L-1 i-DRX cycles within the PTW
      * L=4

Agreement

Update the additional transition energy from [TLR, ramp-up \*(PON+POFF)/2] to [TLR, ramp-up \*(PON-POFF)/2] for LP-WUR power model.

* Note: this assumes the power consumption during the transition time is sum of additional transition energy and LP-WUR OFF energy, e.g., similar definition as the additional transition energy in TR38.840

Working Assumption

For Model 1 of frequency error, Frequency displacement (Fd), defined as the difference between ideal frequency and frequency due to 1) clock drifting (ΔF); and 2) residual frequency error from previous synchronization/calibration (Fr), is given as Fd (ppm)=ΔF (ppm) +Fr(ppm),

* Companies to report Fr and important assumptions for achieving Fr, e.g., if MR can assist to calibrate LP-WUR to correct the frequency error or if LP-WUR can only correct the frequency error based on LP-WUS synchronization signal.

Agreement

The period of synchronization signal that LP-WUR used for at least power evaluation can be

* Existing SSB periodicity can be used from gNB transmission perspective for evaluations assuming SSB, companies to report how often used for LP-WUR
* For evaluations assuming LP-SS
  + {320ms, 640ms, 1280ms, 2560ms, 5120ms, 10240ms}
  + Companies to report other important assumptions if any, e.g., durations of LP-SS to achieve enough T/F accuracy
* Other values are not precluded

Note: companies to report the purpose of the synchronization signal along with evaluations, e.g. can be for LR synchronization (i.e., time and/or frequency tracking) and/or measurement.

Working Assumption

For evaluation purpose, FAR target is determined across a reference time duration T of one or multiple LP-WUS attempts/trials,

* UE have N attempts within T,
  + Company to report (FAR target, T, N)
* For example,
  + if UE makes a single decision based on multiple correlations for a sequence in the monitor occasion, these correlations are considered as UE implementation in ONE trial/attempt.
  + if UE performs decoding in a monitor occasion, a single decoding is considered as ONE trial/attempt.
* If UE performs N non-overlap attempts within the reference time duration, the false alarm event for the attempts are assumed as independent.

Companies to provide the assumed side conditions to attain the used FAR over T or per one attempt e.g. CRC/sequence length in LP-WUS design.

Agreement

RAN1 further study the designs [target]/techniques of LP-WUS to have a comparable coverage as NR channel X. The NR channel X is

* Option #1: PDCCH for paging
* Option #2: PUSCH for message3
* FFS other options, e.g., between option1and option2 (better than PUSCH, worse than PDCCH)
* The final design will jointly consider the coverage with other KPIs
* FFS additional detail assumptions for NR channels, e.g., the message size for MSG3 and etc.

Agreement

Confirm Alt 2 in the following agreement and update as follows

Agreement

For evaluation, at least for FR1 MR ultra-deep sleep state, (Ramp-up and down transition energy, ramp-up time) is as follows,

* Alt 1: (15000, 400ms) as baseline
* Alt 2: (~~[~~40000~~]~~, ~~[~~800ms~~]~~)

Company to report which alternative they use for which use cases.

**Agreement**

Confirm the WA from RAN1#112 and update as followings

**Working Assumption**

* For evaluation of LP-WUR frequency and time errors, the following is used,

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | |
| **Oscillator max frequency error [ppm], Oscillator frequency drift [ppm/s]** | option 1: (200, 0.1)  option 2: (50, 0.1)  option 3: (10, 0.05)  option 4: (5, 0.05)  Other values are not precluded for studying, reported by companies | |
| **RTC max frequency error [ppm],**  **FFS: RTC** **frequency drift [ppm/s]** | * + - 1. FFS:[0.1]) |  |

* Company to report how to use the clocks for LR on/off state**s**
  + The above clock assumptions for LR assumes the MR is in ‘ultra-deep sleep’ power state.
  + ~~For Option 3/4,~~ 
    - ~~FFS applicability when MR is in ultra-deep sleep power consumption state and associated power consumption for LR on state and LR off state,~~
      * ~~e.g., option 3/4 is not applicable~~
        + ~~when MR is in ‘ultra-deep sleep state’ with [0.015] power units and LR is in off state or,~~
        + ~~when LR monitoring power less than [TBD] power unit,~~
  + Note: Assumptions important for achieving performance by option 1/2/3/4 clock for LR should be declared, including active on/off power, transition energy/ ramp-up time TLR, ramp-up for LR and etc.
  + If MR is in other state than ‘ultra-deep sleep state’, the clock running for MR can be used for LR.
    - assumptions important for achieving performance by using MR clock for LR should be declared
  + Other clock accuracy options are not precluded. Companies to report options based on a feasibility analysis of clock power consumption and UE power consumption to use the clock accuracy option
* Company to report the frequency error assumption for the detection of LP-WUS/synchronization signal,
  + The following are examples for consideration, other approaches are not precluded,
    - Model 1:
      * The relationship between a drifted frequency error(ΔF), frequency drift ( F’) over a time (T1) is ΔF = ±F’ \* T1
      * When frequency displacement [Fd] reaches max frequency error, it is assumed to be equaled to max frequency error
      * T1 is the time from the previous frequency synchronization. T1 may take different values depending on the chosen frequency synchronization approach.
      * FFS: Frequency displacement (Fd), defined as the difference between ideal frequency and frequency due to 1) clock drifting (ΔF); and 2) residual frequency error from previous synchronization/calibration (Fr), is given as Fd (ppm)=ΔF (ppm) +Fr(ppm).
    - Model 2: random frequency drifting, FFS details
* Company to report the timing drifting error assumption for the detection of LP-WUS/synchronization signal,
  + The following are examples for consideration, other approaches are not precluded,
    - Model 1 [[R1-2301438](file:///D:\My%20Documents\002.Report\5G%20NR-vivo\Rel-18\AZP接收机\3GPP\Docs\R1-2301438.zip)] [[R1-2301558](file:///D:\My%20Documents\002.Report\5G%20NR-vivo\Rel-18\AZP接收机\3GPP\Docs\R1-2301558.zip)][R1-1714993]:
      * The relationship between the maximum frequency error(Fe) and corresponding timing drift( ΔT) over a time(T) is ΔT = ±Fe \* T (linear region)
      * The relationship between a frequency drift( F’), and corresponding timing drift(ΔT) over a time(T) is ΔT = Fr\*T ±0.5 \* F’ \*T2 (transient region)
      * The transition between transient and linear region (from synchronization or calibration point/time) occurs at time [Ts= (Fe-Fr)/( F’)]



* T is the time from the previous time synchronization. T may take different values depending on the chosen synchronization approach
* FFS: Time error (Te) before detection of a current sync signal is defined as the difference between ideal time of the current sync signal and the time error due to 1) clock time drift (ΔT); and 2) residual time error from previous synchronization/calibration (Tr); Te= ΔT+ Tr
* Model 2: random time drifting, FFS details
* FFS: Phase noise model

**Working Assumption**

**The following for usage of the clock is assumed for LP-WUR OFF/ON**

|  |  |
| --- | --- |
| Assumption on LP-WUR OFF power | Assumptions on the clock usage |
| 0.001 | When LP-WUR is OFF   * + Time offset cumulated in the off period cannot be calculated based on the parameters of the oscillator option 1/2/3/4. RTC should be used(Only RTC is running during sleep.)   When LP-WUR is ON, frequency offset and time offset calculation can follow the parameters of the oscillator option 1/2/3/4 [Note2] (cumulating based on the frequency drift and not exceed maximum frequency error)   * + The initial frequency offset when LP-WUR switches on can be set to the [FFS: maximum frequency error or a random value within the maximum frequency error] following the parameters of the oscillator option 1/2/3/4[Note2].   + When LP-WUR is synced with LP-SS/SSB or MR is used to assist to calibrate LP-WUR to correct the time/frequency error, residual frequency error Fr is assumed at the time when the synchronization/calibration is done. |
| TBD: value(s) | For both LP-WUR OFF and ON   * + Time offset cumulated in the off period can be calculated based on the parameter of the oscillator option 1/2 or option 3/4[Note2]. RTC can be used too.   + Frequency offset calculation can follow the parameter of the oscillator option 1/2 or option 3/4[Note2] (cumulating based on the second value in the value pair and not exceed maximum frequency error).   When at the time point after LP-WUR is synced with LP-SS/SSB or if MR can assist to calibrate LP-WUR to correct the frequency error   * + Frequency offset is the Fr, which is residual frequency error from previous synchronization/calibration |

[Note1: Any additional LO/FLL/PLL could start running during LP-WUR On duration. The power consumption of any of those LO/FLL/PLL is captured in LP-WUR On power]

FFS: Note2: option 3/4 can only be assumed when LP-WUR ON power value and LP-WUR OFF power value>=TBD2, option 1/2 can only be assumed when LP-WUR ON power value and LP-WUR OFF power value>=TBD1

Note3: The clock error (of both RTC and LO) could be improved to be less than max ppm error of option 1,2,3,4 with clock calibation based on sync signal such as LP-SS or preamble.

Low power WUS receiver architectures

Agreement

Provide the following response to RAN4 on “Whether IoT/wearables/smartphone UE types are all considered for LP-WUR design”:

* Yes, IoT/wearables/smartphone UE types are all considered for LP-WUR design, according to the following agreement made in RAN1#112:

|  |
| --- |
| **Agreement**  The following characteristics for target use cases are considered in the study item:   * IoT cases including e.g., industrial wireless sensors, controllers, actuators and etc, including the following characteristics,   + FFS: latency   + primary for small form devices   + power-sensitive   + static, nomadic or limited mobility * Wearable cases including e.g., smart watches, rings, eHealth related devices, and medical monitoring devices etc.,   + FFS: latency   + primary for small form devices,   + power-sensitive   + low/medium speed, FFS: high speed * eMBB cases including e.g., XR/smart glasses, smart phones and etc.,   + FFS: latency   + devices form is various and not restricted   + power-sensitive   + low/medium speed, FFS: high speed   Note: other use cases/characteristics are not precluded if any. |

Agreement

Provide the following response to RAN4 on “Whether FR1 is considered as first priority frequency range”:

* Yes, FR1 is considered as first priority frequency range in RAN1, and it is still FFS whether FR2 should be included in the scope of the SI.

