3GPP TSG RAN WG1#112bis-e R1-230XXXX

**e-Meeting, April 17th – April 26th, 2023**

Source: Moderator (vivo)

Title: FL summary #1 of evaluation methodologies on LP-WUS/WUR

Agenda Item: 9.11.1

Document for: Discussion and Decision

# Introduction

This document summarizes the contributions [1 - 19] for AI 9.11.1 and email discussions.

The issues in this document are tagged and color coded with [H] or [M].

# Evaluation methodologies

## Issue 1: Simulation assumptions

### 1A: Link-level assumptions

#### 1A-1: FAR/MDR

In last meeting, following agreements are made, and definition of FAR is still not converged.

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| **Agreement*** The false-alarm rate (FAR) of LP-WUS
	+ [0.1%, 1%]
	+ Other values are not precluded for studying, reported by companies
	+ Further discuss on the following alternatives for FAR target
		- Alt 1: FAR target is determined per single WUS attempt/trial,
		- Alt 2: FAR target is determined across a reference time duration of one or multiple WUS attempts/trials
			* FFS: possible values for reference time durations
		- Companies to report details, e.g., receiver behaviour, how to compute MDR, detection threshold
	+ Companies to report the selected reference time duration values and the associated number of WUS attempts/trials
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**Summary of company views:**

**Alt 1:** FAR target is determined per single WUS attempt/trial,

* Supported by Futurewei (For Coverage evaluation), OPPO, interdigital, LG (for duty cycle monitoring), Ericsson, MTK

**Alt 2:** FAR target is determined across a reference time duration of one or multiple WUS attempts/trials

* Supported by Futurewei (For power evaluation), Huawei, vivo, LG (for continuous monitoring), ZTE, Samsung

Proposals from contributions are as follows,

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| **Futurewei** | * Number of false alarms in any duration T cannot simply be determined as the product of FAR and number of LP-WUS monitoring occasions in that duration T for ‘always-on’ and short ‘duty-cycled’ monitoring modes.
* For power evaluation, only one false alarm is expected in any duration corresponding to MR’s wake-up, determination of false alarm, and return back to sleep.
* Support definition of a simulation step size of, e.g., one subframe, for the evaluation of ‘always-on’ LP-WUS power saving gain using system level simulation, where the step size corresponds to the LP-WUS duration.
* For the same FAR and reference time duration in FAR Alt 2, LP-WUS design under ‘always-on’ monitoring may require a longer sequence and/or a longer CRC compared to the LP-WUS design under ‘duty-cycled’ monitoring.
* For power saving gain, support using FAR Alt 2 to simplify the evaluation and consider the impact on LP-WUS design for ‘always-on’ and ‘duty-cycled’ monitoring modes.
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| **Huawei** | * if the FAR value per single WUS attempt/trial is $p$, and during a time duration there are $N$ attempts/trials, the joint FAR value for this time duration is $1-(1-p)^{N}$ since the attempt/trials are independent.
* Alt.2 can be generally used to compare different designs, e.g. the continuous monitoring and duty cycle based monitoring. The main impact of FAR is the false-wakeup of MR which consumes additional power. By setting the FAR target within a duration for different modulation/waveform or operation mode (e.g. continuous monitoring or duty cycle mode monitoring), the power saving gain can be aligned by maintaining proper FAR target with in the same duration for fair comparison of other metrics, e.g. miss-detection performance of the LP-WUS.
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| **vivo** | * Reporting per attempt FAR is not necessary
* UE power consumption mainly depends on reference duration FAR.
* The detection results from multiple attempts may be highly correlated, per attempt FAR cannot be easily derived from the per reference duration FAR.
* The reference time duration can be T, e.g., one DRX cycle, during which UE detect N WUS occasions,
* For always on monitoring, N>1, is the number of occasions within T.
* For duty cycled monitoring, value N depends on WUS periodicity. N=1, if reference time duration is WUS periodicity.
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| **OPPO** | For evaluation of power consumption, FAR target is determined per single WUS attempt/trial. |
| **interdigital** | Alt 1 provides a simple FAR target per single WUS attempt/trial, Alt 2 defines an FAR target across a reference time duration. Alt 2 requires further discussion on possible values for reference time durations as captured as FFS, benefits of Alt 2 are not clear. |
| **LG** | For evaluation, only one alternative for FAR should be considered for each monitoring behavior of LP-WUR. E.g., Alt 1 for duty cycle based monitoring and Alt 2 for continuous monitoring. |
| **Ericsson** | False alarm probability is defined per detection attempt/trial. And if each WUR detection duration is *D* ms, then during *T* ms active time the WUR has [*T*/*D*] attempts for detecting WUS, where false alarm can occur in each attempt with a certain probability. |
| **ZTE** | FAR P is defined in a time duration T* The FAR for each detection is LLS is less than x0, where x0 is the FAR for the detection when the step size for sliding is the sequence length L, satisfying P=$1-\left(1-x\_{0}\right)^{T/L}$
* The reference time duration is a DRX cycle.
* MDR has the similar definition.
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| **Samsung** | * When the finer sliding granularity for LP-WUS detection is considered, how to count the number of wake-up can affect to calculate FAR.
* For calculation of FAR, FAR target is determined across a reference time duration of one or multiple WUS attempts/trials
* The number of wake-up within the reference time is 1 even if the multiple wake-ups are indicated by multiple attempts/trials.
* Propose to consider three cases for something that gNB can transmit within the LP-WUS monitoring window: 1) LP-WUS, 2) Other NR signal(s)/channel(s) (PDSCH, PDCCH, …), 3) the absence of gNB transmission (only considering channel noise).
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| **MTK** | * Clarify the baseline of [0.1%, 1%] for the false-alarm rate (FAR) of LP-WUS agreed in RAN1#112 is defined by FAR per single WUS attempt/trial, otherwise, non-feasible FAR targets will be included.
* Support of Alt 2 (FAR target is determined across a reference time duration of one or multiple WUS attempts/trials) may result in the target FAR values below 1% or below 0.1%, which may not be feasible if there is no CRC for further confirmation.
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Based on company inputs, moderator would like to **align the understanding on UE behaviors and terminologies** to facilitate further discussion and down selection on Alt-1/Alt-2

Firstly, moderator would like to **align the understanding on detection behavior** for duty cycle and continuous monitoring for LP-WUS.

* Time drifting: considering time drifting, UE may start detection of LP-WUS earlier than the actual transmission occasion of LP-WUS. For LP-WUS with sequence part, either sequence only or with subsequent payload, UE performs correlation to search for the sequence part within certain sliding window, in which the correlation is performed multiple times
* Continuous monitoring: It means WUR does not know when gNB will start transmission of LP-WUS, and UE monitors the LP-WUS in continuous manner, UE will monitor the LP-WUS multiple times within certain durations. Note that, although UE monitors continuously, it does not mean gNB can start WUS transmission anytime, e.g., sample Ts level. The gNB transmission still follows existing time domain resource grid, e.g., slot can be considered transmission unit for a LP-WUS for evaluation purpose. In other words, the continuous monitoring is actually short duty cycled monitoring. Thus, the number of LP-WUS transmission occasions can be obtained within a time duration.

Further, moderator would like to **align following understanding and terminologies** among companies.

* **Per single WUS attempt/trial,** means ONE trial/attempt to detect ONE LP-WUS transmission occasion.
	+ The output of Multiple correlations/hypothesis may be highly correlated due to oversampling of OOK chips. Hence, it is difficult to derive per correlation FAR from per attempt FAR. [R1-2302948, ZTE], [R1-2303150, Samsung], [R1-2302526, vivo]
	+ Note: If UE performs multiple correlations for detection the potential LP-WUS transmission in that transmission occasion, it can be considered as UE implementation in ONE trial/attempt, rather than multiple attempts/trials.
* **Number WUS attempts/trials across a reference time duration,** if each detection duration/LP-WUS occasion duration is D ms, then during T ms reference time duration, and the WUR has [T/D] attempts for detecting WUS.
	+ Similarly, each detection duration/LP-WUS occasion duration may require multiple correlations/hypothesis at WUR receiver.
	+ Similar view can be found in [R1-2302339, Huawei], [R1-2303759, Ericsson], [R1-2302506, vivo], [R1-2302948, ZTE], [R1-2302331 FUTUREWEI].

Based on above clarification, moderator have the following understanding

* For duty cycled LP-WUS monitoring, and if the reference time duration is equal to LP-WUS periodicity and only one LP-WUS transmission per LP-WUS period, UE only need to monitor LP-WUS once. In this case, the per single attempt FAR(Alt-1) is identical to per reference duration FAR(Alt-2).
* For always-on/continuous monitoring, if false alarm occurs at any occasion within the reference time duration, UE would wake up. Hence, Alt 2, FAR target determined across a reference time duration of one or multiple WUS attempts/trials is more intuitive for UE power consumption for Always on/Continuous monitoring.
* For always-on/continuous monitoring, each attempt on different WUS occasions can be assumed as independent, the per single attempt FAR and per duration FAR can be derived from each other.
* The per attempt FAR would be varied if companies report different assumptions on the duration for each attempt, which depends on WUS configurations. FAR target determined across a reference time duration of one or multiple WUS attempts/trials can be more easily aligned.

For the reference time duration used for evaluation

* + Typical DRX cycle can be assumed as the reference time duration. [R1-2302506, vivo], [R1-2302339, Huawei], [R1-2302948, ZTE].

A brief depicts of FAR calculation Alt-1 and Alt-2 is provided in the following figure.

 

***Hence, moderator have the following proposal which covers both duty-cycled and continuously monitoring,***

##### [H] Proposals 1A-1-v1:

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

* UE have N attempts within T, where N is the number of LP-WUS transmission occasions with in T.
	+ N is the number of attempts within T.
	+ where T is {1.28s, 2.56, …}
	+ Company to report (FAR, T, N)
		- Note: FAR = {0.1%, 1%} as agreed in RAN1#112
* Note 1: For example, if UE performs multiple correlations for sequence part for potential LP-WUS transmission in that monitor occasion, these correlations are considered as UE implementation in ONE trial/attempt.
* Note 2: If UE performs multiple non-overlapping attempts within the reference time duration, the false alarm event for the attempts are assumed as independent.
* Note 3: Number of Attempts per second ($λ$) can be calculated from T and N, i.e., $λ={N}/{T}$.

