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

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

**Title: [Draft] Reply LS to RAN4 on LP WUR architectures**

**Response to: R1-2302287 /** **R4-2303712**

**Release: Rel-18**

**Work Item: FS\_NR\_LPWUS**

**Source: [RAN1]**

**To: RAN4**

**Cc:**

**Contact person: [Sigen Ye]**

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**Send any reply LS to: 3GPP Liaisons Coordinator,** **mailto:3GPPLiaison@etsi.org**

**Attachments:** **None**

# 1 Overall description

RAN1 would like to thank RAN4 for the reply LS on low-power wake-up receiver architectures.

RAN1 would like to provide the following feedback on the clarification questions from RAN4.

1. **Whether IoT/wearables/smartphone UE types are all considered for LP-WUR design**

[RAN1 response]

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

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| **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. |

1. **Power consumption, coverage and SNR targets**

[RAN1 response]

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

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

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| **Power State** | **Relative Power (unit)** | **Additional 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 has not agreed on the coverage and SNR targets for LP-WUR. RAN1 is still studying these aspects.
	+ For coverage, the following agreement was reached.

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| AgreementRAN1 further study the designs [target]/techniques of LP-WUS to have a comparable coverage as NR channel X. The NR channel X is-        Option #1: PDCCH for paging-        Option #2: PUSCH for message3-       FFS other options, e.g., between option1and option2 (better than PUSCH, worse than PDCCH)-        The final design will jointly consider the coverage with other KPIs-        FFS additional detail assumptions for NR channels, e.g., the message size for MSG3 and etc.Agreement* Study techniques/mechanisms to enhance coverage performance of LP-WUS
* Study potential gains available as well as drawback(s) of the technique(s)/mechanisms(s), e.g. system overhead, increased complexity network energy consumption etc…
* Study potential issues and corresponding solutions for the case when LP-WUS coverage is insufficient
	+ At least study fallback mechanisms where the Main Radio switches to legacy operation in case the channel condition of LP-WUS is not sufficient, e.g. below threshold
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* + For evaluation of the coverage of LP-WUS, RAN1 has agreed to use MIL as the metric, with more details in the following agreement.

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| **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 lossCompanies are encouraged to compare LP-WUS with at least PDCCH for paging, PUSCH, others are not precluded.FFS: Target coverage of LP-WUS |

1. **Max occupied RB number in channel bandwidth for LP-WUS, for 1.4MHz and 5MHz RF bandwidth case**

[RAN1 response]

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

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

FFS: Whether FR2 is included in the scope of LP-WUS SI**Agreement**At least for IDLE/Inactive mode, at least one BW-size <=5MHz is recommended to be supported for FR1* Other BW sizes are not precluded
	+ if additional BW-size(s) are recommended to be supported, BW-size can be up to 20MHz
* LP-WUS bandwidth size (including guard-bands) is assumed to be an integer number of PRBs
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* RAN1 has not discussed the RF bandwidth of 1.4MHz for LP-WUS, and has not reached any conclusion on the maximum occupied RB number in 5MHz RF bandwidth case for LP-WUS. As the starting point for link-level simulations of LP-WUS, RAN1 has agreed on the following for LP-WUS bandwidth, the guard band and the filter.

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| 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 |

1. **Possible supported SCS for LP-WUS, if applicable**

[RAN1 response]

* RAN1 has reached the following agreement on SCS:

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| **Agreement**For MC-ASK or MC-FSK waveform generation, SCS of a CP-OFDM symbol used for LP-WUS generation can be the same as SCS used for other NR transmissions in CP-OFDM symbol overlapping in time with, study whether SCS can be different, also study* FDM/TDM multiplexing with other NR transmissions
* link performance
* impact to legacy UEs
* impact on gNB
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* In addition, as the starting point for link level simulations for LP-WUS, RAN1 has agreed on the following assumptions for LP-WUS:

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| 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 |

1. **Whether WUS can be located in a band separate from the UE’s NR band**

[RAN1 response]