Agreement

Provide the following response to RAN4 on “Whether in-band power boosting of LP-WUS is considered from RAN1 perspective”:

* RAN1 is considering as part of evaluation, the in-band power boosting of LP-WUS. As the starting point for link level simulations for LP-WUS, RAN1 has agreed on the following for the modelling of adjacent subcarrier interference. RAN1 would appreciate feedback from RAN4, if any, on the power boosting assumptions made in RAN1.

|  |  |
| --- | --- |
| Adjacent subcarrier interference | * PDSCH mapped on resources other than that for WUS and guard band;   EPRE of LP-WUS / EPRE of PDSCH =ρ, where ρ=0 dB as baseline, ρ= {3, 6} dB as optional |

Agreement

OOK-2 can be received using the agreed receiver architectures for OOK with parallel envelope detection.

**Decision:** As per email decision posted on April 21st,

Agreement

Provide the following response to RAN4 on “Power consumption, coverage and SNR targets”:

* RAN1 has not reached any agreements on LP-WUR power consumption targets. RAN1 is still studying it.
  + For the power consumption of LP-WUR, the following power model was agreed for evaluation purpose. Note that the power consumption is defined as the relative power w.r.t. the deep sleep state of the main radio following the non-RedCap UE power model defined in Section 8.1 of TR 38.840. The UE power model for RedCap UEs can be found in Section 6.2 of TR 38.875.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Agreement**  The following power model for LP-WUR is used for evaluation for FR1,   |  |  |  |  | | --- | --- | --- | --- | | **Power State** | **Relative Power (unit)** | **Transition energy:**  **(unit multiplied by ms)** | **Ramp-up time TLR, ramp-up (ms)** | | **Off** | 0.001 | [TLR, ramp-up \*(PON+POFF)/2] | TLR, ramp-up = FFS, and company to report TLR, ramp-up    FFS: Relation between Receiver architecture and its relative power and value of TLR, ramp-up | | **On** | ~~0.005/~~0.01/~~0.02/0.03/~~0.05/0.1/~~0.2/~~0.5/1/2/4  FFS: If other values are needed |   FFS: whether further categorization/sub-categorization is needed and how. |

* RAN1 has not reached any agreements on the coverage and SNR targets for LP-WUR. RAN1 is still studying these aspects.
  + For evaluation of the coverage of LP-WUS, RAN1 has agreed to use MIL as the metric, with more details in the following agreement.

|  |
| --- |
| Agreement  For evaluation of the coverage of LP-WUS, the methodology and assumptions in R17 CovEnh SI (described in TR38.830) is reused as baseline.   * MIL is used as the metric for LP-WUS coverage evaluation * urban (2.6GHz/4GHz), rural(700MHz) scenario for FR1 are considered to be evaluated, others (e.g., FR2) are not precluded.   Note: For IoT/wearables devices, refer to R17 Redcap SI TR38.875 if the assumptions differ from TR38.830.  Companies report any other assumptions which differ from the TR38.875/ TR38.830, e.g., Tx and Rx loss  Companies are encouraged to compare LP-WUS with at least PDCCH for paging, PUSCH, others are not precluded.  FFS: Target coverage of LP-WUS |

Agreement

Provide the following response to RAN4 on “Max occupied RB number in channel bandwidth for LP-WUS, for 1.4MHz and 5MHz RF bandwidth case”:

* For the bandwidth of LP-WUS, RAN1 has agreed on the following:

|  |
| --- |
| Agreement  For the purpose of study, the BW of one LP-WUS is not greater than X (FFS X is 5 or 20) MHz for FR1, study further   * whether BW of LP-WUS is configurable (implicitly or explicitly) * size of guard band [FFS: within or outside of BW X], if any * whether there is different X for Idle, Connected, Inactive modes   FFS: Whether FR2 is included in the scope of LP-WUS SI |

* RAN1 has not discussed the RF bandwidth of 1.4MHz for LP-WUS, and has not reached any conclusion on the maximum occupied RB number in 5MHz RF bandwidth case for LP-WUS. As the starting point for link-level simulations of LP-WUS, RAN1 has agreed on the following for LP-WUS bandwidth, the guard band and the filter.

|  |  |
| --- | --- |
| LP-WUS BW | Option 1:   * 5MHz including subcarriers for guard band * 4.32MHz (i.e.,12 RBs) for LP-WUS transmission for 30kHz SCS   Option 2:   * {2.16, 4.32} MHz including subcarriers for guard band * 1.44MHz, 2.88MHz (i.e.{4, 8} RBs) for LP-WUS transmission for 30kHz SCS   FFS: other options are up to companies to report  GB is symmetrically placed on each side of LP-WUS |
| Filter | X-th Order filter (e.g. Butterworth, Chebyshev, …) with Y MHz bandwidth,   * X = {3, 5} * Companies to report Y   Companies to report any other assumptions if needed |

Agreement

Provide the following response to RAN4 on “Possible supported SCS for LP-WUS, if applicable”:

* RAN1 has reached the following agreement on SCS:

|  |
| --- |
| **Agreement**  For MC-ASK or MC-FSK waveform generation, SCS of a CP-OFDM symbol used for LP-WUS generation can be the same as SCS used for other NR transmissions in CP-OFDM symbol overlapping in time with, study whether SCS can be different, also study   * FDM/TDM multiplexing with other NR transmissions * link performance * impact to legacy UEs * impact on gNB |

* In addition, as the starting point for link level simulations for LP-WUS, RAN1 has agreed on the following assumptions for LP-WUS:

|  |  |
| --- | --- |
| Configuration for LP-WUS signal | For OOK/FSK waveform,   * Option 1a: M=1 and SCSs = 15kHz (same as NR signal) * Option 1b: M=1 and SCSs = 30kHz (same as NR signal) * Option 2a: M =2/4/8 for SCS = 15KHz (same as NR signal) * Option 2b: M =2/4/8 for SCS = 30 kHz (same as NR signal) * Option 3: M=1 and SCSs = 60kHz/120kHz/240kHz * Note: M is referred to the definition of “M” in the agreements for OOK-1/2/3/4 and FSK-1/2   For OFDM: FFS, e.g., ZC sequence  Other options are up to companies to report |

Agreement

Provide the following response to RAN4 on “Whether WUS can be located in a band separate from the UE’s NR band”:

* RAN1 has reached the following agreement, and the case where WUS is located in a band separate from the UE’s NR band is to be further studied from RAN1 perspective.

|  |
| --- |
| Agreement   * Capture in TR: From RAN1 perspective, LP-WUS and signals/channels used by MR can be within the same FR1 band.   + At least LP-WUS and signals/channels by MR can be on the same carrier in the band * Study further   + Whether LP-WUS and signals/channels used by MR can be different carriers in the band   + Details on the LP-WUS location within a carrier   + ~~Whether LP-WUS is applicable for TDD / FDD (with full duplex operation)~~   + Band can be different than band of signals/channels used by MR   + LP-WUS association with BWP   + LP-WUS can be configurable within guard-band of a band (like NB-IoT) |

Agreement

Observation for FSK with frequency to amplitude conversion:

* The FSK architectures with frequency to amplitude conversion is applicable to single-SC FSK, but it may be challenging to make the frequency to amplitude conversion work well with multi-subcarrier FSK.
  + Note: single-SC FSK refers to the waveform where each frequency segment has a single subcarrier, and multi-subcarrier FSK refers to the waveform where each frequency segment has multiple subcarriers, as described in the agreements for FSK-1 and FSK-2.

[**R1-2304250**](file:///C:\Users\11048224\AppData\Local\Temp\Docs\R1-2304250.zip) **[Draft] Reply LS to RAN4 on LP WUR architectures Moderator (Apple)**

**Decision:** As per email decision posted on April 28th, the draft LS is revised and endorsed as [R1-2304288](file:///C:\Users\11048224\AppData\Local\Temp\Docs\R1-2304288.zip). Final LS is approved in [R1-2304251](file:///C:\Users\11048224\AppData\Local\Temp\Docs\R1-2304251.zip).

L1 signal design and procedure for low power WUS

Agreement

* Capture in TR: From RAN1 perspective, LP-WUS and signals/channels used by MR can be within the same FR1 band.
  + At least LP-WUS and signals/channels by MR can be on the same carrier in the band
* Study further
  + Whether LP-WUS and signals/channels used by MR can be different carriers in the band
  + Details on the LP-WUS location within a carrier
  + Whether LP-WUS is applicable for TDD / FDD (with full duplex operation)
  + Band can be different than band of signals/channels used by MR
  + LP-WUS association with BWP
  + LP-WUS can be configurable within guard-band of a band (like NB-IoT)

Agreement

Update the RAN1#112 agreement as the following:

* + ~~[time/frequency resources (including any guard bands), if applicable]~~
  + ~~[total energy of LP-WUS across the time/frequency resources]~~

For Working assumption in place of the above deleted bullets:

* + Alt 1:
    - average EPRE within the [time]/frequency resources used for LP-WUS (including any guard bands)
    - time/frequency resources used for LP-WUS (including any guard bands)
  + Alt 2:
    - average EPRE within the [time]/frequency resources used for LP-WUS (including any guard bands)
  + SNR is calculated as average EPRE divided by power of noise [and interference].
  + Companies to report whether and how power pooling across and within MR OFDMA symbols is used.
  + FFS: PAPR applicable to LP-WUS

Agreement

Replace in RAN1#112 agreement

Companies to report

* + ~~power consumption of the MR if false alarm probability/rate not fixed across MC-ASK, MC-FSK, and CP-OFDMA waveforms~~

with

* + receiver architecture type and its relative power consumption

Agreement

* For IDLE/INACTIVE 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
  + FFS: cell information
  + FFS: SI change and ETWS/CMAS information, tracking area information, and RAN area information
* 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.
* Other information candidates are not precluded
* Study pros and cons of including above information to LP-WUS.
* Note: the information may be explicitly or implicitly indicated.

Agreement

* For RRC connected mode, the following is assumed for LP-WUS study in RAN1
  + RLM/BFD/CSI are performed by UE Main Radio (MR)
  + RRM measurements are performed by UE Main Radio (MR)
  + Ultra-deep sleep state is not allowed for MR.
* Study additional support of RRM measurement by LP-WUR for RRC connected mode
* Study RRC connected mode LP-WUS functionality/purpose/procedures
* Study RRC connected mode LP-WUS activation/deactivation procedures.
* Study RRC connected mode LP-WUS BW, whether same as IDLE/Inactive mode or different
* In RRC connected, study the relationship between LP-WUS and legacy UE power saving techniques.