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| **Company** | **Comments** |
| Futurewei | We are OK with the proposal. |
| OPPO | OK with the proposal. |
| Spreadtrum | This FAR definition may be used for continuous monitoring. We don’t see the need to change the FAR definition for duty cycle.For evaluation purpose of continuous monitoring of LP-WUS, |
| Huawei, HiSilicon | We are fine in general with moderator’s analysis and the proposal, with some following:1. Considering it was not agreed that LP-WUS always includes a sequence/preamble, therefore Note 1 should be updated as e.g.:

Note 1: For example, if LP-WUS transmission is agreed to include a sequence/preamble part, for which UE performs multiple correlations ~~for sequence part for potential LP-WUS transmission~~ in that monitor occasion, these correlations are considered as UE implementation in ONE trial/attempt. |
| QC | Agree on this proposal. With this proposal, we think we have no need to discuss Alt 1 and Alt 2 any more. We think correlation can be done to detect a sequence only (which does not necessarily require preamble). |
| ZTE, Sanechips | We are generally OK. Additionally, in a time duration, we think 10% also can be optionally considered. In our simulation, in some cases, FAR 10% still has some power saving gain. |
| Xiaomi | Fine with the proposal. |
| Nokia1 | As discussed in last meeting, we should have some common understanding of the side-conditions that are needed FAR e.g. in terms of LP-WUS design. The assumed design for (FAR=0.1%, T=1.28s, N=1) would be very different that the design (FAR=0.1%, T=1.28s, N=1280). Thus if the resulting false alarm probability per one detection attempt (of the N) is very low, the assumed side conditions should also be disclosed. Minor note that N is defined at end of first sub-bullet as number of transmissions occasions, and in second sub-bullet (and implied start of first sub-bullet) as number of attempts within T. While these could be the same, would it be simplest just define N as the number of WUS detection attempts within T. |
| Intel | We are OK with the proposal. Regarding N, we’d like to clarify whether N is non-overlapped attempts. In our understanding, if N can be overlapped attempts, there is no simple relation between per-attempt FAR and the FAR in duration T. In other words, reporting N in the 3rd sub-bullet doesn’t help, if N can be overlapped attempts.  |
| InterDigital | We understand the point of the FL, but the proposal needs some clarification. In our understanding, Note 1 and Note 2 are important information, so they shouldn’t be notes but a part of agreements. In addition, “N is the number of attempts within T.” is duplicated information. Therefore, it’s better to remove as well. Having said that, the below is our updated proposal. [H] Proposals 1A-1-v1:For evaluation purpose, FAR target is determined across a reference time duration T of one or multiple WUS attempts/trials, * UE have N attempts within T, where N is the number of LP-WUS transmission occasions with in T.
	+ ~~N is the number of attempts within T.~~
	+ where T is {1.28s, 2.56, …}
	+ Company to report (FAR, T, N)
		- Note: FAR = {0.1%, 1%} as agreed in RAN1#112
* ~~Note 1: For example, i~~If UE performs multiple correlations for sequence part for potential LP-WUS transmission in that monitor occasion, these correlations are considered as UE implementation in ONE trial/attempt.
* ~~Note 2:~~ If UE performs multiple non-overlapping attempts within the reference time duration, the false alarm event for the attempts are assumed as independent.
* Note ~~3~~: Number of Attempts per second ($λ$) can be calculated from T and N, i.e., $λ={N}/{T}$.
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#### 1A-2: Frequency error/drifting

In RAN1 #112 meeting, the following working assumption was made [1].

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

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| **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]** | 20 |

* 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] [R1-2301558][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
 |

**Huawei:** 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), where Fr is:

* 1. 0.1 ppm, if MR can assist to calibrate LP-WUR to correct the frequency error
	2. 5 ppm, if LP-WUR can only correct the frequency error based on LP-WUS synchronization signal

**Vivo:** Option 3/4 cannot be used when MR is in ultra-deep sleep power consumption state and associated power consumption for LR on state and LR off state.

**Interdigital:** For high frequency error/drift case, there may be increased power consumption and therefore the agreed power consumption for MR and LP-WUR may not be applicable. However, there is no clear evidence that only Option 3/4 are not applicable with the current assumption. In that regard, applying the current assumptions for Option 3/4 as well as Option 1/2 is preferred.

**Qualcomm:** The accuracy of clock mostly depends on the cost or clock. The clock with higher power accuracy does not necessarily consumes higher power. Therefore, we suggest removing following text from working assumption. The frequency of clock correlates more with power consumption. So, it would be good to remove following FFS on option 3 and 4.

##### [H] Proposals 1A-2-v1:

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), where Fr is:

a) 0.1 ppm, if MR can assist to calibrate LP-WUR to correct the frequency error

b) 5 ppm, if LP-WUR can only correct the frequency error based on LP-WUS synchronization signal

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| **Company** | **Comments** |
| Futurewei | We are OK with the proposal |
| OPPO | OK with the proposal. |
| Huawei, HiSilicon | We support the proposal. |
| QC | It is not clear why the Fr should be modeled as 0.1ppm or 5ppm for each case. The Fr depends on LP-SS detection and clock calibration mechanism. So, we think these should be reported by individual company. |
| ZTE, Sanechips | We are fine with the main bullet. For the subbullets, clarification is needed.For a), we assume that MR should wake-up and receive SSB for calibration to achieve 0.1 ppm.For b), For the OFDM receiver, SSS monitored by WUR also is included in the LP-WUS synchronization signal |
| Xiaomi | We agree to consider both 0.1 ppm and 5 ppm as Fr, which can provide more choices for UE’s implementation. But comments for each option are not necessary. We suggest the following modifications: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), where Fr is:a) 0.1 ppm, ~~if MR can assist to calibrate LP-WUR to correct the frequency error~~ b) 5 ppm~~, if LP-WUR can only correct the frequency error based on LP-WUS synchronization signal~~Note: Both cases in which MR can and cannot assist to calibrate LP-WUR to correct the frequency error are taken into account. |
| Nokia1 | In principle we are fine to consider the residual frequency error. On the exact numbers, specifically point b), we share the view with QCM that the value of Fr is heavily dependent on the (possible) LP-SS design as well as on the (possible) LP-WUS design (e.g. preamble), thus the exact value could be left for FFS. |
| Intel | What is the relation between this proposal and option 1/2/3/4 in the WA? Does it intended to say, with help of MR or LP-SS, the frequency error (the first value in each value pair of Option 1/2/3/4) can be replaced by 0.1 or 5 ppm ? Then, Option 1/2/3/4 is for the case if oscillator is free run?  |

##### [H] Proposals 1A-3-v1:

Option 3/4 clocks is not applicable to be used when MR is in ’ultra-deep sleep state’ with [0.015] power units and LR is in off state

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| **Company** | **Comments** |
| Futurewei | To address Qualcomm’s point, we can specify that this is true for low cost devices used for IoT use cases. |
| OPPO | OK with the proposal. |
| Huawei, HiSilicon | The proposal may need to be clarified first. Should it be “not applicable……when MR is in ’ultra-deep sleep state’ with [0.015] power units or LR is in off state”? |
| QC | Given that clock accuracy highly depends on cost of clock, we think option 3 and 4 clock should be able to be considered when MR is in ultra deep sleep. |
| ZTE, Sanechips | We are OK with this proposal. |
| Xiaomi | We are fine with the proposal. |
| Nokia1 | Firstly, agree with the need to clarify as Huawei commented. Also as noted by QCM, if the cost penalty is taken in the LR, there should not be a reason to omit this when MR is in ultra deep sleep. |
| Intel | We are OK with the FL proposal  |
| InterDigital | We believe that option 3/4 clocks should be applicable with ultra-deep sleep state in general.  |

#### 1A-5: Others

**Huawei**

* + Huawei propose to Adopt the phase noise model defined by IEEE 802.11ba for LP-WUS study.
	+ Huawei propose the random 16-QAM symbols can be mapped on the REs of the PDSCH to model the neighboring subcarrier interference.
	+ Huawei propose to consider one or two neighboring cells to transmit random 16QAM symbols on REs within the cell bandwidth in the link simulation.

**MTK**

* + In the assumption of delay spread corresponding to the TDL models, the value of 1000ns has the max delay span of 8.6us, three times larger than the CP length of 2.34us for 30kHz SCS.
	+ Change the assumption of delay spread from optional 1000ns to optional: 100ns, considering the agreed values of 300ns and 1000ns result in larger delay spans than the CP length for 30kHz SCS.

**Qualcomm** propose to discuss LLS assumptions for FR2.

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| Parameter | Value |
| Carrier frequency | 28GHz |
| SCS | 120KHz |
| Channel Model | CDL-C, TDL-A |
| Delay spread | 30ns, 100ns |
| UE speed | 3Km/h |
| Antenna configuration:  | gNB antenna: 2UE antenna: 1  |
| LP-WUS bandwidth  | TBD |
| LP-WUS payload | Same as FR1 |
| LP-WUS raw data rate |  Same as FR1 |
| Receiver Model  | [Same as FR1] |
| Performance metrics | Same as FR1 |

***Moderator suggest companies to provide feedback with respect to the above proposals***

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| **Company** | **Comments** |
| Futurewei | We are OK to adopt proposals from Huawei and MTK. However, we feel that FR2 should be deprioritized for now given the limited discussion on that aspect. |
| OPPO | OK with proposals from Huawei and MTK. |
| Xiaomi | Considering the poor coverage of LP WUS signal, we think that discussion of LP WUS in FR2 should be postponed. |
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### 1B: Coverage evaluation assumptions

#### 1B-1: Noise Figure

**Vivo** propose to assume 12dB noise figure, because 8.7dB and 11 dB NF can be achieved according to literatures.

**Samsung:** The presence of LNA should be reflected to select the NF value for link budget evaluation.

**Ericsson:**

* WUS1: sequence-based OOK WUS (1 slot WUS), WUR noise figure 6 dB worse than main receiver
* WUS2: SSS-based signal detection based WUR capable of processing I/Q samples in time-domain (4 OFDM symbols WUS), WUR noise figure 3 dB worse than main receiver

***Moderator suggest to handle the value of NF corresponds to each receiver in AI9.11.2***

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| **Company** | **Comments** |
| Futurewei | We agree with moderator’s proposal. |
| DOCOMO | We support this proposal. |
| Spreadtrum | It can be left to RAN4 discussion and it is architecture specific. |
| Huawei, HiSilicon | It is fine for us to map the noise figure and power consumption assumption for each receiver type in AI 9.11.2. |
| QC | Given that NF depends on the choice receiver types, implementation, and power consumption, it would be enough to determine two/three representative NF values to cover different receiver type/implementations. |
| ZTE, Sanechips | We are Okay. |
| Xiaomi | We are fine with the proposal. |
| Nokia1 | Fine to concentrate the RAN1 discussion to 9.11.2, with the note that RAN1 also asked RAN4 view on the NF. |
| Intel | Agree |

#### 1B-2: Others

* + **Nokia** propose to consider whether the LR has it’s own separate antenna or whether (one of) the main receiver antenna is shared. If antenna is shared, additional loss due to possible switch could be considered, (while this could be assumed to be relatively low i.e. ~0.2dB). If separate antenna is used, it would need to be considered whether additional antennal efficiency should be considered for LR to reflect the possible constraints set by the ID of the device to the antenna design/dimensions.
	+ **Nokia** There maybe different type of deployments, which assume different type of receiver baseline for cell coverage. Redcap UE and Normal UE have different references in coverage evaluation.