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

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| Agreement* Capture in TR: From RAN1 perspective, LP-WUS and signals/channels used by MR can be within the same FR1 band.
	+ At least LP-WUS and signals/channels by MR can be on the same carrier in the band
* Study further
	+ Whether LP-WUS and signals/channels used by MR can be different carriers in the band
	+ Details on the LP-WUS location within a carrier
	+ Band can be different than band of signals/channels used by MR
	+ LP-WUS association with BWP
	+ LP-WUS can be configurable within guard-band of a band (like NB-IoT)
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1. **Whether FR1 is considered as first priority frequency range**

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

1. **Whether in-band power boosting of LP-WUS is considered from RAN1 perspective**

[RAN1 response]

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

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| 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 |

RAN1 will inform RAN4 if further progress is made on any of the aspects above, and would appreciate input from RAN4 on these aspects, if any.

In addition to the agreements provided in R1-2212999/ R4-2300011, the agreements made in RAN1#112 and RAN1#112bis-e on LP WUR architectures are provided in the Appendix for information.

# 2 Actions

**To RAN4:**

**ACTION:** RAN1 respectfully asks RAN4 to take the above into consideration.

# 3 Dates of next TSG RAN WG1 meetings

TSG RAN WG1 Meeting #113 May 22-26, 2023 Incheon, KR

TSG RAN WG1 Meeting #114 August 21-25, 2023 Toulouse, FR

**Appendix:**

**RAN1#112**

**Agreement**

Study the parallel receiver architectures (as examples that can be captured in the TR) for FSK based on the following diagrams:

* Parallel homodyne architecture



* + The observations made for homodyne/zero-IF architecture with baseband envelope detection in RAN1#110b/111 are also applicable here.
* Parallel heterodyne architecture



* + The observations made for heterodyne architecture with IF envelope detection in RAN1#110b/111 are also applicable here.
* Note: Other architectures are not precluded.
* The OOK receiver architectures agreed for study in RAN1#110bis-e are also examples that can be captured in the TR

**Agreement**

Study the receiver architectures (as examples that can be captured in the TR) for FSK with frequency to amplitude conversion based on the following diagrams:

* Homodyne architecture with frequency to amplitude conversion
	+ I/Q branches are required for frequency to amplitude conversion in digital BB.



* Heterodyne architecture with frequency to amplitude conversion



* + Companies provide the exact type of frequency to amplitude conversion being studied.
* Note: Other architectures are not precluded.

**Agreement**

For OFDMA-based signals/channels, study the receiver architectures based on the following diagrams:

* I/Q branches are required for digital BB processing.
* Digital BB processing may or may not include FFT (companies to provide details on how).
* For sequence-based OFDM signals/channels, digital BB processing includes sequence correlation in either time domain (without FFT) or frequency domain (after FFT).
* Proponent companies should at least provide details on power consumption reduction compared to the MR regarding the RF and digital BB processing.
	+ Companies are encouraged to provide the break-down for the components.
	+ The potential power reduction compared to the main radio may come from e.g.:
		- Lower performance LNA/amplifier
		- Oscillator/PLL with relaxed performance requirements
		- ADC with lower sampling rate and smaller bit-width
		- Reduced BB processing complexity compared to the MR
	+ Companies are encouraged to provide the performance analysis corresponding to the considered power consumption considering the impact of e.g. phase noise, I/Q mismatch.
	+ Companies to report whether the LP WUR is assumed to share components with MR. In case of component sharing, the potential impact on the MR ultra-deep sleep state should be considered.
	+ Companies to report the possible number of information bits
* In addition, companies should consider the power consumption in the OFF state and the transition energy.

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**Agreement**

For the study on LP WUR architecture, power consumption relative to the deep sleep state of the MR is provided.

* Deep sleep state of non-RedCap UE should be assumed

**RAN1#112b-e**

**Agreement**

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

**Agreement**

The FSK architectures with frequency to amplitude conversion is applicable to single-SC FSK, but it may be challenging to make the frequency to amplitude conversion work well with multi-subcarrier FSK.

* Note: single-SC FSK refers to the waveform where each frequency segment has a single subcarrier, and multi-subcarrier FSK refers to the waveform where each frequency segment has multiple subcarriers, as described in the agreements for FSK-1 and FSK-2.