Agreement

* Study further following alternatives to carry the LP-WUS information using:
  + Alt 1: by sequence(s) detection/selection
    - FFS sequence type
  + Alt 2: by encoded bits
    - FFS: what type of encoding scheme
    - FFS: with or without other bits (e.g. CRC/FCS)
  + Other alternatives are not precluded
* Study whether LP-WUS information needs to be preceded by known one or more sequence(s).

Agreement

At least for IDLE/Inactive mode, at least one BW-size <=5MHz is recommended to be supported for FR1

* Other BW sizes are not precluded
  + if additional BW-size(s) are recommended to be supported, BW-size can be up to 20MHz
* LP-WUS bandwidth size (including guard-bands) is assumed to be an integer number of PRBs

Agreement

Study further methods to modulate input signal of the DFT/Least-Square block for OOK-4, and methods to modulate input signal of N SCs for other MC-ASK/FSK schemes

* study methods with respect to
  + improving frequency diversity by flattening the spectrum, frequency repetition and frequency hopping
  + impact to dynamic range of RE power in frequency domain
  + FFS: impact to PAPR of generated time domain modulated MC-ASK/FSK symbol
  + improving robustness to timing error necessary spectrum adjustment for compatibility with CP-OFDM generation

Agreement

* Study techniques/mechanisms to enhance coverage performance of LP-WUS
* Study potential gains available as well as drawback(s) of the technique(s)/mechanisms(s), e.g. system overhead, increased complexity network energy consumption etc…
* Study potential issues and corresponding solutions for the case when LP-WUS coverage is insufficient
  + At least study fallback mechanisms where the Main Radio switches to legacy operation in case the channel condition of LP-WUS is not sufficient, e.g. below threshold.

**RAN1 #113**

[**R1-2305954**](file:///C:\Users\11048224\AppData\Local\Temp\Docs\R1-2305954.zip) Draft TR 38.869 v020: Study on low-power wake up signal and receiver for NR Rapporteur (vivo)

The TR is endorsed.

Evaluation on low power WUS

**Agreement**

Use the same channel specific assumptions as defined in TR38.830 for reference PUSCH for message3, i.e.,

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Frequency hopping | w/ or w/o frequency hopping |
| Number of UE transmit chains | 1, 2 (optional) |
| Number of DMRS symbol | w/o frequency hopping: 3,  w/ frequency hopping: 2 for each hop |
| Waveform | DFT-s-OFDM |
| SCS | 30kHz for TDD, 15kHz for FDD. |
| HARQ configuration | Whether HARQ is adopted is reported by companies. |
| PUSCH duration | 14 OS |
| Number of PRBs | 2 |
| TBS | 56 bits |
| Other parameters | Reported by companies. |

**Agreement**

For reference setting for further study on LP-SS performance and resource overhead (including sync and/or measurement), companies to report the following used in their evaluations

* the number of slots or symbols per period
* the periodicty
* the functionality of the LP-SS

**Agreement**

----------------------------TP start for TR38.869 v0.1.0-------------------------------------------

**6.3.2 Power model for LP-WUR (LR)**

The following power model for LP-WUR is used for evaluation for FR1,

|  |  |  |  |
| --- | --- | --- | --- |
| **Power State** | **Relative Power (unit)** | **Transition energy:**  **(unit multiplied by ms)** | **Ramp-up time TLR, ramp-up (ms)** |
| **Off[1]** | 0.001 /  0.02/  ~~1% of ON Power value~~ 0.1~~/0.2/0.3~~, ~~only for 10/20/30~~, for 0.1, [oscillator option 3/4] are not used for envelope detection based receiver | [TLR, ramp-up \*(PON+POFF)/2] | TLR, ramp-up = FFS, and company to report TLR, ramp-up  FFS: Relation between Receiver architecture and its relative power and value of TLR, ramp-up |
| **On[2]** | 0.01/0.05/0.1/0.2/0.5/1/2/4/10/20/30   * ~~FFS: If other values are needed~~ |

* FFS: whether further categorization/sub-categorization is needed and how.
* FFS: Mapping from values to a LP-WUR architecture or LP-WUR mode of operation
* For evaluation, 10/20/30 for LP-WUR ON power state are not used for envelope detection based receiver for LP-WUS monitoring.
* For evaluation, 10/20/30 for LP-WUR ON power state are used for OFDM receiver when noise figure is less than [MR noise figure + 2.5dB], [0.2/0.5/1/2/4] for LP-WUS can be assumed for other NF values larger than [MR noise figure + 2.5dB]
* FFS: LP-WUR power consumption values for FR2.
* Note1: A unit of power is defined to be the same for main receiver and LP-WUS receiver.
* Note2: the values provided is for the purpose of studying power saving gain, and the values can be further revisit and categorization depending on the receiver architecture discussion.
* Note3: For LP-WUR ‘on’ state, more than one values within the above range may be used for evaluation (e.g. for a single LP-WUR architecture)
* Note4:
  + For WUR Off value 0.001, oscillator option 1, 2, 3, 4 are not assumed and only RTC is maintained;
  + [For WUR Off value 0.02, ~~only~~ oscillator option 1, 2 ~~can be assumed~~ and ~~only~~ RTC can be~~is~~ maintained; ]
  + ~~[For other WUR Off value, oscillator option 1,2,3,4 can be assumed.]~~
* Note5: Up to companies to report whether same or different values are assumed for WUS monitoring and time/frequency synchronization.

----------------------------TP End-------------------------------------------

**Agreement**

Confirm the following WA with the following changes

Working Assumption

The following for usage of the clock is assumed for LP-WUR OFF/ON

|  |  |
| --- | --- |
| Assumption on LP-WUR OFF power | Assumptions on the clock usage |
| 0.001 | When LP-WUR is OFF   * + Time offset cumulated in the off period cannot be calculated based on the parameters of the oscillator option 1/2/3/4. RTC should be used(Only RTC is running during sleep.)   When LP-WUR is ON, frequency offset and time offset calculation can follow the parameters of the oscillator option 1/2/3/4 ~~[Note2]~~ (cumulating based on the frequency drift and not exceed maximum frequency error)   * + The initial frequency offset when LP-WUR switches on can be set to the [FFS: maximum frequency error or a random value within the maximum frequency error] following the parameters of the oscillator option 1/2/3/4~~[Note2]~~.   + When LP-WUR is synced with LP-SS/SSB or MR is used to assist to calibrate LP-WUR to correct the time/frequency error, residual frequency error Fr is assumed at the time when the synchronization/calibration is done. |
| ~~TBD: value(s)~~  >0.001 | For both LP-WUR OFF and ON   * + Time offset cumulated in the off period can be calculated based on the parameter of the oscillator option 1/2 or option 3/4~~[Note2]~~. RTC can be used too.   + Frequency offset calculation can follow the parameter of the oscillator option 1/2 or option 3/4~~[Note2]~~ (cumulating based on the second value in the value pair and not exceed maximum frequency error).   When at the time point after LP-WUR is synced with LP-SS/SSB or if MR can assist to calibrate LP-WUR to correct the frequency error   * + Frequency offset is the Fr, which is residual frequency error from previous synchronization/calibration |

[Note1: Any additional LO/FLL/PLL could start running during LP-WUR On duration. The power consumption of any of those LO/FLL/PLL is captured in LP-WUR On power]

~~FFS: Note2: option 3/4 can only be assumed when LP-WUR ON power value and LP-WUR OFF power value>=TBD2, option 1/2 can only be assumed when LP-WUR ON power value and LP-WUR OFF power value>=TBD1~~

Note3: The clock error (of both RTC and LO) could be improved to be less than max ppm error of option 1,2,3,4 with clock calibation based on sync signal such as LP-SS or preamble.

**Agreement**

Observations:

|  |
| --- |
| For RRM with duty-cycled LP-WUS monitoring, the following observations are made with the assumption that   * MR in ultra-deep sleep * Effective per UE paging arrival rate <=1% * LP-WUR duty cycle ratio <=2% * MR ramp-up time/transition energy option 1 (i.e., 400ms, 15000) * RRM relaxation is assumed for both serving and neighbouring cells   Compared with i-DRX, LP-WUS operation with   * No RRM relaxed * Compared with i-DRX with and without PEI, LP-WUS provide mean power saving gain ([-301%~-569%]) * MR relaxed < 8 times * Compared with i-DRX with and without PEI, LP-WUS provide mean power saving gain ([-10%~7%)) * 8 times<= MR relaxed <=16 times * Compared with i-DRX with and without PEI, LP-WUS provide mean power saving gain ([31%~60%]) * RRM relaxed > 16 times * Compared with i-DRX with and without PEI, LP-WUS provide mean power saving gain ([60~92%]) * RRM offload RRM to LR * Compared with i-DRX with and without PEI, LP-WUS provide mean power saving gain ([76%~92%])   Note: The ‘Effective per UE paging arrival rate’ is defined as (without taking FAR into account)   * Per UE paging probability RE if LP-WUS is per UE paging * Per group paging probability RG = 1 – (1 – RE)N, if LP-WUS is per group paging (N is the number of UEs in the group) |

There will be another observation for continuous monitoring case

Low power WUS receiver architectures

**Agreement**

Include the following in the reply LS to RAN4:

*For LP-WUS/WUR evaluation purpose, RAN1 has not included the case when the WUS/WUR is same as NR channel bandwidth. As the starting point for link level simulations for LP-WUS, RAN1 has agreed on the following for gNB channel BW and LP-WUS BW:*

|  |  |
| --- | --- |
| *gNB Channel BW* | *20MHz, FFS other values* |
| *LP-WUS BW* | *Option 1:*   * *5MHz including subcarriers for guard band* * *4.32MHz (i.e.,12 RBs) for LP-WUS transmission for 30kHz SCS*   *Option 2:*   * *{2.16, 4.32} MHz including subcarriers for guard band* * *1.44MHz, 2.88MHz (i.e.{4, 8} RBs) for LP-WUS transmission for 30kHz SCS*   *FFS: other options are up to companies to report*  *GB is symmetrically placed on each side of LP-WUS* |

**Agreement**

Proposed observation 4-1: (FSK parallel receiver)

For FSK receiver based on parallel OOK receivers with heterodyne or zero-IF architecture,

* If no interference between the segments’ detectors is allowed, the frequency gap between two adjacent frequency segments should not be smaller than two times the maximum frequency offset, and at least two times of the max frequency offsets within the frequency gap should not be used by other DL signals/channels or other WUS signals.
* If some interference between the segments’ detectors is allowed, it can be possible to have frequency gap between two adjacent frequency segments smaller than two times the maximum frequency offset, where the gap is not used by other DL signals/channels or other WUS signals.