### 1C: Power model

#### 1C-1: power model for MR ramp-up transition time and transition energy

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| ZTE | ***Proposal 3: The relative power of ultra-deep sleep is 0.015 unit for LP-WUS power consumption evaluation.******Proposal 4: The ramp up and down transition energy and ramp-up time of ultra-deep sleep is 15000 units\*ms and 400ms for IoT/Wearable cases and 40000 units\*ms and 800ms for eMBB cases for power consumption evaluation.*** |
| MTK | 1. Confirm Alt 2: (40000, 800ms) being the transition energy and transition time for FR1 MR ultra-deep sleep state.
 |
| Qualcomm | **Proposal 3: For evaluation, at least for FR1 MR ultra-deep sleep state, (Ramp-up and down transition energy, ramp-up time) confirm following assumptions.*** **Alt 1: (15000, 400ms)**
* **Alt 2: (40000, 800ms)**
 |
| InterDigital | ***Proposal 2:*** *Confirm the relative power value 0.015 for Ultra-deep sleep of MR.****Proposal 3:*** *For ramp-up/down transition energy and ramp-up time of MR, support Alt 1 (15000, 400ms) and deprioritize Alt 2 ([40000], 800ms)).* |
| LG | **Proposal 2: Confirm Alt 2 of (Ramp-up and down transition energy, ramp-up time) for evaluation at least for FR1 MR ultra-deep sleep state.*** **It can be used as an option only applicable for eMBB cases.**
 |

##### [H] Proposal 1C-1-v1:

**Confirm Alt 2 in the following agreement**

**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)
* Alt 2: ([40000], [800ms])

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

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| **Company** | **Comments** |
| OPPO | OK with FL’s proposal. |
| Huawei, HiSilicon | We are fine to confirm the working assumption of Alt.2, but no need to further map the alternatives to specific device types. |
| QC | agree |
| ZTE, Sanechips | Fine with the proposal. Alt 1 for IoT/Wearable cases and Alt 2 for eMBB cases |
| Xiaomi | Fine with the proposal. |
| Nokia1 | We are OK to confirm |
| Intel | Agree |

#### 1C-2: power model for OFDM-based LP-WUR

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| --- | --- |
| ZTE | ***Proposal 6: For OFDM based receiver, WUR ‘on’ relative power should be no less than 20 and WUR ‘off’ relative power should be 0.01.******Proposal 7: The relative power of WUR on is 0.01, 0.5, 1, 20 and 40 for LP-WUS power consumption evaluation.***  |
| Samsung | **Proposal 5: To reflect the higher power consumption of receiver architectures for various waveform e.g., OFDMA-based signal, FSK waveform, the following approaches should be considered for LR power model.*** **Company can use higher on/off power for LR, and the details for assumed receiver architecture should be provided.**
* **Candidates of LR power model for higher power-consumed LR can be added. e.g., 10, 20, 40 for on-state of LR.**
 |
| MTK | 1. The current relative power values for LPWUR are up to 4 and they cannot reflect the need to support OFDMA-based LPWUR.
2. Add relative power values 20 and 40 for the power state ON to support OFDMA-based LPWUR and set ramp-up time to zero for OOK/FSK LPWUR with relative power values smaller than 20.
 |
| Qualcomm | For study purpose and given that it is well-understood that OFDM-based receivers will consume higher power than OOK/FSK-based receivers, we may need to consider higher range of monitoring power values for LP-WUR.**Proposal 5: For study, add following additional power numbers (0, 10,20,40) for LP-WUR power consumption in On state.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Power State** | **Relative Power (unit)** | **Transition energy:****(unit multiplied by ms)** | **Ramp-up timeTLR, 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** | **0/0.01/0.05/0.1/0.5/1/2/4/10/20/40****FFS: If other values are needed** |
| * **Note: 0 is for Genie LP-WUR which can be used to show the lowest power consumption (or highest PSG).**
* **Note: Ramp-up time for LP-WUR must be much lower than 15 ms since deep sleep (DS) ramp-up + ramp-down time in 38.840 is 20 ms**
* **TLR, ramp-up is FFS, and company to report TLR, ramp-up**
* **FFS: Relation between Receiver architecture and its relative power and value of TLR, ramp-up**
* **~~FFS: whether further categorization/sub-categorization is needed and how~~**
 |

 |
| vivo | **Proposal 6: Adopt the following power model for LP-WUR for OFDMA-based signals/channels detection:*** **Relative power unit for LP-WUR ‘off’ state, i.e., the LP-WUR does not perform monitoring: 0.01unit**
* **Relative power unit for LP-WUR ‘on’ state, i.e., the LP-WUR performs monitoring: 20 or 40units**
 |

The following power model for OFDM-based LP-WUR is used for evaluation:

* Relative power unit for LP-WUR ‘off’ state, i.e., the LP-WUR does not perform monitoring: [0.01 unit]
* Relative power unit for LP-WUR ‘on’ state, i.e., the LP-WUR performs monitoring: 10, 20 or 40units

While in 9.13.2 AI , there is some proposals also related to OFDM receiver, e.g.,

* Two company propose 1-5 unit,
* One company propose 0.15-0.2 unit(only for LO with 200ppm or 50ppm, i.e., clock option 3 and 4)

##### [H] Proposal 1C-2-v1:

The following TPs is proposed for TR38.869v0.1.0 section 6.3.2

----------------------------TP start-------------------------------------------

**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 timeTLR, ramp-up (ms) |
| **Off[1]** | 0.001 | [0.01] | [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]** | 0.01/0.05/0.1/0.5/1/2/4FFS: If other values are needed | OFDM-cat 1: FFS 5, 10, 20, 40FFS: OFDM-cat 2: 0.2 |

* 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
* 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 OFDM-cat1, clock error option 3 or 4 is assumed, for OFDM-cat2, clock error option 1 or 2 is assumed

[1] Relative power unit for LP-WUR ‘off’ state, i.e., the LP-WUR does not perform monitoring

[2] Relative power unit for LP-WUR ‘on’ state, i.e., the LP-WUR performs monitoring

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

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | We are in general OK with the proposal. |
| OPPO | OK with the proposal. |
| Spreadtrum | For OFDM-based, it can be discussed in AI 9.11.2, since some companies have provided values. Anyway, we are fine for using two categories for OFDM-based. The specific values can be added with bracket. |
| Huawei, HiSilicon | We are not fine with the current proposal. 1. We agreed the list of “0.01/0.05/0.1/0.5/1/2/4” for LP-WUR receiver, and we have never agreed that “0.01/0.05/0.1/0.5/1/2/4” is only for envelope-detection based receivers, and in fact the values are general across the sequence-based correlation receivers also. The higher values proposed for proposed OFDM cat 1 can be added to the end of the existing list, and the Rx architectures agenda item is the better place to perform the mapping of power consumption to architecture.
2. We should also clarify that whether the LP-WUR “On” state includes the power consumption of synchronization. Based on the discussion in previous meetings, it seems current list of “0.01/0.05/0.1/0.5/1/2/4” only considers the detection power but not consider the synchronization power consumption. On the other hand, some companies propose very high power consumption of OFDM based receiver for the purpose of only time/frequency synchronization. Therefore, there exists mis-alignment among companies. In our view, it is better to separately discuss the LP-WUS signal detection power and the synchronization power consumption, considering the power consumption of these two operations on UE shall be very different and the synchronization power consumption can be actually averaged over the long synchronization signal period with a small impact on the final power consumption.

In summary, we propose separately discuss the power consumption of LP-WUS signal detection and time/frequency synchronization:* Clarify that the agreed that the agreed value range of “[0.005/0.01/0.02/0.03/0.05/0.1/0.2/0.5/1/2/4]” only considers the power consumption due to LP-WUS signal detection. This can be reflected actually in the text in the RAN1#110bis agreement: “Relative power unit for LP-WUR ‘on’ state, i.e., the LP-WUR performs monitoring”;
* Further discuss the power consumption due to time/frequency synchronization, this power consumption value could be much higher considering UE may need to under different hypothesis to detect the correct timing and frequency (as analyzed in MTK’s contribution.). However, it should be noted that this power consumption shall be averaged over the periodicity the UE needs to do the synchronization.
 |
| QC | Although we know that typical OFDM receiver implementation will have higher power consumption than OOK receiver, making hard boundary between the two types of receiver does not make strong sense. We prefer to just add additional power numbers in the list instead of categorizing them as separate column. |
| ZTE, Sanechips | 20, 30, 40 are possible values for OFDM receiver. 5 and 10 are more appropriate for FSK or other modulation schemes. For OFDM-cat 2, it is strange why the relative power could be lower than OOK. The difference between Zero-IF architecture for OFDMA based signal and Zero-IF architecture for OOK based signal should be clarified. |
| Xiaomi | Fine with the proposal. |
| Nokia1 | OK in principle. Noting also that in our paper for the architecture discussion we touched upon the possible saving that could be achieved. Based on that and taking the relative power consumption of 50 (for SSB/CSI processing), we considered 12 in our evaluations. Thus at least relative power of 10 could be considered. |
| Intel | We are Ok with adding relative power values for OFDM receiver.  |
| InterDigital | Support |