**Agreement**

Proposed observation 4-3: (FSK with frequency to amplitude conversion)

For the FSK architectures with frequency to amplitude conversion, the bandwidth between the frequency segments used for FSK transmissions may not be used for other LP-WUSs or legacy NR transmission in order to allow frequency to amplitude conversion to work properly.

**Agreement**

LS to RAN4 is endorsed (draft in [R1-2306125](file:///D:\My%20Documents\002.Report\5G%20NR-vivo\Rel-18\AZP接收机\3GPP\Docs\R1-2306125.zip)). Final LS in [R1-2306126](file:///D:\My%20Documents\002.Report\5G%20NR-vivo\Rel-18\AZP接收机\3GPP\Docs\R1-2306126.zip)

**Agreement**

For the LP WUR architectures analysis, in addition to LP-WUS detection, consider the following functions when necessary:

* Synchronization signal processing and time/frequency synchronization for LP-WUR
* RRM measurement at least for the serving cell

**Agreement**

For the baseband processing of the LP WUR architectures,

* The baseband processing may use Goertzel filters as an alternative for FFT to compute the signals for one or more tones. Tone energy is computed and a detection algorithm is used to detect the presence of LP-WUS. One example diagram is shown below:
  + A diagram of a flowchart

    Description automatically generated with low confidence
  + This can be used with the receiver architecture for OFDMA-based signals/channels for OOK-3.
  + This can be used with heterodyne receiver architecture with IF envelope detection or the homodyne receiver architecture with baseband envelope detection for [OOK-1]/FSK-2.
* For the receiver architecture for OFDMA-based signals/channels,
  + The receiver architectures for OFDMA-based signals/channels can be used for OOK/ASK and FSK modulated LP-WUS
  + For sequence-based OFDM signals/channels, one example diagram with time domain correlator (without FFT) for LP-WUS detection is shown below:
    - A picture containing line, diagram, font, text

      Description automatically generated

L1 signal design and procedure for low power WUS

**Agreement**

* For at least RRM serving cell measurement performed by LP-WUR based on reference signal(s), RAN1 identified at least the following metrics for further study and evaluation (including feasibility, complexity, power consumption, etc)
  + LP-RSSI or Energy detection: linear average of total received power over a RSSI resource.
    - FFS RSSI resource.
  + LP-RSRP: linear average of received power of resource of reference signal(s) or signal(s) parts.
    - FFS resource of reference signal(s) or signal(s) parts
  + LP-SINR = LP-RSRP/(power of interference and noise)
    - FFS how to define “power of interference and noise”
  + LP-RSRQ= [N x] LP-RSRP/LP-RSSI, where N is the factor of resource size difference for evaluation LP-RSRP and LP-RSSI.
  + Accounting AGC accuracy, ADC of at least 4 bits is required.
* Note: Reference signal for performing measurements can be e.g. SSB (PSS/SSS/PBCH DMRS), LP-WUS-waveform sequence, LP-SS
* Note: The definition of metrics could be further refined based on future study

**Agreement**

Power pooling between OFDM symbols is not assumed for evaluation purposes. Average EPRE is defined per OFDM symbol.

**Agreement**

**The following observations are to be captured in the TR**

* At least for LP-WUR that cannot receive existing PSS/SSS, periodic LP-SS signal is beneficial for the following functionality.
  + RRM measurements by LP-WUR, if supported
  + at least coarse time synchronization of LP-WUR.
  + at least coarse frequency synchronization of LP-WUR.
* Additional periodic LP-SS system overhead depends on LP-SS periodicity, system BW, # of beams, and resource required to fulfil the target functionality, etc. Periodic signal if used for coarse synchronization may reduce overhead of signal preceding LP-WUS, if any. LP-SS can be designed to be common among UE groups (cell-specific) and such further reduce system overhead.
* For LP-WUR that can receive existing PSS/SSS potentially assisted by PBCH DMRS/TRS for synchronization, existing PSS/SSS potentially assisted by PBCH DMRS/TRS may be used for above functionality.
* Periodic LP-SS coverage should be equal or better than that of LP-WUS.
* For fine time and frequency synchronization, a signal (e.g. preamble) preceding or part of LP-WUS may be used.

**Agreement**

* For Idle/Inactive mode, study offloading of RRM measurements of serving cell to LP-WUR under certain conditions, if any, and relaxation of serving/neighboring cell RRM measurements in MR considering
* Periodic reference signal(s) is/are used for LR measurements.
* FFS: reference signal(s) to measure, e.g. PSS/SSS/PBCH DMRS, LP-WUS waveform sequence, LP-SS
* FFS: periodicity, content
* MR performs measurements
* Alt2: with relaxed periodicity if RRM measurement in MR is relaxed.
  + - FFS: Condition for relaxation if any
    - Can apply for both neighboring and serving cell
* Alt3: only when reference signal(s) based measurements by LP-WUR satisfy certain condition(s), e.g. are below threshold.
  + - FFS threshold.
    - Above MR measurement under certain conditions can apply for both neighboring and serving cell
    - Potentially with relaxation methods for MR neighboring cell measurement
* Other alternatives are not precluded
* FFS: Feasibility of RRM measurements of neighbor cells by LP-WUR

**Agreement**

* For waveform generation the following observations are made
  + Flat spectrum in frequency domain provides robustness against frequency selective fading compared to concentrated energy in frequency domain.
    - for OOK-4, sequence before DFT/LS with variation in phase via such as ZC, M-sequence or QAM sequence can achieve more flattened spectrum.
  + Sequences(s) used in LP-WUS symbol generation with different pulse shape or spectral shape may have different performance.
  + Knowledge of sequence(s) used in LP-WUS waveform generation may improve performance for at least a receiver with I/Q branches
* Further discuss the following potential observations for waveform generation:
  + When DFT is employed in OOK-4 (M>=2), -1/1 alternation in time or frequency shift in frequency domain may be needed to match CP-OFDM generation.
  + Pre-storing of the generated frequency domain samples at gNB may reduce complexity of waveform generation at gNB with memory requirement depending on number of possible combination. This may be up to gNB implementation.
  + quantization of generated waveform in frequency domain to existing constellation (e.g. 64QAM) has low impact on performance and reduces complexity. This may be up to gNB implementation.
  + Repetition of a sequence(s) used in LP-WUS generation in frequency can be used to improve diversity for MC-OOK and robustness against frequency offsets for MC-FSK.

**For companies to consider for providing evaluation results**

* Cross-waveform-comparison
  + OOK-1 M=1 and OOK-4 M=1 (may not need to be simulated, difference can be only in frequency domain sequence used)
  + OOK-1 with M x higher SCS than NR, and OOK-4 M
    - M=2,4
  + OOK-4 M=2 and OOK-2 M=2
  + OOK-3 M=1 and OOK-1 M=1
  + OOK-1 and OOK-2 M=2 with further reduced coderate/increased sequence length
  + OOK-1 and OOK-4 M=2 with further reduced coderate/increased sequence length
  + FSK1/2 M=1 (1bit per OFDMA symbol) and OOK-1 M=2
  + FSK1/2 M=2 (2bits per OFDMA symbol) and OOK-2 M=4
  + FSK1/2 M=2 (2bits per OFDMA symbol) and OOK-4 M=4
  + OFDMA and other waveforms with roughly matching T-F resources
  + Note: Above cases should result in same length of LP-WUS in OFDMA symbols and BW for both compared waveforms
* Manchester coding 1/2 is applied to OOK for at least encoded bits (payload).
* At least time and frequency impairments should be included.
  + residual time offset 0, 1, 2 and 4 us
  + residual frequency offset 0, 1, 2, 5 and 10
    - optional 50, 100 ppm
  + showing tolerance higher than above values is not precluded
* If further improvement of the signal generation for the agreed waveforms is applied, companies are to provide relevant details
* For evaluation of LP-SS accuracy, assume SNR at [-3dB] and LP-WUR noise figure should be reported

**Agreement**

* Study the following techniques/mechanisms to enhance coverage performance of LP-WUS
  + low complex channel coding
    - FEC
    - spreading code in time domain
    - time domain repetition
    - with combining before or after ED
    - time-domain interleaving
    - Note: Also Manchester coding can be considered as channel code
  + non-contiguous transmission in the frequency domain
  + frequency domain repetition
  + frequency-hopping
  + power-boosting
  + transmit diversity
  + study whether any above techniques could be transparent to UE.

**Agreement**

* For Idle/Inactive mode, following options for activation and deactivation of LP-WUS monitoring by LP-WUR for a UE can be considered for study
* Alt 1a:
  + gNB transmits legacy paging indication and LP-WUS
  + UE activation and/or deactivation of LP-WUS WUS monitoring is up to UE implementation.
  + This behavior may apply based on channel condition, e.g. when coverage is sufficient/insufficient.
* Alt 1b:
  + gNB transmits legacy paging indication and LP-WUS
  + UE activation and/or deactivation of LP-WUS monitoring is based on preconfigured criteria
  + This behavior may apply based on channel condition, e.g. when coverage is sufficient/insufficient.
* Alt 2:
  + activation and/or deactivation of LP-WUS monitoring in a cell is based on signalling.
* Paging misdetection performance shall not be impacted.

**Agreement**

* In RRC CONNECTED mode, study benefit of LP-WUS over existing Rel-15, R16, and R17 power saving techniques for following functionalities:
  + LP-WUS with similar functionality as R16 DCP.
  + LP-WUS activates/resumes PDCCH monitoring when LP-WUS is received.
    - interaction with legacy power saving techniques, if any
  + other functionalities are not precluded
  + for evaluation
    - companies to report
      * assumption on MR sleep state when LP-WUR is monitoring LP-WUS
        + deep sleep,
        + light sleep,
        + micro sleep
      * how to activate/deactivate LP-WUS monitoring and deactivate/activate PDCCH monitoring
      * LP-WUS waveform
* 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.

#### 2.1.2 Remaining Open issues

* Conclude from RAN1 perspective on the study and evaluate wake-up signal designs to support wake-up receivers [RAN1, RAN4]
* Conclude from RAN1 perspective on the study and evaluate L1 procedures and higher layer protocol changes needed to support the wake-up signals [RAN2, RAN1].
* Conclude the study potential UE power saving gains compared to the existing Rel-15/16/17 UE power saving mechanisms and their coverage availability, as well as latency impact. System impact, such as network power consumption, coexistence with non-low-power-WUR UEs, network coverage/capacity/resource overhead should be included in the study [RAN1]
* Conclude from RAN1 perspective on the study for low-power wake-up receiver architectures [RAN1, RAN4]

## 2.2 RAN2

#### 2.2.1 Agreements

**RAN2#121bis-e**

* Aim to do every Q: Collect RAN2 text proposals in a single document during the following meeting(s) and send the document to RAN1 as the input to the TR 38.869.
* Confirm that we follow R1 and include RRC idle/inactive/connected.
* Ultra-deep-sleep = R2 understands for now that this is a power saving state (introduced by R1) to denote a state when the Main Receiver (MR) may sleep/turn off.
* In scope: Use LPWUS with Idle / Inactive UE camping with reception of paging and other necessary transmissions (from serving cell), reusing if possible/reasonable concepts from earlier releases, where the LPWUS either wakes the UE to receive by MR, or it conveys information by itself, or both.

**RAN2#122**

* RAN2 expect that different coverage LR/MR may have RAN2 impact, e.g. UE need to stop using LP WUS when moving out of LR coverage, other aspects FFS. What to cover (if anything) in TS 38.304 is FFS.
* For UE in RRC\_IDLE/RRC\_INACTIVE state, it is FFS to what extent the network is or need to be aware of which receiver the UE uses MR/LR or both (for paging reception etc). A potential drawback of not knowing could be increased LP WUS load, a potential drawback of awareness is increased signalling.
* RAN2 assumes that UE uses LP WUS when pre-configured condition(s) are fulfilled.   
  (Other control methods not precluded)
* RAN2 assumes that using subgrouping for LP-WUS could be beneficial to reduce false alarms rate (depend on L1 capacity to carry payload).

#### 2.2.2 Remaining Open issues

The following open issues need to be addressed:

* Study and evaluate higher layer protocol changes needed to support the wake-up signals [RAN2, RAN1]

## 2.3 RAN3

#### 2.3.1 Agreements

#### 2.3.2 Remaining Open issues

## 2.4 RAN4

#### 2.4.1 Agreements

**RAN4 #106bis-e**

* General
* Reply LS to RAN1 on LP-WUS is approved [20]
* Topic summary on LP-WUS in [18]
* WF on LP-WUS was approved in [19]

**Issue 2-1-1: Frequency range**

Agreements:

* + RAN4 focus on FR1 frequency ranges first priority, 2.6GHz can be selected as an example band.

**Issue 2-1-2: UE type**

Agreements:

* + Based on RAN1 agreements, RAN4 should consider all the UE types mentioned in the SID, e.g. IoT devices, Wearable devices, and e-MBB devices. The cost aspect can also be considered for the design of LP-WUS/WUR scheme.

**Issue 2-1-4: general views for WUR architectures**

Agreements:

* + Further discuss WUR need to be capable of configuring the same raster point with main receiver.
  + WUS repetition is signal design which is RAN1 task, no RAN4 discussion is needed.
  + Architecture in P3 could belong to the variant of general architectures mentioned in RAN1 LS.

**Issue 2-2-1: Guard RBs definition for LP-WUS**

Agreements:

* RAN4 use guard RBs (if needed) for LP-WUS, which is Granularity of RB. The traditional guardband for NR channel bandwidth defined in TS 38.101-1 should not be changed.
  + For case when WUS is smaller than NR channel bandwidth
    - For case 2-1, the LP-WUS guard RB is number RBs between LP-WUS and NR signals (edge of WUR RB location to nearest edge of eMBB RB)
    - For case 2-2, the WUS is placed at the edge of the NR channel bandwidth, i.e. the lowest/highest RB of WUS with guard RBs is aligned with the lowest/highest NR transmission bandwidth configuration in spec TS 38.101-1.
  + [For case when the WUS/WUR is same as NR channel bandwidth]
    - For case 1, the LP-WUS guard RBs is number RBs between LP-WUS and traditional guardband (edge of WUR RB location to Outermost of NRB)
    - RAN4 should further check with RAN1 for this case
* FFS whether the guard RBs should be symmetric within the WUS channel bandwidth.

**Issue 2-2-2: Whether guard RBs is needed for LP-WUR**

Agreement:

* How many RBs (if needed) for guard is FFS. RAN4 should further evaluate this number based on the cases identified in issue 2-2-1.
* The size of guard RBs from implementation perspective for LP-WUS should be determined in RAN4.

**Issue 2-3-1: General evaluation framework for both ACS and ASCS**

Agreement:

* The following aspects can be starting point for further discussions
* Framework in RAN4 that the ACS and ASCS value can be evaluated based on the following aspects:
  + Typical filter characteristic, e.g. filter order, pass BW, cut-off frequency
  + Guard RB size within LP-WUS channel bandwidth
  + RF impairment can also be considered
* Averaged power attenuation at ACS or ASCS frequency range
* FFS whether SINR of the wanted signal at detector input is needed
* FFS whether use ICS to instead ASCS
* FFS Coexistence-simulation-based framework can also be considered
  + FFS on details of coexistence study (if needed) of LP-WUS
  + Coverage should be considered

**Issue 2-3-2: LP-WUS evaluation scenarios for study purpose**

Agreements:

* Consider a limited set of WUS scenarios in table below for study purpose in RAN4

**Table 1: LP-WUS evaluation scenarios**

|  |  |
| --- | --- |
| NR RF channel BW | 5MHz for 1.4MHz WUS; 20MHz/100MHz for 5MHz WUS |
| Guardband of NR channel | Unchanged, defined in Clause 5.3.3 in TS 38.101-1 |
| WUS BW within NR channel | 1.44MHz, 5.04 MHz |
| WUS RB allocation (Note 1) | [6] RB in 1.44 MHz, total 8 RBs, or other number of RBs  [24] RB in 5.04 MHz, total 28 RBs, or other number of RBs |
| WUS placement within NR channel | 3 cases:   * case 1: Center; * case 2: edge; * case 3: between center and edge of NR channel |
| Guard RB size of LP-WUS | * 0 RB, 1RB at each side, 2RBs at each side, or other number of RBs. * Asymmetric guard RB can also be considered |
| ACS interferer | According to RF CBW |
| Filter characteristic | 2nd to 5th order Butterworth  Both analog and digital filter can be considered |
| Filter passband BW | At least WUS bandwidth (number of RBs), depends on guard RB size |
| LO frequency | Case 1: In the middle of WUS (modeling fixed WUS position)  Case 2: In the middle of RF channel (modeling flexible WUS location) |
| Target ACS | TBD |
| Target ASCS | TBD |
| Target WUS SNR | TBD |
| RF impairment | FFS |
| Note 1: the maximum number of allocated WUS RBs, depends on how many Guard RBs are needed. 5MHz WUS within 5MHz NR CBW is not considered currently. | |

**Issue 2-3-3: How to determine guard RBs for LP-WUS**

**Agreements:**

* RAN4 can perform more analysis based on the framework in issue 2-3-1 and selected scenarios in 2-3-2, and further discuss how to determine guard RBs next meeting.

**Issue 2-3-4: Whether WUS can be flexibly located within the NR carrier**

**Agreements:**

* FFS whether LP-WUS can be flexible or partially flexible located within NR carrier.
  + pros and cons of flexible WUS location can be studied

**Issue 2-3-6: RF impairment impacts**

**Agreements:**

* ACS, ASCS and guard RBs study can consider the receiver RF impairments and the required wake-up signal SNR.
* FFS whether RAN4 should agree on a phase noise profile for wake-up receiver study
* FFS on the CFO assumed in simulation
* FFS on other receiver RF impairment modeling.

**Issue 2-5-1: Whether and which power boosting level RAN4 should study LP-WUS power boosting**

Agreement:

* RAN4 should study the power boosting if triggered by RAN1, to check whether the values are feasible from RAN4 perspective.

**Issue 2-5-3: other gNB impacts**

**Agreements:**

* RAN4 recommends RAN1 to prioritize signal design which allow re-use of current gNB HW.

**Issue 2-6-1: Whether a dedicated band for WUS is needed**

Agreement:

* Wait for RAN1 response for further discussion and decision.

**Issue 2-7-1: SNR evaluation activity in RAN4**

Agreements:

* RAN1 is performing SNR evaluation, the WUS SNR analysis can be done in RAN1. RF impairment aspects, e.g. frequency error and ADC sampling accuracy, if identified and confirmed, can be sent to RAN1 for consideration

**Issue 2-8-1: Whether make down-selection is needed in RAN4**

Agreement:

* RAN4 further evaluate the pros and cons of each architecture based on agreed framework and selected scenario. Make decision on architecture down-selection next meeting and send decisions to RAN1.

**Issue 3-4: other receiver architectures for WUR**

Agreement:

* RAN4 focus on the discussions on LS related issues.

**RAN4 #107**

* General
* Topic summary on LP-WUS in [14]
* Ad-hoc meeting minutes in [16]
* WF on LP-WUS was approved in [15]

**Issue 1-1-1: Refinement of ACS evaluation framework for LP-WUR in RAN4**

**Agreement:**

* Focus on the issues in the RAN1 LS.
* For ACS evaluation, focus on the evaluation of guard RB rather than ACS requirements
  + Take implementation complexity into account

**Issue 1-1-2: Target ACS value for LP-WUR receiver**

**Agreement:**

* The methodology for guard RB is that at first conclude the relationship between guard RB and adjacent channel selectivity.
* WUR ACS should be further discussed in the context of the guard RB design and main receiver test requirement.

**Issue 1-1-3: Required number of guard RBs for LP-WUS ACS**

**Agreement:**

* Companies provide the analyzed results with the RF impairment assumptions. RAN4 target to make decision on required number of guard RBs next meeting.
* RF impairments and power cost impacts can be claimed by companies used in the analysis
* For each RF impairment could be reported for different RF architecture
* Companies are encouraged to provide the text proposals for RAN4 RF architecture evaluation.

**Issue 1-1-4: Whether guard RBs should be symmetric**

**Agreement:**

* No need to restrict symmetric guard RBs within the WUS channel bandwidth

**Issue 1-1-5: Whether ACS Guard RB at channel edge should be empty RB, or can also be used for NR signal**

**Agreement:**

* RAN4 could further discuss whether the guard RB for WUS ACS could be used for NR.

**Issue 1-1-6: Filter implementation**

**Agreement:**

* The possible degradation of filter rejection for real implementation can be counted in evaluation of guard RBs for LP-WUS

**Issue 1-1-7: WUR RF impairments impacts**

**Agreement:**

* At least, the CFO should be considered, and the assumed value needs to be reported by companies next meeting.