#### 1C-3: LR Ramp-up time

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CATT | Ramp up time from LP-WUS off to ON is assumed as 1ms with the relative power of LP-WUS on to be 0.01 – 0.1.**Proposal 8: The suggested power model for LP-WUR is as follows:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Power State** | **Characteristics** | **Relative Power**  | **Ramp-up time** |
| Periodic low power WUS“ON” state | Front end wakeup receiver is configured to detect the wakeup signals periodically associated with C-DRX or PO.  | [0.01 – 0.1] | --- |
| Periodic low power WUS“OFF” state | Front end wakeup receiver is configured to detect the wakeup signals periodically associated with C-DRX or PO. Otherwise, the wakeup receiver is shut down. | [0.001] | [1ms] |
| Continuous low-power WUS monitoring | Front end wakeup receiver with free-running clock in the active device or passive device monitoring of wakeup signals continuously. | [0.001 – 0.01] | [0ms] |

 |
| ZTE | ***10ms*** *ramp-up time of WUR could be used as the starting point.* |
| Samsung | **Proposal 3: When the relative power value for the on-state of LP-WUR is chosen for the evaluation, the characteristics of the assumed LR architecture should be reflected.*** **E.g., the types of receiver architecture, the presence of LNA/AMP, the type of oscillator, the type of BPF/LPF filter and etc.**
* **The details of LR assumed for the evaluation are up to each company.**

**Proposal 4: Ramp-up time and transition energy from ‘off’ to ‘on’ states should be different according to the power level of ‘on’ state for LR.*** **E.g., on state for 1/2/4 relative power unit, ramp-up time should not be neglected.**
 |
| Ericsson | 10ms is assumed for ramp up time of LP-WUR on-off |
| vivo | 10ms |
| Nokia | **Table 2. WUR power consumption assumptions**

|  |  |  |
| --- | --- | --- |
| *LP-WUR* | Relative power  | Transition time and energy(if applicable) |
| LP-WUS monitoring, always-on receiver  |  [0.1]\* |  |
| LP-WUS monitoring, duty cycled receiver | Monitoring: [4.0] or [12.0]Off: [0.001] | { 10ms, TLR, ramp-up \*(PON - POFF)/2 } |
| []\* : Values are preliminary and to be considered further based on the LP-WUR architecture discussion. |

 |

##### [H] Proposal 1C-3-v1:

**When the relative power of LP-WUR “on” is no less than 1unit, the ramp-up time from LP-WUR ‘off’ to ‘on’ is assumed as 10ms for evaluation.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | We are OK with the proposal |
| OPPO | OK with the proposal. |
| Huawei, HiSilicon | For the LP-WUR power consumption, currently the agreed power is 2 and 4, and some companies are proposing larger values, e.g. 20 and 40. It is not clear regarding the assumption of power unit for LP-WUR when we propose the corresponding ramp-up time is 10ms.Therefore, we prefer to firstly discuss Proposal 1C-2-v1 clearly, then discuss the ramp-up latency for the considered values.  |
| QC | It is not clear why the boundary is “1 unit”. |
| ZTE, Sanechips | From relative power 0.01 to 40, we do not think the 10ms is enough, since for RedCap UE from deep sleep 0.8 to PDCCH only for cross-slot scheduling with relative power 40, the transition time is 20ms. |
| Xiaomi | Fine with the proposal. |
| Nokia1 | OK. On relation to ZTE comment, in our view the transition time is more defined by the change in processing, and not solely determined by the (relative) power difference. |

#### 1C-4: measurement assumptions details

|  |  |
| --- | --- |
| vivo | **Proposal 7: For RRM measurement assumptions in RRC idle/inactive mode, the following options can be considered.*** **Option 1: RRM measurement is only performed by MR.**
* **Option 2: LP-WUR performs RRM measurement based on periodic lower power signal e.g., LP-SS. MR performs relaxed RRM measurement every X I-DRX cycles, where X can be 10 or 20.**
* **Option 3: RRM measurement is only performed by LP-WUR.**

**Vivo suggest 1.28s in contributions submitted in AT9.11.3** |
| Sony | ***Proposal 4 – Consider low-power mechanism to support mobility and cell re-selection mechanism for UEs with LP-WUR.***  |
| Huawei | The periodicity of LP-SS can be assumed to be 400 ms, which can be used for the evaluation of resource overhead and network energy consumption. |
| Qualcomm | **Chart, line chart  Description automatically generated**Figure CDF of Delta RSRP = Genie RSRP – LP-SS based RSRP**Observation 15:** $\pm 2$ **dB delta RSRP relative to genie RSRP may be achievable 90% of the time using OOK based LP-SS at SNR=-3 dB and realistic clock model.**  |
| Nokia | Now as the LP-WUS maybe sent rather infrequently (depending on the paging rate and number of UEs addressed by the LP-WUS), maintaining a frequency syncronisation during these periods would still be necessary. Hence, as discussed in past meetings considering some form of periodic LP signal to facilitate maintaining the frequency synchronisation would be beneficial. However, based on the performance evaluations [5] and assumed assumed drift and maximum error models agreed in last meeting (below), the periodicity of the LP syncronisation signal can be rather long, e.g. in order of 10s.**Proposal 11: Consider LP synchronisation signal for (at least) for frequency tracking.** |

##### [H] Proposal 1C-4-v1:

The period of low power synchronization signal for evaluation can be {400ms, 1.28s, 10s(at least for frequency tracking) }

* Note: the purpose of the low power synchronization signal can be for LR synchronization (i.e., time and/or frequency tracking) or measurement.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| OPPO | Generally OK with the proposal. |
| Spreadtrum | Periodic synchronization can be relaxed for LP-WUS. Periodic measurement can be in the order of I-DRX cycle like that of main radio. Therefore, we think it should be no smaller than 1.28s. |
| Huawei, HiSilicon | We are in general fine with the proposal with the following comments:1. The periodicity relates to the design of LP-SS and also the required timing error/frequency error budget for LP-WUS signal detection. Based on our study, 400ms is needed for the synchronization. Larger value may be possible if the LP-SS can provide better synchronization performance and the LP-WUS signal waveform is designed more robust w.r.t time/frequency error. Therefore, we prefer to keep 400ms as a starting point and say larger value can be considered if justified;
2. Regarding the note, it should be “Note: the purpose of the low power synchronization signal can be for LR synchronization (i.e., time and/or frequency tracking) and/or measurement”
 |
| QC | Agree on the proposal. Other values should not be precluded.  |
| ZTE, Sanechips | Serving cell measurement period is based on DRX cycle, i.e., 0.32s,0.64s,1.28s, 2.56s. To offload the measurement to WUR, similar measurement period can be assumed for LP-SS. Therefore, we would suggest the following values for LP-SS evaluation: {160ms, 320ms, 640ms, 1280ms, 2560ms, 5120ms, 10240ms}Regarding 160ms, we think if LP-SS can be used to replace SSB, the performance may be worse than SSB. Therefore, more frequent LP-SS could be considered to guarantee the measurement performance. |
| Xiaomi | Generally fine. But other values for periodicity should not be precluded and can be reported by companies.  |
| Nokia1 | (Based on agenda) the proposal seems to be for the purpose of power saving evaluations. We think that it would be good to clarify the purpose e.g. (…for power saving evaluation..). As noted by others, the sync performance etc. the performance together with the assumed clock drift would determine the needed periodicity, thus these could be preliminary values for power saving evaluation.A minor note that our note “(at least for frequency tracking)” related more to the purpose of the LP-SS rather than the period, thus is not needed as it is covered in sub-bullet.  |
| Intel | We are fine to take the proposed values as start point. other values should not be excluded which are subjected to further study. For the note, it may be revised as ‘for LR synchronization (i.e., time and/or frequency tracking) and/or measurement’ since a LP-SS may be used for both sync and RRM too. Then, what will be the metric in the study of proper periodicity? The example may be timing/frequency error, RRM accuracy, power consumption, and etc.  |

#### 1C-5: Sync/re-sync assumption:

|  |  |
| --- | --- |
| Futurewei | LP-WUS may imply/convey some timing and serving cell information to MR. And study two alternatives for MR sync/re-sync:* *MR Sync Alt 1: PSS/SSS search for, e.g., [40, 80, 120]ms, with no LP-WUS assistance.*
* *MR Sync Alt 2: No PSS/SSS search with LP-WUS assistance.*
 |
| CATT | at least 3 SSBs are needed for MR acquiring Time/Frequency synchronization after wakeup |
| ZTE | at least 3 SSBs are required for sync/re-sync when main radio wakes up from the state of ultra-deep sleep. |
| Qualcomm | 1 or 3SSBs for sync/re-sync considering different SNR.**Proposal 4: Use the following values for additional X time units required for sync/re-sync of the MR:*** **X = 50 ms for low SNR**
* **X= 20 ms for high SNR**
 |
| vivo | Table 1. The assumptions of Sync/re-sync time and energy

|  |  |  |
| --- | --- | --- |
|  | **Sync/re-sync time [ms]** | **Sync/re-sync energy [ms\*units]** |
| **Number of SSBs for sync/re-sync =3[1]** | 60 | 2180 |
| **Number of SSBs for sync/re-sync =5[1]** | 100 | 3340 |
| Note 1: 10ms continuous monitoring from the beginning of sync-re-sync time is assumed. |

**Proposal 4: For sync/re-sync time and energy, Table 1 of R1-2302506 can be assumed.** |
| Spreadtrum | ***Proposal 1: 3/6/9 SSBs for sync/re-sync for ultra-deep sleep can be assumed for different channel condition respectively.*** |
| InterDigital | ***Proposal 4:*** *For total time for sync/re-sync of MR, support up to 10 SSBs for FR2 as well as FR1.* |

##### [M] Proposal 1C-5-v1:

For FR1 evaluation,

* Number of SSBs for sync/re-sync for MR can be at least 3
	+ Companies to report sync/re-sync time and energy consumption

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | The minimum number of SSBs required for sync/re-sync and timeline will depend on whether LP-WUR can assist the MR in time and frequency synchronization or not. We suggest to wait till discussions on LP-WUR synchronization and assistance to MR is progressed under AI9.11.3. |
| DOCOMO | We agree with Futurewei the number of SSBs needed depends on whether there is the ability of the WUR to transfer information about synchronization to the MR. Thus, we suggest the following modification. For FR1 evaluation,* Number of SSBs for sync/re-sync for MR can be at least 3 in cases where LP-WUR does not assist the MR in time and frequency synchronization,
	+ Companies to report sync/re-sync time and energy consumption
	+ FFS: Number of SSBs for sync/re-sync for MR in cases where LP-WUR assist the MR in time and frequency synchronization
 |
| Spreadtrum | Fine |
| Huawei, HiSilicon | Not sure what’s the purpose of this proposal since it implies a large range of sync/re-sync time.The number of SSB needed could be reduced to less than 3 if LP-WUR can assist the synchronization of MR. |
| QC | As HW pointed, LP-WUR could also help MR sync.Prefer to leave company to report. |
| ZTE, Sanechips | OK with the proposal. |
| Xiaomi | Fine with the proposal. |
| Nokia1 | As noted others, it would be good to clarify whether this assumption is independent of e.g. possible existence of LP-SS and related assistance information from LR. As discussed earlier, the RAN4 requirements (for CONNECTED mode UEs) give somewhat pessimistic picture of the timeline/number of SSBs, thus these numbers seem rather aggressive, but if companies are fine to commit to these from latency perspective, no strong concern. Also the time for continuous search would be good to align e.g. 20ms prior the 3 SSBs. |
| Intel | After waking-up, the MR needs to do sync/resync and do RRM too. Is the current proposal of 3 SSBs shared for both sync/resync and RRM (for both serving cell and intra-frequency cells) ?We share views from FutureWei and DoCoMo. With assistance of LP-WUS, UE can know the timing of MR (assuming LP-WUS timing is configured related to MR timing), though there is still a need for frequency synchronization.  |

### 1D: Others

* **Discussion on resource overhead or NW power consumption:**

need to be considered and modeled: Futurewei, Ericsson, ZTE,vivo, Sony

not support to consider NW power consumption as performance metric: InterDigital

* **Evaluation assumption on MR sleep state during LP-WUS monitoring for RRC connected mode**

Vivo: In RRC connected mode, Ultra-deep sleep state of main radio should not be applied. And UE main radio can enter micro, light or deep sleep state during LP-WUS monitoring.

* **Correct per UE paging probability to**RE = 1 – (1 – RE, REF )(K-L+1)Y/YREF

Nordic

* **Number of UE in each group:**

CATT: less than 8

Ericsson: 10

|  |  |
| --- | --- |
| Futurewei: | * Study the impact of defining a shorter DRX cycle (<320 ms), i.e., for the MR to monitor POs after waking up due to reception of LP-WUS, on latency and overall paging resource overhead.
* Resource overhead: LP-WUS design options/functions and mapping to time/frequency resource requirements need to be defined for proper evaluation of the network resource overhead in support of LP-WUS/WUR.
* Consider LP-WUR monitoring of at least a tracking and/or a RAN notification area level beacon that is transmitted with reasonable periodicity to alleviate the impact of MR’s low periodicity RRM measurements on latency.
* Latency definition: For a LP-WUS carrying a UE unique ID, the latency is defined as the average time between the arrival of data at gNB and the UE’s completion of MR synchronization upon detection of a corresponding LP-WUS.
* Ignore the latency impact of SI update on paging procedure due to its infrequent occurrence as part of paging procedure.
 |
| CATT | **Proposal 4: The Latency\_2 is mainly affected by the MR ramp-up and preparation for paging message reception with the addition of the RACH response time. The Latency\_2 is suggested in a range of 500ms~2200ms.****Proposal 5: The total latency can be divided into three independent parts associated with different dependent components: Latency\_0 for gNB preparation, Latency\_1 for LP-WUR monitoring the LP-WUS and Latency\_3 for MR waking up and detecting paging message, the expression of latency can be formulated as: Total Latency = Latency \_0 + Latency\_1 + Latency \_2.**Discussion on the maximum number of UE in each group should be less than 8**Proposal 6: The number of UE in the same group should be less than 8 for 14.8% paging group rate under 1% paging rate per UE.** **Proposal 7: The number of UE in the same group should not be more than 8 for i-DRX and e-DRX with RE, REF below 1%.**  |
| Ericsson | For evaluations, use **N=10** and the resulting range of RG={10%, 1%, 0.1%, 0.01%} for the per group paging probability.1. The following general framework should be used as starting point for WUS evaluations:
* Transmission of LP-WUS should not require new gNB hardware and should not trigger new emissions/compliance requirements for gNBs.
* It should be possible to dynamically reuse unused LP-WUS resources for other NR transmissions (i.e., dedicated time/frequency resource reservation for WUS should be avoided).
* It should be possible to multiplex LP-WUS with other NR transmissions in time or frequency domain without causing interference.
* LP-WUS is transmitted on Uu interface from gNB to UE.
1. Impact of LP-WUS/WUR operation on NW Energy Efficiency should be considered especially if LP-WUS transmissions require significantly more time/frequency resources compared to PDCCH or require additional always-on transmissions (e.g., LP-SS) from gNB.
 |
| ZTE | Discuss the assumption for system overhead and NW power evaluation.***Proposal 1: The following KPIs on LP-WUS should be further evaluated******• System overhead******• Network power consumption******• Co-existence impacts******Proposal 2: Clarify the latency definition for different RRC states.*** the latency means the time interval between LP-WUS and PRACH in idle/inactive mode. In connected mode, the latency means the time interval between LP-WUS and PDSCH with data.***Proposal 13: Discuss the LP-WUS transmission assumption in idle/inactive mode for evaluation and capture how to calculate the system overhead.******Proposal 14: For NW power evaluation, discuss the LP-WUS or LP-SS transmission assumption, and load scenarios in idle/inactive mode.*** |
| Samsung | **Proposal 2: The latency for RRC\_CONNECTED state is defined as the time interval between the data arrival time at the gNB and the time of the first UE specific data channel reception.****Proposal 6: The power model in the Table 3.2 should be considered as a baseline to evaluate i-DRX/e-DRX operation for eMBB case.** |
| Qualcomm | **Proposal 2: Following KPIs are evaluated: data rate, false wakeup probability (due to grouping and false alarm), and misdetection probability.****Proposal 5: For study, add following additional power numbers (0, 10,20,40) for LP-WUR power consumption in On state.**

|  |  |  |  |
| --- | --- | --- | --- |
| Power State | Relative Power (unit) | Transition energy:(unit multiplied by ms) | Ramp-up timeTLR, 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** | **0/0.01/0.05/0.1/0.5/1/2/4/10/20/40****FFS: If other values are needed** |
| * Note: 0 is for Genie LP-WUR which can be used to show the lowest power consumption (or highest PSG).
* Note: Ramp-up time for LP-WUR must be much lower than 15 ms since deep sleep (DS) ramp-up + ramp-down time in 38.840 is 20 ms
* TLR, ramp-up is FFS, and company to report TLR, ramp-up
* FFS: Relation between Receiver architecture and its relative power and value of TLR, ramp-up
* ~~FFS: whether further categorization/sub-categorization is needed and how~~
 |

**Observation 1: Possible options for LP-WUS BW configuration include 1MHz, 5MHz, and 20MHz.** **Proposal 8 : Prioritize 5MHz for LP-WUS bandwidth.****Proposal 10: For both link level and power evaluations LP-WUS, the following false-alarm rate (FAR) of LP-WUS can be assumed: ~~[~~0.1%, 1%~~, 10%~~].****Proposal 11: Target false alarm probability of LP-WUS is at most 1%.** |
| Nokia | Proposal 1: Down prioritize the sidelink related studies for time being.**Proposal 2: Consider implications to network energy efficiency in studied LP-WUS related designs.**Proposal 3: LP-WUS design and LP-WUR architecture should support flexible placement in frequency domain.Proposal 4: The wake-up signal design and wake up receiver architecture defined, allows efficient reuse of gNB hardware for signal generation.Proposal 5: The LP-WUS/WUR design should ensure that legacy receiver performance is not affected and efficient multiplexing with existing NR signals and channels is possible to limit the resource reservation.Proposal 6: Coverage and mobility implications should be accounted for in LP-WUS design and LP-WUR architecture assumptions. |
| vivo | **Observation 28:** **Additional network energy consumption caused by LP-WUS/WUR operation can be minimized, e.g., gNB can transmit LP-WUS in the slot with existing NR signal that to be transmitted.****Proposal 8: In RRC connected mode, Ultra-deep sleep state of main radio should not be applied. And UE main radio can enter micro, light or deep sleep state during LP-WUS monitoring.** |
| Xiaomi | ***Proposal 1: For RRC idle/inactive state, two use cases can be considered for evaluation:******Case 1, LP WUS combined with legacy paging mechanism;******Case 2, LP WUS combined with enhanced paging mechanism.***  |
| Nordic  | ***Proposal-3:*** *For e-DRX, per UE paging probability should corrected* *to* RE = 1 – (1 – RE, REF )(K-L+1)Y/YREF |
| Sony | ***Observation 5 – LP-WUS length, the amount information it carries, and the technique used for its multiplexing in an OFDM transmitter impact the number of resources for LP-WUS transmission and its associated system overhead.*** ***Proposal 5 – Support an adaptive configuration where the UE, depending on its delay requirement, can operate based on an always-on or a duty-cycle scheme.***Average delay = ½ sleep time + transition time + signal miss detection × average time for re-transmission |
| InterDigital | ***Proposal 1:*** *NW power consumption/energy efficiency is not adopted as a performance metric.****Proposal 5:*** *Confirm the current definition of transition energy (i.e., TLR, ramp-up \*(PON – POFF)/2) for LP-WUR.* |
| Huawei | If UE is not required to monitor a PO after wake-up, latency is the time interval between the data arrival time at the gNB, and the time of the first RO UE can transmit PRACH in after LP‑WUS detection. |

##### [M] Proposal 1D-1-v1:

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

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | We are OK with the update. |
| DOCOMO | We support this proposal. |
| OPPO | OK with the proposal. |
| Huawei, HiSilicon | OK |
| QC | We prefer to have L=1 and 4. L=1 would correspond to the case of having i-DRX with much larger cycle than allowed for now. This is useful configuration for study purpose. |
| ZTE, Sanechips | OK |
| Xiaomi | Fine with the proposal. |
| Nokia1 | OK |
| Intel | We support this proposal. |

##### [M] Proposal 1D-2-v1:

Update the 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 transition energy and LP-WUR OFF energy, e.g., similar definition as the transition energy in TR38.840

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | We are OK with the update. |
| DOCOMO | We support this proposal. |
| OPPO | OK with the proposal. |
| Huawei, HiSilicon | We are fine with the update. |
| QC | okay |
| ZTE, Sanechips | OK |
| Xiaomi | Fine with the proposal. |
| Nokia1 | OK |
| Intel | We support this proposal. |