**Issue 1-2-1: ASCS evaluation**

**Agreements:**

* RAN4 should define a detailed description for ASCS metric for evaluation purpose, i.e., similar to ACS, for 5MHz WUS, the ACSC BWinterference is set as 5MHz, for both ~5MHz and ~1.4MHz WUS cases, as a starting point.

**Issue 1-2-3: Guard RBs for LP-WUS ASCS**

**Agreement:**

* The methodology for adjacent sub-carrier selectivity is that at first conclude the relationship between guard RB and adjacent sub-carrier selectivity.
* WUR ASCS should be further discussed in the context of the guard RB design
  + Assume the same PSD with WUS signal
    - Power boosting evaluation for BS is not precluded
* FFF whether ASCS evaluation should consider two different cases, e.g. high SNR and Low SNR

**Issue 1-2-4: WUS location within the carrier**

**Agreements:**

* Study UE and filter complexity and power consumption due to flexible WUS frequency location within the NR carrier except the traditional minimum guard-band of NR channel
* The guard RBs within WUS should not be overlapped with NR guardband
* The WUS flexibility vs UE and filter complexity is aimed to be documented in the TP to RAN1 TR and sent to RAN1

**Issue 1-4-1: LP-WUS power boosting**

**Agreement:**

* + Study whether gNB can boost WUS of 24 RB with X dB., e.g X = 3 or 6 dB based on the information from RAN1 LS in R4-2307012.

**Issue 1-5-1: dedicated band for LP-WUS operation**

**Agreement:**

* + Dedicated band should be global operation band with commercial network proposed by operator or spectrum management organization
  + Dedicated band considered together with RF ED architecture

**Issue 1-6-1: Variant of different LP-WUR architectures**

**Agreement:**

* + As long as the variant LP-WUR architectures belong to the architectures mentioned in RAN1 LS, they can be considered in RAN4 evaluation

**Issue 1-6-2: LP-WUR architectures down selection**

**Agreement:**

* + RAN4 could make down-selection based on the analysis outcome from issue 1-1, 1-2 and 1-3, in future meetings.

**Agreement:**

* + LP-WUR RF evaluation could consider all possible LP-WUS waveforms identified by RAN1.

#### 2.4.2 Remaining Open issues

The following open issues need to be addressed:

* From RAN4 perspective, study and evaluate low-power wake-up receiver architectures [RAN1, RAN4]
* From RAN4 perspective, study and evaluate wake-up signal designs to support wake-up receivers [RAN1, RAN4]
* Final LS feedback to RAN1 on LP-WUR architecture
* RAN4 TPs on LP-WUR RF aspects to TR

## 2.5 RAN5

#### 2.5.1 Agreements

#### 2.5.2 Remaining Open issues

#### 2.5.3 Remaining Open issues with cross-WG dependencies

## 2.6 RAN6

#### 2.6.1 Agreements

#### 2.6.2 Remaining Open issues

## 3. Detailed progress in SA/CT WGs since last TSG meeting (for all involved WGs)

NOTE: This section only needs to be filled in for WI/SIs where there is a corresponding relevant WI/SI in SA/CT.

## 3.1 SAx/CTs

#### 3.1.1 Agreements with cross-TSG impacts

#### 3.1.2 Remaining Open issues with cross-TSG impacts

NOTE: This section should also flag any critical dependencies that need TSG attention.

## 4. References

NOTE: This can be e.g. a list of all related Tdocs in the affected WGs since last TSG, references to LSs, produced TRs/TSs, the work/study item description or status reports of previous TSGs.

RAN1 #113:

1. R1-2304355 Discussion on LP-WUS Receiver Architectures FUTUREWEI
2. R1-2304356 LP-WUS Physical Signal Design and Performance FUTUREWEI
3. R1-2304415 Low Power WUS receiver architectures Nokia, Nokia Shanghai Bell
4. R1-2304417 L1 signal design and procedures for low power WUS Nokia, Nokia Shanghai Bell
5. R1-2304441 Discussion on evaluation on LP-WUS InterDigital, Inc.
6. R1-2304442 Discussion on LP-WUS receiver architectures InterDigital, Inc.
7. R1-2304501 Remaining issues on low power wake-up receiver architecture vivo
8. R1-2304520 L1 signal design and procedure for low power WUS TCL Communication Ltd.
9. R1-2304530 Evaluation on LP-WUS ZTE, Sanechips
10. R1-2304531 LP-WUS receiver architectures ZTE, Sanechips
11. R1-2304532 LP-WUS design and related procedure ZTE, Sanechips
12. R1-2304579 Discussion on L1 signal design and procedure for low power WUS Spreadtrum Communications
13. R1-2304618 Evaluations for LP-WUS Huawei, HiSilicon
14. R1-2304619 Discussion on architecture of LP-WUS receiver Huawei, HiSilicon
15. R1-2304620 Further details on signal design and procedure for LP-WUS Huawei, HiSilicon
16. R1-2304714 Remaining issues of Deployment scenarios and evaluation methodologies and preliminary performance results of LP-WUR CATT
17. R1-2304715 Low-Power WUS receiver Architectures and its performance CATT
18. R1-2304716 Physical layer signals/procedures and higher layer protocol for Low-Power WUR CATT
19. R1-2304797 Evaluation of LP-WUS and Performance Results FUTUREWEI
20. R1-2304803 Evaluations on LP WUS Intel Corporation
21. R1-2304804 Discussions on L1 signal design and procedure for LP-WUS Intel Corporation
22. R1-2304864 Discussion on signal design and procedure for LP-WUS China Telecom
23. R1-2304882 Evaluation on low power WUS xiaomi
24. R1-2304883 Discussions on L1 signal design and procedure for low power WUS xiaomi
25. R1-2304994 Discussion on L1 signal design and procedure for LP-WUS NEC
26. R1-2305013 Discussion on L1 signal design and procedure for low power WUS EURECOM
27. R1-2305051 Evaluation of low power WUS Sony
28. R1-2305052 On L1 signal design and procedures for low power WUS Sony
29. R1-2305055 On L1 signal design and procedure for LP-WUS Vodafone
30. R1-2305114 Discussion on L1 signal design and procedure for LP-WUS CMCC
31. R1-2305146 Discussion on evaluation for LP-WUS LG Electronics
32. R1-2305147 Discussion on L1 signal design and procedure for LP-WUS LG Electronics
33. R1-2305266 On low power wake-up receiver architectures Apple
34. R1-2305267 Summary #1 on LP WUR architectures Apple
35. R1-2305268 Summary #2 on LP WUR architectures Apple
36. R1-2305269 Summary #3 on LP WUR architectures Apple
37. R1-2305270 On the L1 signal design and procedures for low power wake-up signal Apple
38. R1-2305309 Discussion on L1 signal design and procedure for low power WUS Sharp
39. R1-2305359 Receiver architecture for LP-WUS Qualcomm Incorporated
40. R1-2305360 L1 signal design and procedures for LP-WUR Qualcomm Incorporated
41. R1-2305450 Evaluation for lower power wake-up signal OPPO
42. R1-2305451 Discussion on low power WUS receiver OPPO
43. R1-2305535 Evaluation on LP-WUS/WUR Samsung
44. R1-2305536 Receiver architecture for LP-WUS Samsung
45. R1-2305537 Signal design and procedure for LP-WUS Samsung
46. R1-2305576 Low power WUS receiver architectures Ericsson
47. R1-2305577 L1 signal design and procedure for low power WUS Ericsson
48. R1-2305615 Discussion on L1 signal design and procedure for low power WUS NTT DOCOMO, INC.
49. R1-2305652 Evaluation on low power WUS MediaTek Inc.
50. R1-2305653 Low power WUS receiver architectures MediaTek Inc.
51. R1-2305654 L1 signal design and procedure for low power WUS MediaTek Inc.
52. R1-2305767 Discussion on low power wake up receiver architectures Panasonic
53. R1-2305768 Discussion on low power wake up signal design Panasonic
54. R1-2305854 On LP-WUS signal design Nordic Semiconductor ASA
55. R1-2305919 Discussion on the L1 signal design and procedure for low power WUS Lenovo
56. R1-2305952 FL summary #1 of evaluation methodologies on LP-WUS/WUR Moderator (vivo)
57. R1-2305953 Summary of  evaluation results #1 Moderator (vivo)
58. R1-2305954 Draft TR 38.869 v020: Study on low-power wake up signal and receiver for NR Rapporteur (vivo)
59. R1-2305963 Discussion on evaluation on low power WUS Spreadtrum Communications
60. R1-2305965 Design consideration on lower power wake-up signal and procedure OPPO
61. R1-2305974 Low power WUS evaluations Ericsson
62. R1-2305976 Low power WUS Evaluation Methodology Nokia, Nokia Shanghai Bell
63. R1-2306012 On performance evaluation for low power wake-up signal Apple
64. R1-2306013 Discussion on physical signal and procedure for low power WUS vivo
65. R1-2306077 Evaluation methodology for LP-WUS Qualcomm Incorporated
66. R1-2306084 Discussion on L1 signal design and procedure for LP-WUS InterDigital, Inc.
67. R1-2306108 Summary#1 of discussions on L1 signal design and procedure for low power WUS Moderator (Nordic Semiconductor ASA)
68. R1-2306126 Reply LS to RAN4 on LP WUR architectures RAN1, Apple
69. R1-2306129 Evaluation methodologies and results for LP-WUS/WUR vivo
70. R1-2306133 Summary#2 of discussions on L1 signal design and procedure for low power WUS Moderator (Nordic Semiconductor ASA)
71. R1-2306181 Summary#3 of discussions on L1 signal design and procedure for low power WUS Moderator (Nordic Semiconductor ASA)
72. R1-2306195 FL summary #2 of evaluation methodologies on LP-WUS/WUR Moderator (vivo)
73. R1-2306204 Summary #4 on LP WUR architectures Apple
74. R1-2306234 Summary#4 of discussions on L1 signal design and procedure for low power WUS Moderator (Nordic Semiconductor ASA)
75. R1-2306251 FL Summary (final) of evaluation results for RAN1#113 on LP-WUS/WUR Moderator (vivo)

RAN1 #112-bis:

1. R1-2302331 Evaluation of LP-WUS and Performance Results FUTUREWEI
2. R1-2302332 LP-WUS Physical Signal Design FUTUREWEI
3. R1-2302339 Evaluations for LP-WUS Huawei, HiSilicon
4. R1-2302340 Discussion on architecture of LP-WUS receiver Huawei, HiSilicon
5. R1-2302341 Signal design and procedure for LP-WUS Huawei, HiSilicon
6. R1-2302391 Discussion on low power wake up receiver architectures Panasonic
7. R1-2302409 L1 signal design and procedure for low power WUS TCL Communication Ltd.
8. R1-2302507 Discussion on low power wake-up receiver architecture vivo
9. R1-2302508 Discussion on physical signal and procedure for low power WUS vivo
10. R1-2302570 Evaluation for lower power wake-up signal OPPO
11. R1-2302571 Discussion on low power WUS receiver OPPO
12. R1-2302572 Design consideration on lower power wake-up signal and procedure OPPO
13. R1-2302621 Discussion on evaluation on low power WUS Spreadtrum Communications
14. R1-2302622 Discussion on L1 signal design and procedure for low power WUS Spreadtrum Communications
15. R1-2302687 Remaining issues of Deployment scenarios and evaluation methodologies and preliminary performance results of LP-WUR CATT
16. R1-2302688 Low-Power WUS receiver Architectures and its performance CATT
17. R1-2302689 Physical layer signals/procedures and higher layer protocol for Low-Power WUR CATT
18. R1-2302815 Evaluations on LP-WUS Intel Corporation
19. R1-2302816 Discussion on LP-WUS receiver architecture Intel Corporation
20. R1-2302817 Discussions on L1 signal design and procedure for LP-WUS Intel Corporation
21. R1-2302827 Discussion on evaluation on LP-WUS InterDigital, Inc.
22. R1-2302828 Discussion on LP-WUS receiver architectures InterDigital, Inc.
23. R1-2302829 Discussion on L1 signal design and procedure for LP-WUS InterDigital, Inc.
24. R1-2302861 Evaluation of low power WUS Sony
25. R1-2302862 On L1 signal design and procedures for low power WUS Sony
26. R1-2302890 Low power WUS Evaluation Methodology Nokia, Nokia Shanghai Bell
27. R1-2302891 Low Power WUS receiver architectures Nokia, Nokia Shanghai Bell
28. R1-2302892 L1 signal design and procedures for low power WUS Nokia, Nokia Shanghai Bell
29. R1-2302948 Evaluation on LP-WUS ZTE, Sanechips
30. R1-2302949 LP-WUS receiver architectures ZTE, Sanechips
31. R1-2302950 LP-WUS design and related procedure ZTE, Sanechips
32. R1-2302968 Evaluation on low power WUS xiaomi
33. R1-2302969 Discussions on L1 signal design and procedure for low power WUS xiaomi
34. R1-2303061 L1 signal design and procedure for low-power WUS Sharp
35. R1-2303150 Evaluation on LP-WUS/WUR Samsung
36. R1-2303151 Receiver architecture for LP-WUS Samsung
37. R1-2303152 Signal design and procedure for LP-WUS Samsung
38. R1-2303255 Discussion on L1 signal design and procedure for LP-WUS CMCC
39. R1-2303333 Low power WUS receiver architectures MediaTek Inc.
40. R1-2303334 L1 signal design and procedure for low power WUS MediaTek Inc.
41. R1-2303421 Discussion on L1 signal design and procedure for low power WUS EURECOM
42. R1-2303429 Discussion on evaluation for LP-WUS LG Electronics
43. R1-2303430 Discussion on L1 signal design and procedure for LP-WUS LG Electronics
44. R1-2303505 On performance evaluation for low power wake-up signal Apple
45. R1-2303506 On low power wake-up receiver architectures Apple
46. R1-2303507 On the L1 signal design and procedures for low power wake-up signal Apple
47. R1-2303537 On LP-WUS evaluation Nordic Semiconductor ASA
48. R1-2303538 On LP-WUS signal design Nordic Semiconductor ASA
49. R1-2303612 Evaluation methodology for LP-WUS Qualcomm Incorporated
50. R1-2303613 Receiver architecture for LP-WUS Qualcomm Incorporated
51. R1-2303614 L1 signal design and procedures for LP-WUR Qualcomm Incorporated
52. R1-2303673 Discussion on L1 signal design and procedure for LP-WUS NEC
53. R1-2303729 Discussion on low power WUS receiver architectures NTT DOCOMO, INC.
54. R1-2303730 Discussion on L1 signal design and procedure for low power WUS NTT DOCOMO, INC.
55. R1-2303759 Low power WUS evaluations Ericsson
56. R1-2303760 Low power WUS receiver architectures Ericsson
57. R1-2303761 L1 signal design and procedure for low power WUS Ericsson
58. R1-2303808 Discussion on the L1 signal design and procedure for low power WUS Lenovo
59. R1-2303894 Discussion on low power wake up signal design Panasonic
60. R1-2303897 Evaluation methodologies for R18 LP-WUS/WUR vivo
61. R1-2303900 Discussion on signal design and procedure for LP-WUS China Telecom
62. R1-2303941 Summary #1 on LP WUR architectures Moderator (Apple)
63. R1-2303942 Summary #2 on LP WUR architectures Moderator (Apple)
64. R1-2303943 Summary #3 on LP WUR architectures Moderator (Apple)
65. R1-2304036 Summary#1 of discussions on L1 signal design and procedure for low power WUS Moderator (Nordic Semiconductor ASA)
66. R1-2304057 Evaluation on low power WUS MediaTek Inc.
67. R1-2304076 FL summary #1 of evaluation methodologies on LP-WUS/WUR Moderator (vivo)
68. R1-2304144 Summary#3 of discussions on L1 signal design and procedure for low power WUS Moderator (Nordic Semiconductor ASA)
69. R1-2304150 FL summary #2 of evaluation methodologies on LP-WUS/WUR Moderator (vivo)
70. R1-2304151 FL summary #1 of evaluation results on LP-WUS/WUR Moderator (vivo)
71. R1-2304248 Summary#4 of discussions on L1 signal design and procedure for low power WUS Moderator (Nordic Semiconductor ASA)
72. R1-2304249 Summary #4 on LP WUR architectures Moderator (Apple)
73. R1-2304251 Reply LS to RAN4 on LP WUR architectures RAN1, Apple
74. R1-2304269 Collection of LLS results on low power WUS Moderator (Nordic Semiconductor ASA)
75. R1-2304287 Final summary of evaluation methodologies on LP-WUS/WUR Moderator (vivo)

RAN2#121bis-e:

1. [R2-2302661](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302661.zip) Scope of Rel-18 SI on LP-WUS/WUR vivo (Rapporteur) discussion Rel-18 FS\_NR\_LPWUS
2. [R2-2303462](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2303462.zip) Update of TR 38.869 for LP-WUS WUR vivo (Rapporteur) discussion Rel-18 FS\_NR\_LPWUS
3. [R2-2303463](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2303463.zip) Work Plan for Rel-18 SI on LP-WUS/WUR vivo (Rapporteur) discussion Rel-18 FS\_NR\_LPWUS
4. [R2-2302977](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302977.zip) Impact of LP-WUR in RRC Idle/Inactive Intel Corporation discussion Rel-18 FS\_NR\_LPWUS
5. [R2-2302662](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302662.zip) Discussion on LP-WUS/WUR in RRC\_Idle/Inactive vivo discussion Rel-18 FS\_NR\_LPWUS
6. [R2-2302518](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302518.zip) Use of low-power receiver in RRC Idle/Inactive Qualcomm Incorporated discussion Rel-18 FS\_NR\_LPWUS
7. [R2-2303747](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2303747.zip) Discussion on impact to IDLE/INACTIVE procedures to support LP-WUR SAMSUNG R&D INSTITUTE INDIA discussion Rel-18
8. [R2-2302706](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302706.zip) General considerations on the procedure of LP-WUS Xiaomi Communications discussion
9. [R2-2302801](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302801.zip) On low-power wake-up signal in RRC IDLE and INACTIVE Nokia, Nokia Shanghai Bell discussion Rel-18 FS\_NR\_LPWUS
10. [R2-2303469](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2303469.zip) High layer procedures for low-power WUS in IDLE and INACTIVE state Huawei, HiSilicon discussion Rel-18 FS\_NR\_LPWUS
11. [R2-2302827](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302827.zip) Considerations on RAN2 impacts of LP-WUS ZTE Corporation, Sanechips discussion Rel-18 FS\_NR\_LPWUS
12. [R2-2302828](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302828.zip) Paging mechanism with LP-WUS ZTE Corporation, Sanechips discussion Rel-18 FS\_NR\_LPWUS
13. [R2-2302707](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302707.zip) Discussiong on LP-WUS monitoring Xiaomi Communications discussion
14. [R2-2302542](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302542.zip) Discussion on LP-WUR’s operation OPPO discussion Rel-18 FS\_NR\_LPWUS
15. [R2-2302981](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302981.zip) Impact of LP-WUR in RRC Connected mode Intel Corporation discussion Rel-18 FS\_NR\_LPWUS
16. [R2-2302519](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302519.zip) Use of low-power receiver in RRC Connected Qualcomm Incorporated discussion Rel-18 FS\_NR\_LPWUS
17. [R2-2302537](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302537.zip) Discussion on RRM measurement for LP-WUR OPPO discussion Rel-18 FS\_NR\_LPWUS
18. [R2-2302663](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302663.zip) Discussion on LP-WUS/WUR in RRC\_Connected vivo discussion Rel-18 FS\_NR\_LPWUS
19. [R2-2302777](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302777.zip) Discussion on general aspect for LPWUS from RAN2 perspective NEC Corporation discussion Rel-18 FS\_NR\_LPWUS
20. [R2-2302984](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2302984.zip) Discussion on LP-WUS impact on higher layer procedures CATT discussion Rel-18 FS\_NR\_LPWUS
21. [R2-2303209](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2303209.zip) Low-power WUS in RRC\_CONNECTED Nokia, Nokia Shanghai Bell discussion
22. [R2-2303423](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2303423.zip) RAN2 impact on LP-WUS Apple discussion Rel-18 FS\_NR\_LPWUS
23. [R2-2303493](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2303493.zip) RAN2 impacts to support LP-WUS Huawei, HiSilicon discussion Rel-18 FS\_NR\_LPWUS
24. [R2-2303750](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2303750.zip) Discussion on impact to Connected mode procedures to support LP-WUR SAMSUNG R&D INSTITUTE INDIA discussion Rel-18
25. [R2-2304067](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2304067.zip) LP-WUS design and L1 procedure Ericsson discussion Rel-18 FS\_NR\_LPWUS
26. [R2-2304068](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\TSGR2_121bis-e\Docs\R2-2304068.zip) LP-WUR Higher-Layer Aspects Ericsson discussion Rel-18 FS\_NR\_LPWUS