## Issue 2: Others

### 2A: Remaining issues for use case descriptions

|  |  |
| --- | --- |
| Qualcomm | **Proposal 1:*** **Latency requirement for IoT Idle mode cases including e.g., industrial wireless sensors, controllers, actuators and etc.**
	+ **Order of seconds (0.64, 1.28 sec)**
* **Latency requirement for wearable Idle mode cases including e.g., smart watches, rings, eHealth related devices, and medical monitoring devices etc.,**
	+ **Order of seconds (0.64, 1.28 sec)**
* **Latency requirement for eMBB Idle mode cases including e.g., smart phones and etc.,**
* **Latency requirement for eMBB/XR Connected mode cases including**
	+ **Order of milliseconds [0.5, 1, 2ms]**
 |
| Ericsson | **Observation 1 Latency requirements for use cases mentioned in the SID such as industrial controllers, actuators etc., and wearables range from tens of milliseconds, hundreds of milliseconds to several seconds. For XR, the requirements are in few milliseconds to few tens of milliseconds range.****Proposal 1 Study the following further:****• Applicability of RRC IDLE/INACTIVE vs. RRC CONNECTED mode operation of LP-WUS/WUR considering latency requirements and expected data activity for different use cases mentioned in the SID.****• Feasible latency at which LP-WUR can wake up MR while still providing power saving gain.****Proposal 2 Include ‘latency’ as a use case characteristic for IoT, Wearables, and eMBB.** |
| vivo | **Proposal 2: Consider the following as the latency target by applying LP-WUS/WUR:*** **Within 1 or 2 seconds for latency-sensitive IoT cases and within several or tens of seconds for other IoT cases;**
* **Within several seconds for wearable cases;**
* **Within several milliseconds for XR use case and within tens of milliseconds for other eMBB use cases;**
 |
| Sony | **Proposal 1 – Prioritize LP-WUS/WUR for power-sensitive, low-traffic, small form factor devices as in IoT use cases (such as industrial sensors, controllers) and wearables where delay requirement or device reachability in time is short.**  |
| LG | **Proposal 1: Update the following latency characteristic for target use cases.*** **IoT cases including e.g., industrial wireless sensors, controllers, actuators and etc, including the following characteristics,**
	+ **latency-tolerable (e.g., the order of seconds)**
* **Wearable cases including e.g., smart watches, rings, eHealth related devices, and medical monitoring devices etc.,**
	+ **latency- tolerable (e.g., the order of seconds)**
* **eMBB cases including e.g., XR/smart glasses, smart phones and etc.,**

**latency-sensitive (e.g., the order of milliseconds)** |
| Nordic  | ***Proposal-1:*** *For the latency of industrial IoT use-case, consider 100ms to 10s as design criteria.* |

##### [M] Proposal 2A-v1:

The latency for the target use cases are considered as follows:

* IoT cases including e.g., industrial wireless sensors, controllers, actuators and etc, including the following characteristics,
	+ Latency for RRC IDLE/INACTIVE mode is in the order of seconds
* Wearable cases including e.g., smart watches, rings, eHealth related devices, and medical monitoring devices etc.,
	+ Latency for RRC IDLE/INACTIVE mode is in the order of seconds
* eMBB cases including e.g., XR/smart glasses, smart phones and etc.,
	+ Latency for RRC CONNECTED mode is in the order of milliseconds

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | We are OK with the proposal |
| OPPO | OK with the proposal. |
| Spreadtrum | Latency for RRC CONNECTED mode should be stringent for indication in scheduling PDCCH, e.g. PDCCH skipping, SSSG switching, but it can be relaxed for WUS before C-DRX like DCI format 2\_6. For RRC IDLE/INACTIVE, some companies proposed to use LP-WUS for IoT case to enable latency reduction. In this case continuous monitoring is efficient. * IoT cases including e.g., industrial wireless sensors, controllers, actuators and etc, including the following characteristics,
	+ Non time critical: Latency for RRC IDLE/INACTIVE mode is in the order of seconds
	+ Time critical: Latency for RRC IDLE/INACTIVE mode is in the order of milliseconds
* Wearable cases including e.g., smart watches, rings, eHealth related devices, and medical monitoring devices etc.,
	+ Latency for RRC IDLE/INACTIVE mode is in the order of seconds
* eMBB cases including e.g., XR/smart glasses, smart phones and etc.,
	+ Latency for RRC IDLE/INACTIVE mode is in the order of seconds
 |
| Huawei, HiSilicon | It is already clear enough for the use cases discussion, and we have already used much time to discuss without a consensus to includes these latency target. No need to use our limited time to repeat the discussion. |
| QC | Agree with FL w/o change. |
| ZTE, Sanechips | For eMBB especially for XR traffic, to be more specific, the latency should be order of several milliseconds |
| Nokia1 | We are OK with the FL proposal. |
| Intel | We support this proposal. |
| InterDigital | Support |

### 2B: target power for LP-WUR

|  |  |
| --- | --- |
| vivo | **Observation 1: In the case that the relative power of LP-WUR “on” state is 0.03~0.5 unit, substantial power saving gain e.g., up to 80% can be achieved.****Observation 2: LP-WUR should address all traffic arrival cases for IoT/Wearable/eMBB, thus keeping the “ON” state power as low as possible is important for increasing the battery life of the device.****Proposal 1: The target relative power of LP-WUR “on” state should be less than 1 unit.**  |
| OPPO | ***Proposal 2: For I-DRX cycle, the different value of “additional transition energy from ultra-deep sleep” will case different conclusion of whether LP-WUR has power saving gain compared to I-DRX with PEI or not. Prioritize the case ‘LP-WUR on state’ is smaller than 1.*** |
| Apple  | **Proposal 1: Do not set a tight power consumption target for LP WUR at this stage. The tradeoffs should be carefully considered.** |

Moderator encourage companies to express more views on this topic and how to proceed.

##### [M] Proposals 2B-v1:

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | In our observations, we noticed that even with duty cycled monitoring, considering LP-WUR relative “ON” power greater than 4 units can result in a noticeable reduction in the power saving gain. Therefore, we suggest considering a target maximum “ON” relative power <4 units.  |
| Spreadtrum | There are values for evaluation purpose already. The power saving gain is more important. |
| QC | RAN1 is in the middle of studying various LP-WUS power numbers (including 1, 4, 10, 20) with duty cycled based monitoring scheme. So, we think there is no need to make premature conclusion especially toward “1 unit”. |
| Intel | The targeted relative power should be discussed together with OFDM based receiver. From the power consumption study, the high relative power cause smaller power reduction gain, and even larger power consumption compared with the baseline for certain value of relative power.  |
|  |  |
|  |  |
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|  |  |
|  |  |

### 2C: target coverage for LP-WUS

**E****ricsson** propose that, for coverage evaluations, LP-WUS/WUR designs that strive to match the coverage for NR PDCCH should be considered.

**Samsung:** The coverage for LP-WUS/WUR should be comparable to at least that of the NR downlink channel.

**Huawei** propose to use PUSCH or Msg3, as the reference for coverage evaluation of LP-WUS.

**ZTE** propose that the target coverage of LP WUS should be better than PUSCH.

**Proposal 12: RAN1 strives to design LP-WUS to have a similar coverage as NR** [**PDCCH] channel.**

Moderator encourage companies to express more views on this topic and how to proceed.

##### [M] Proposals 2C-v1:

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | We suggest to consider a coverage target that is at least equivalent to PUSCH and strives to approach that of PDCCH, but not necessarily set PDCCH coverage as target to have more flexibility to trade-off power saving gain, resource overhead, and latency. |
| Spreadtrum | Strive to paging PDCCH, otherwise LP-WUS cannot be used at cell edge and transition of main radio may happen often, and thus the power saving gain in real deployment will be gone. |
| Huawei, HiSilicon | The bottleneck channel, i.e. PUSCH, is preferred to be as the coverage target. For LP-WUS used in IDLE/inactive mode, we can be flexible to further compromise to set the target as the coverage of PUSCH for Msg3 considering the Msg3 is the bottleneck of coverage during the IDLE/inactive states. We don’t see a need to over-optimize the LP-WUS to have the same coverage of PDCCH.  |
| QC | @FL, please capture QC view (above) as well.We encourage companies to do detailed study on coverage, data rate and overhead.We propose to make an agreement on following proposal as a first step.**Proposal: RAN1 strives to design LP-WUS to have a similar coverage as NR channel X. FFS: The NR channel X is either PDCCH or PUSCH. FFS: Channel configuration of X**  |
| ZTE, Sanechips | Better than PUSCH would be enough, which can cover most of the UEs in a cell. Moreover, this is a good starting point, since we still can pursue the coverage similar with PDCCH. |
| Xiaomi | The bottleneck channel needs to take PUSCH into account and the LP WUS coverage should be superior to the bottleneck channel. |
| Nokia1 | Thus the question is whether we will aim for full coverage or partial coverage. There is evidently cost associated to requiring LR (and LP-WUS) to support higher/full coverage. If we on the other hand in practice require MR to be used at the cell edge for mobility evaluations e.g. for neighboring cells, implying more power consuming design for LR might not be justified. From this perspective, it might be more practical to consider partial coverage. However, it would increase the feasible deployments for LP-WUS if better coverage can be attained.  |
| Intel | From our evaluation, the MIL for LP-WUS can be better than PUSCH but is much worse than common PDCCH. Since PUSCH or msg3 is involved in cell section/tracking area update, it would be fine to take PUSCH or msg3 as baseline. The assumed data rate for PUSCH should be further clarified.  |

# Evaluation results

***Moderator: To be handled in another documents after consolidating the results.***

# void

# void

# Summary of the previous agreements

## RAN1#110bis-e

**For future meetings on LP WUS:**

Use the following terminology for future discussion,

* Main radio (MR): the Tx/Rx module operating for NR signals/channels apart from signals/channel related to low-power wake-up
* LP-WUR (LR): The Rx module operating for receiving/processing signals/channel related to low-power wake-up.

**Agreement**

For evaluation, 1 Rx chain for LP-WUS receiver is baseline.

**Agreement**

Both RRC IDLE/INACTIVE and CONNECTED modes are to be studied as part of the LP-WUS/WUR SI.

* FFS: Further prioritization if needed during the study item.

**Agreement**

Take the following power model for main radio for evaluation in LP-WUS/WUR SI,

* For IoT and wearable cases, reuse TR38.875 power model as baseline.
* For eMBB and other cases, reuse TR38.840 power model as baseline.
* Introduce ‘*Ultra-deep sleep*’ power state for main radio of UEs with LP-WUS receiver
	+ FFS: The details of ‘*Ultra-deep sleep*’ power state

**R1-2210512** FL summary#2 of evaluation on low power WUS Moderator (vivo)

**Agreement**

* The following power models are used ‘*Ultra-deep sleep*’ power state for main radio for evaluation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Power State | Relative Power (unit) | Ramp-up and down transition energy (Note1):(unit multiplied by ms) | Ramp-up time | Time for sync/re-sync |
| **Ultra-deep sleep** | **[0.015]** | [2000 ~ 40000]* Study to converge on candidate numbers to use for evaluation
* FFS: other values and reported by companies.
* FFS: down-selection of the values,
* companies are encouraged to provide details for down-selection
 | [400ms], FFS: 100ms | **X** |

 Note1:

* + Ramp-up time may consist of the procedure for [main radio hardware tune on e.g., boot, memory load and etc.],
	+ Time for sync/re-sync consists of the procedure for [main radio to re-synchronization with the serving gNB etc.],
		- FFS: X and whether/how to have different values depending on other factors, e.g., signal-to-noise ratio
		- Companies can report the assumption of X in the initial evaluation.
	+ Ramp up and down energy includes power for ramp-up and ramp-down. Energy consumption for sync/re-sync is separately calculated.
* The total time for main radio transition from ultra-deep sleep to active/micro sleep state is the sum of ramp-up time and time for sync/re-sync.
	+ FFS whether/how to define ramp-down time, whether to separately describe the ramp-down energy consumption

Note 2: the power state transitions in this table refer to transitions between ultra deep sleep state and active / micro sleep state.

Note 3: The values inside of ‘[ ]’ are to be used as starting point of future study on LP-WUS

**Agreement**

The following power model for LP-WUR/WUS evaluation is considered,

* + Relative power unit for LP-WUR ‘off’ state, i.e., the LP-WUR does not perform monitoring:
		- [0.001]
	+ Relative power unit for LP-WUR ‘on’ state, i.e., the LP-WUR performs monitoring:
		- [0.005/0.01/0.02/0.03/0.05/0.1/0.2/0.5/1/2/4]
		- Other values are not precluded to be evaluated.
		- FFS: Mapping from values to a LP-WUR architecture or LP-WUR mode of operation
	+ No additional transition energy and transition time between ‘on’ and ‘off’ state as start point, FFS any transition energy and transition time if needed.

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)

FFS: LP-WUR power consumption values for FR2.

**Agreement**

For R18 LP-WUS/WUR power evaluation in RRC connected mode, the following can be considered,

* XR traffic model with evaluation methodologies and assumptions captured in TR 38.838.
* eMBB traffic model with evaluation methodologies and assumptions captured in TR 38.840
* Heartbeat traffic models in 3GPP TR 38.875.
* Other models are not precluded.

Company to further provide the followings,

* Parameters (e.g., frame rate, data rate, jitter range, DRX configurations and etc if needed.)
* How to use LP-WUS, e.g., LP-WUS to trigger/adapt PDCCH monitoring
* Other details if any

**Agreement**

* For LP-WUS coverage evaluation, the noise figure of LP-WUR is
	+ Options : [9, 12, 15, 18, 21, 24], Other values can be reported by companies
* FFS: how to determine the NF option.
* The values provided is for the purpose of studying coverage of LP-WUS, and it can be further revisited depending on the receiver architecture discussion.

**Agreement**

For the performance evaluations of LP-WUS candidate designs, it is assumed that

* The miss-detection rate (MDR) of LP-WUS [1%],
* The false-alarm rate (FAR) of LP-WUS
	+ [0.1%, 1%, 10%]
	+ Other values are not precluded for studying reported by companies
* Note: if LP-WUS for wake-up indication consists of two parts or even multiple parts, the proposed MDR/FAR should take into account the reception performance of the two or more parts jointly
* The above values applied in both RRC CONNECTED and IDLE/INACTIVE mode.
* FFS FAR requirement based on the study outcome of the impact of FAR on power consumption / power saving gain / system overhead
* FFS: Note: FAR should be evaluated both in the absence of gNB transmissions and in the presence of transmissions from gNB. Proponent to provide the details.

**Agreement**

For system impact analysis, the following performance metrics are considered to be provided,

|  |  |
| --- | --- |
| **Performance Metric** | **Note** |
| System overhead | expressed as percentage of used part of all REs for LP-WUS (including guard band or time or others resource used for LP-WUR if any) among all resourcesOther assumptions related to the system overhead analysis can be reported, e.g., the LP-WUR raw data rate evaluated in the coverage evaluations. |
| FFS: Capacity impact | [Evaluate the system capacity impact due to introducing of LP-WUS] |
| FFS: NW power consumption / Energy Efficiency | [Impact of LP-WUS/WUR operation on gNB energy consumption as performance metric in system impact analysis.] |

 For power and latency evaluation of the LP-WUS, the following performance metrics are considered to be provided.

|  |  |
| --- | --- |
|  **Performance Metric** | **Note** |
| Power consumption | Relative power consumption in units. The power consumption includes main radio and LP-WUR. For comparison, the relative power consumption and evaluation period for baseline schemes should also be provided, as well as the power saving gain (i.e., percentage of power consumption reduction of the proposed power saving scheme from the baseline scheme). |
| Latency | For IDLE/INACTIVE state, the latency is the time interval between the data arrival time at the gNB and the time of the first PO UE can [monitor/detect] the paging message* FFS: if UE is not required to monitor a PO after wake-up, e.g., latency is the time interval between the data arrival time at the gNB and the time UE transmits the PRACH after LP-WUS detection.
* sync/re-sync for main radio is included

For CONNECTED state, TBD |
| FFS: UPT | FFSNote: it is for connected mode purpose. |

Companies to report baseline scheme, e.g., PO monitoring with i-DRX, e-DRX, with or without PEI

Companies to report the power consumption / power saving gain considering the FAR impact , latency considering MDR impact

Other performance metrics (e.g., mobility) can be reported by companies (if any)

**Agreement**

The following is assumed for RRC IDLE/INACTIVE evaluation,

|  |  |
| --- | --- |
| **Parameters** | **Value** |
| i-DRX cycle length | 1.28s and other values not precluded and reported by companies, consider both with PEI/ without PEI |
| e-DRX cycle length | 20.48s, 61.44s and other values not precluded, company to report which value(s) are used.  *Note: ‘ultra-deep sleep’ state can be assumed for eDRX whenever necessary for baseline UE* |
| Number of POs in Paging Frame | 1 |
| Number of DRXs per PTW | 4 |
| Number of SSB before PO / PEI | 1, 2 or 3, (used for e.g., AGC adjustment, T/F tracking, serving cell and intra-F measurement)company to report which value(s) are usedNote: the assumptions is for MR wakes from ‘Deep sleep’ |
| Sync/re-sync after ultra-deep sleep | companies to report the timeline of sync/re-sync and X value, X is the time for sync/re-sync |
| RRM Measurement | Company to report whether and how the RRM measurement is assumed, e.g., whether RRM performed by main radio or LP-WUR, whether RRM is relaxed or not. |
| LP-WUS monitoring | Option 1: continuously monitoringOption 2: discontinuously monitoring, with [T] ms as the period for complete an on-and-off cycle, and [D] ms as the active time for monitoring LP-WUS every cycle. |
| Traffic | Option 1 (baseline):Per UE paging rate (*R\_E*)= ([1%]) or ([0.1%]) or ([0.01%]) or ([0.001%]) within duration Y, [FFS Y is an i-DRX cycle length or an absolute time duration length]* *R\_G* denotes as the group paging rate and *R\_E* denotes as UE paging rate, and 1-*R\_G*=(*1-R\_E)^N*, where *N* is the number of UEs in the group, and N is [TBD]
* FFS: how (*R\_G*, *R\_E*) for e-DRX derived from

 FFS: Option 2 (optional):Reusing TR 38.875 heart beat traffic model

|  |  |
| --- | --- |
| Model | FTP3 |
| Packet size | 100 Bytes |
| Mean inter-arrival time | 60s (per UE paging rate≈2%) |

 Model RRC connection phase power consumption as follows,

|  |  |
| --- | --- |
| RRC connection duration | [30ms] |
| Relative energy consumption of RRC connection block (Relative power x ms) | [=3000] |

 Other options are not precluded can be reported by companies. |
| Others | Reported by companies |

**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

## RAN1#111

**Agreement**

For system impact analysis, the following performance metrics are considered to be provided,

|  |  |
| --- | --- |
| **Performance Metric** | **Note** |
| System overhead | expressed as percentage of used part of all REs for LP-WUS (including guard band or time or others resource used for LP-WUR if any) among all resourcesOther assumptions related to the system overhead analysis can be reported, e.g., the LP-WUR raw data rate evaluated in the coverage evaluations. |
| Capacity impact | Evaluate the system capacity impact due to introducing of LP-WUSNote: it is for UEs which are in connected mode. Definition is the same as in XR TR. |
| FFS: NW power consumption / Energy Efficiency | [Impact of LP-WUS/WUR operation on gNB energy consumption as performance metric in system impact analysis.] |

For power and latency evaluation of the LP-WUS, the following performance metrics definitions provided for future study

|  |  |
| --- | --- |
|  **Performance Metric** | **Note** |
| Power consumption | Relative power consumption in units. The power consumption includes main radio and LP-WUR. For comparison, the relative power consumption and evaluation period for baseline schemes should also be provided, as well as the power saving gain (i.e., percentage of power consumption reduction of the proposed power saving scheme from the baseline scheme). |
| Latency | For IDLE/INACTIVE state, * the latency is the time interval between the data arrival time at the gNB and the time of the first PO UE can monitor the paging message
* alternatively, if UE is not required to monitor a PO after wake-up, company to report detailed procedure and definition of the latency

. In RAN1#111, there are no definitions being precluded* sync/re-sync for main radio is included
 |
| UPT | The definition is the same as in [TR38.840]Note: it is for connected mode purpose. |

Companies to report baseline scheme, e.g., PO monitoring with i-DRX, e-DRX, with or without PEI

Companies to report the power consumption / power saving gain considering the FAR impact, latency considering MDR impact

Other performance metrics (e.g., mobility) can be reported by companies (if any)

**Agreement**

Update the IDLE/INACTIVE state traffic model option 1 as follows and remove traffic model option 2,

* The traffic arrival is modeled as a Poisson Arrival Process where inter-arrival times are exponentially distributed, the mean arrival time is P = YREF / RE, REF, where
	+ RE, REF= 1%, 0.1%, 0.01% or 0.001% and YREF = 1.28s
	+ Per group paging probability RG = 1 – (1 – RE)N, where N is the number of UEs in the group
		- FFS: Value of N
* For LP-WUS
	+ Both per group and UE paging can be assumed.