RAN2#122

1. [R2-2305745](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2305745.zip) Updated scope clarification of Rel-18 SI on LP-WUS/WUR vivo (Rapporteur) discussion Rel-18 FS\_NR\_LPWUS
2. [R2-2305746](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2305746.zip) Work Plan for Rel-18 SI on LP-WUS/WUR vivo (Rapporteur) discussion Rel-18 FS\_NR\_LPWUS
3. [R2-2305747](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2305747.zip) Update of TR 38.869 for LP-WUS WUR vivo (Rapporteur) discussion Rel-18 FS\_NR\_LPWUS
4. [R2-2304923](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304923.zip) Discussion on LP-WUS WUR in RRC idle/inactive vivo discussion Rel-18 FS\_NR\_LPWUS
5. [R2-2304714](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304714.zip) Use of low-power receiver in RRC Idle/Inactive Qualcomm Incorporated discussion Rel-18 FS\_NR\_LPWUS
6. [R2-2306060](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2306060.zip) MR/LR UE behaviours for paging and mobility in RRC\_IDLE/INACTIVE state Huawei, HiSilicon discussion Rel-18 FS\_NR\_LPWUS
7. [R2-2306238](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2306238.zip) LP-WUS/WUR for RRC Idle and Inactive Ericsson discussion Rel-18 FS\_NR\_LPWUS
8. [R2-2305903](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2305903.zip) LP-WUS in RRC IDLE and INACTIVE Nokia, Nokia Shanghai Bell discussion Rel-18 FS\_NR\_LPWUS
9. [R2-2304936](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304936.zip) Discussion on LP-WUS in RRC\_IDLE&INACTIVE state CATT discussion Rel-18 FS\_NR\_LPWUS
10. [R2-2305960](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2305960.zip) RAN2 impacts of LP-WUS in idle or inactive mode ZTE Corporation, Sanechips discussion Rel-18 FS\_NR\_LPWUS
11. [R2-2304748](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304748.zip) Discussion on RRM measurement for LP-WUR OPPO discussion Rel-18 FS\_NR\_LPWUS
12. [R2-2306162](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2306162.zip) RAN2 impact on LP-WUS in IDLE/INACTIVE state Apple discussion Rel-18 FS\_NR\_LPWUS
13. [R2-2306482](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2306482.zip) On impact to IDLE/INACTIVE procedures to support LP-WUR SAMSUNG R&D INSTITUTE INDIA discussion Rel-18
14. [R2-2305000](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2305000.zip) General considerations on the procedure for RRC\_IDLE\_INACTIVE Xiaomi Communications discussion
15. [R2-2305528](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2305528.zip) Considerations on LP-WUR in RRC Idle/Inactive mode Sony discussion Rel-18 FS\_NR\_LPWUS
16. [R2-2304988](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304988.zip) Discussion on the considerations for LPWUS in RRC\_IDLE INACTIVE NEC Corporation discussion Rel-18 FS\_NR\_LPWUS
17. [R2-2304715](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304715.zip) Use of low-power receiver in RRC Connected Qualcomm Incorporated discussion Rel-18 FS\_NR\_LPWUS
18. [R2-2304750](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304750.zip) Discussion on LP-WUR’s operation OPPO discussion Rel-18 FS\_NR\_LPWUS
19. [R2-2304924](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304924.zip) Discussion on LP-WUS WUR in RRC connected vivo discussion Rel-18 FS\_NR\_LPWUS
20. [R2-2304937](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304937.zip) Discussion on LP-WUS in RRC\_CONNECTED state CATT discussion Rel-18 FS\_NR\_LPWUS
21. [R2-2304989](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304989.zip) Discussion on the considerations for LPWUS in RRC\_CONNECTED NEC Corporation discussion Rel-18 FS\_NR\_LPWUS
22. [R2-2304999](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2304999.zip) Discussing on LP-WUS monitoring for RRC\_Connected Xiaomi Communications discussion
23. [R2-2305473](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2305473.zip) High layer procedures for LP-WUS in RRC\_CONNECTED state Huawei, HiSilicon discussion Rel-18 FS\_NR\_LPWUS
24. [R2-2305961](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2305961.zip) RAN2 impacts of LP-WUS in connected mode ZTE Corporation, Sanechips discussion Rel-18 FS\_NR\_LPWUS
25. [R2-2306239](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2306239.zip) LP-WUS/WUR for RRC Connected Ericsson discussion Rel-18 FS\_NR\_LPWUS
26. [R2-2306489](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2306489.zip) On impact to Connected mode procedures to support LP-WUR SAMSUNG R&D INSTITUTE INDIA discussion Rel-18
27. [R2-2306312](file:///C:\Users\johan\OneDrive\Dokument\3GPP\tsg_ran\WG2_RL2\RAN2\Docs\R2-2306312.zip) LP\_WUS in RRC\_CONNECTED Nokia, Nokia Shanghai Bell discussion

RAN4#106bis:

1. R4-2304035 Evaluation of wake-up signal designs Nokia, Nokia Shanghai Bell
2. R4-2304103 RF aspects of low-power wake up receiver Nokia, Nokia Shanghai Bell
3. R4-2304196 discussion on low power WUS architectures CMCC
4. R4-2304283 Low-power wake-up receiver RF aspects Qualcomm Inc.
5. R4-2304342 On low-power wake-up signal and receiver for NR Apple
6. R4-2304722 Views on LP-WUR architectures Samsung
7. R4-2305110 Further discussions on low-power Wake-up Receiver architectures vivo
8. R4-2305111 Discussions on low-power Wake-up Signal designs vivo
9. R4-2305112 [draft] reply LS to RAN1 on low-power wake-up receiver architectures vivo
10. R4-2305126 Views on LP-WUR/LP-WUS ZTE Corporation
11. R4-2305567 Further consideration on LP-WUS/WUR Huawei, HiSilicon
12. R4-2305639 LS reply on low-power wake-up receiver architectures Ericsson
13. R4-2305640 Evaluation of wake-up signal designs Ericsson
14. R4-2305641 Evaluation of Low power wake-up receiver architectures Ericsson
15. R4-2305766 Views on low-power wake-up signal and receiver for NR Sony
16. R4-2305783 Further discussion on LP-WUR architecture MediaTek Inc.
17. R4-2306215 Topic summary for [106-bis-e][136] FS\_NR\_LPWUS Moderator (Vivo)
18. R4-2306298 Topic summary for [106-bis-e][136] FS\_NR\_LPWUS Moderator (Vivo)
19. R4-2306617 WF on LP-WUS Vivo
20. R4-2306618 reply LS to RAN1 on low-power wake-up receiver architectures vivo

RAN4#107:

1. R4-2307147 Further consideration on LP-WUS/WUR Huawei, HiSilicon
2. R4-2307249 Evaluation of Low power wake-up receiver architectures Nokia, Nokia Shanghai Bell
3. R4-2307316 Evaluation of wake-up signal designs Nokia, Nokia Shanghai Bell
4. R4-2307460 Low-power wake-up receiver RF aspects Qualcomm Incorporated
5. R4-2308179 Views on LP-WUR/LP-WUS ZTE Corporation
6. R4-2308198 discusson on low power WUS CMCC
7. R4-2308260 Discussions on low-power Wave-up Receiver architectures vivo
8. R4-2308261 Reply LS to RAN1 on low-power wake-up receiver architectures vivo
9. R4-2308365 Further discussion on LP-WUR architecture MediaTek Inc.
10. R4-2309033 Views on low-power wake-up signal and receiver for NR Sony
11. R4-2309054 On low-power wake-up signal and receiver for NR Apple
12. R4-2309203 LS reply on low-power wake-up receiver architectures Ericsson
13. R4-2309204 Evaluation of Low power wake-up receiver architectures Ericsson
14. R4-2310022 Topic summary for [107][139] FS\_NR\_LPWUS Moderator (Vivo)
15. R4-2310299 WF on FS\_NR\_LPWUS Vivo
16. R4-2310392 Ad hoc minutes for FS\_NR\_LPWUS Vivo

17.05.2021 minor adaptations for RAN #92e

28.01.2021 minor adaptations for RAN #91e

09.11.2020 minor adaptations for RAN #90e

31.08.2020 minor adaptations for RAN #89e

20.04.2020 minor adaptations for RAN #88e

18.02.2020 minor adaptations for RAN #87e

14.11.2019 minor adaptations for RAN #86

18.08.2019 minor adaptations for RAN #85

12.05.2019 minor adaptations for RAN #84

27.02.2019 minor adaptations for RAN #83

21.11.2018 completion levels with colours added (for RAN #82)

v04.81 31.07.2018 simplification of template and addition of cross-TSG aspects (for RAN #81)

v04.80 21.05.2018 minor adaptations for RAN #80

v04.79 26.02.2018 minor adaptations for RAN #79

v04.78 18.11.2017 minor adaptations for RAN #78

v04.77 06.08.2017 minor adaptations for RAN #77

v04.76 15.05.2017 minor adaptations for RAN #76

v04.75 31.01.2017 minor adaptations for RAN #75

v04.74 28.10.2016 minor adaptations for RAN #74

v04.73 01.09.2016 adaptations for RAN #73 (time units in extra Excel table, RAN6 reporting included)

v04.72 26.05.2016 adaptations for RAN #72 (introduction of NR & GERAN TUs)

v04.71 10.02.2016 minor adaptations for RAN #71

v04.70 30.10.2015 minor adaptations for RAN #70

v04.69 12.08.2015 minor adaptations for RAN #69

v04.68 21.05.2015 minor adaptations for RAN #68

v04.67 01.02.2015 minor adaptations for RAN #67

v04.66 16.11.2014 minor adaptations for RAN #66

v04.65 16.08.2014 minor adaptations for RAN #65

v04.64 22.05.2014 minor adaptations for RAN #64

v04.63 24.01.2014 restructuring for RAN #63 to cover Core & Perf. in one doc file

v03.62 11.11.2013 section 1.2.3 adapted for RAN #62

v03 11.08.2013 section 1.2.3 added on time budget

v02 07.05.2010 history added, some spelling corrections

v01 13.11.2009 First version of the template