Note：

* For i-DRX with ~~i-DRX~~ cycle duration Y second,
	+ Per UE paging probability RE = 1 – (1 – RE, REF )Y/YREF
	+ ~~Per group paging probability R~~~~G~~ ~~= 1 – (1 – R~~~~E~~~~)~~~~N~~~~, where N is the number of UEs in the group~~
* For e-DRX with K i-DRX cycles duration, ~~L~~ 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)Y/YREF for the first i-DRX cycle within the PTW
		- RE = 1 – (1 – RE, REF )~~L~~Y/YREF for each of the remaining L-1 i-DRX cycles within the PTW
	+ ~~Per group paging probability R~~~~G~~ ~~= 1 – (1 – R~~~~E~~~~)~~~~N~~~~, where N is the number of UEs in the group~~
	+ L=4 (as agreed in RAN1#110bis)

**Agreement**

For MR, at least for FR1 evaluation,

* Number of SSBs for sync/re-sync for MR is up to 10
	+ Companies to report timeline and energy consumption
* Companies to provide feasibility analysis for transition time and transition energy with aim to converge to one or two set of values in RAN1#112

**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 timeTLR, 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/~~0.5/1/2/4FFS: If other values are needed |

FFS: whether further categorization/sub-categorization is needed and how.

## RAN1#112

**Conclusion:**

The FAR definition does NOT include the impact of the falsely alarmed for wake-up due to the detection of a LP-WUS which is intended to wake-up/alarm the LP-WUR of another UE within the same UE group

**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**

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)
* Alt 2: ([40000], [800ms])

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

**Agreement**

For coverage evaluation, the following is used,

|  |  |
| --- | --- |
| Number of RX chains at the UE’s MR ~~antenna elements for UE~~ | Case 1: 1 Rx for RedcapCase 2: 2 RxCase 3: 4 RxCompany to report which case is being used. Further decision on antenna assumption for coverage is FFS. |
| Number of RX chains ~~antenna elements~~ for LP-WUR | 1 RxNote: agreed in RAN1#110bis |
| Scenario and frequency | Urban: 4GHz (TDD), 2.6GHz (TDD) Rural: ~~4GHz (TDD), 2.6GHz (TDD), 2GHz (FDD),~~ 700MHz (FDD)~~Rural with long distance: 700MHz (FDD), 4GHz (TDD)~~ |
| Reference data rates for MR ~~eMBB~~ | Urban: PDSCH 10Mbps, PUSCH 1MbpsRural: PDSCH 1Mbps, PUSCH 100kbps~~Rural with long distance: DL 1Mbps, UL 100kbps, 30kbps (optional)~~ |
| Reference PDCCH configuration |

|  |  |
| --- | --- |
| SCS | 30kHz for TDD, 15kHz for FDD. |
| Aggregation level | 8, 16Company to report which case is being used. Further decision on aggregation level for coverage is FFS. |
| Payload | 40 bits |
| CORESET size | 2 symbols, 48 PRBs |
| Tx Diversity | Reported by companies |
| BLER | 1% BLER, |

 |
| Pathloss model (select from LoS or NLoS) | Urban: NloSRural: NloS ~~and LoS~~ |
| Bandwidth | 100MHz for 4GHz and 2.6GHz.~~20MHz for 2GHz (FDD)~~20MHz (optional for 10MHz) for 700MHz. (FDD) |
| Channel model for link-level simulation | TDL-C for NLOS~~, TDL-D for LOS.~~ |
| Delay spread | Urban: 300ns, optional: 1000ns and companies to provide descriptions for such scenariosRural: 300ns~~Rural with long distance: 30ns~~ |
| UE velocity | Urban: 3km/h Rural: 3km/h, FFS: 120km/h (optional 30km/h) for outdoor |
| Number of antenna elements for BS | - Urban: 192 antenna elements for 4GHz and 2.6GHz, (M,N,P,Mg,Ng) = (12,8,2,1,1)(optional) 128 antenna elements for 4GHz, (M,N,P,Mg,Ng) = (8,8,2,1,1)~~- Rural: 64 antenna elements for 4GHz and 2.6GHz~~~~(M,N,P,Mg,Ng) = (8,4,2,1,1)~~~~32 antenna elements for 2GHz~~~~(M,N,P,Mg,Ng) = (8,2,2,1,1)~~- Rural: 16 antenna elements for 700MHz(M,N,P,Mg,Ng) = (4,2,2,1,1) |
| Number of TxRUs for BS | gNB architectures to study:- 2 or 4 TXRUs for ~~2GHz,~~ 700 MHz - 64TxRUs for 2.6 and 4 GHz. ~~- Optional: 32 TXRUs at 2 GHz~~~~gNB modeling in LLS for TDL:~~~~- Option 1: 2 or 4 gNB RF chains in LLS.~~ ~~- Option 2 (Optional): Number of gNB RF chains = number of TXRUs in LLS.~~ ~~- Companies can report if and how correlation is modelled.~~ |

Note: The descriptions above does not change the agreements for coverage in the RAN1#110-bis.

**Agreement**

For link-level simulation of LP-WUS, the following table is used as starting point,

* FFS for other assumptions if any
* Note: The assumptions are not intended to limit the scope of the study or the design.

**Table XX. Simulation assumptions for LP-WUS**

|  |  |
| --- | --- |
| **Attributes** | **Assumptions** |
| Carrier Frequency | 2.6GHz/4GHz/700MHz |
| Waveform | OOK , FSK , OFDMCompany to report which option for OOK /FSK /OFDM is used |
| Channel structure | * Option 1: Sync signal /sequence+ payload + CRC,
* Option 2: Sequence only,
* Option 3: Payload+CRC,
* Other options are not precluded
* Company to report the sequence length, payload size, CRC length (may or may not be presence).
 |
| SCS of OFDM generator for NR signal | 30kHz/15KHz |
| 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 sequenceOther options are up to companies to report |
| WUS duration | Number of OFDM symbols: e.g., 1,2,4, 8, 16,24 symbols  |
| MDR/FAR assumption | * The miss-detection rate (MDR) of LP-WUS 1%,
* The false-alarm rate (FAR) of LP-WUS
	+ [0.1%, 1%]
	+ Other values are not precluded for studying, reported by companies
	+ Further discuss on the following alternatives for FAR target
		- Alt 1: FAR target is determined per single WUS attempt/trial,
		- Alt 2: FAR target is determined across a reference time duration of one or multiple WUS attempts/trials
			* FFS: possible values for reference time durations
		- Companies to report details, e.g., receiver behaviour, how to compute MDR, detection threshold
	+ Companies to report the selected reference time duration values and the associated number of WUS attempts/trials
 |
| Code scheme | Companies to report, if any, the coding scheme (e.g., Manchester code or any other schemes) and the code rate (e.g., 1/2, 1/4, ….) |
| 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 reportGB 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 |
| 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 |
| Sampling Rate | * Companies to report.
 |
| ADC bit width | 1-bit, 4-bit, 8-bit, ideal and other options are not precluded |
| Channel Model | See link coverage assumption table (will copy and paste here) |
| Impairment modelling | * FFS: Frequency and time error model
* Phase noise up to company report, e.g. the modelling used for 802.11ba
* Other cell interference is up to company to report
 |

**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]** | 20 |

* 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] [R1-2301558][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

# Proposals from companies’ submitted contributions

## XXX

# SID

[*RP-222644*](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_97e/Docs/RP-222644.zip)

**The study item includes the following objectives:**

* Identify evaluation methodology (including the use cases) & KPIs [RAN1]
	+ Primarily target low-power WUS/WUR for power-sensitive, small form-factor devices including IoT use cases (such as industrial sensors, controllers) and wearables
		- Other use cases are not precluded
* Study and evaluate low-power wake-up receiver architectures [RAN1, RAN4]
* Study and evaluate wake-up signal designs to support wake-up receivers [RAN1, RAN4]
* Study and evaluate L1 procedures and higher layer protocol changes needed to support the wake-up signals [RAN2, RAN1]
* Study potential UE power saving gains compared to the existing Rel-15/16/17 UE power saving mechanisms, the coverage availability, as well as latency impact of low-power WUR/WUS. 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]
	+ Note: The need for RAN2 evaluation will be triggered by RAN1 when necessary.

# Reference

**The following contributions are submitted in RAN1#112-bis in AI 9.11.1,**

1. R1-2302331 Evaluation of LP-WUS and Performance Results FUTUREWEI
2. R1-2302339 Evaluations for LP-WUS Huawei, HiSilicon
3. R1-2303897 Evaluation methodologies for R18 LP-WUS/WUR vivo

Revised from R1-2302506

1. R1-2302570 Evaluation for lower power wake-up signal OPPO
2. R1-2302621 Discussion on evaluation on low power WUS Spreadtrum Communications
3. R1-2302687 Remaining issues of Deployment scenarios and evaluation methodologies and preliminary performance results of LP-WUR CATT
4. R1-2302815 Evaluations on LP-WUS Intel Corporation
5. R1-2302827 Discussion on evaluation on LP-WUS InterDigital, Inc.
6. R1-2302861 Evaluation of low power WUS Sony
7. R1-2302890 Low power WUS Evaluation Methodology Nokia, Nokia Shanghai Bell
8. R1-2302948 Evaluation on LP-WUS ZTE, Sanechips
9. R1-2302968 Evaluation on low power WUS xiaomi
10. R1-2303150 Evaluation on LP-WUS/WUR Samsung
11. R1-2303332 Evaluation on low power WUS MediaTek Inc.
12. R1-2303429 Discussion on evaluation for LP-WUS LG Electronics
13. R1-2303505 On performance evaluation for low power wake-up signal Apple
14. R1-2303537 On LP-WUS evaluation Nordic Semiconductor ASA
15. R1-2303612 Evaluation methodology for LP-WUS Qualcomm Incorporated
16. R1-2303759 Low power WUS evaluations Ericsson

# History

1. R1-2210437 FL summary#1 of evaluation on low power WUS Moderator (vivo), RAN1#110bis
2. R1-2210512 FL summary#2 of evaluation on low power WUS Moderator (vivo) , RAN1#110bis
3. R1-2210668 FL summary#3 of evaluation on low power WUS Moderator (vivo) , RAN1#110bis
4. R1-2212768FL summary#1 of evaluation on low power WUS Moderator (vivo) , RAN1#111
5. R1-2212899 FL summary#2 of evaluation on low power WUS Moderator (vivo) , RAN1#111
6. R1-2213005 Final FL summary of evaluation on low power WUS Moderator (vivo) , RAN1#111
7. R1-2302006 FL summary#1 of evaluation on low power WUS Moderator (vivo) , RAN1#112
8. R1-2302140 FL summary#2 of evaluation on low power WUS Moderator (vivo) , RAN1#112
9. R1-2302212 FL summary#3 of evaluation on low power WUS Moderator (vivo) , RAN1#112
10. R1-2302251 FL summary #4 (final) of evaluation on low power WUS Moderator (vivo) , RAN1#112