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

e-Meeting, Apr 17 - Apr 26, 2023

Agenda Item: 9.11.3

Source: Moderator (Nordic Semiconductor ASA)

Title: Summary #4 of discussions on L1 signal design and procedure for low power WUS

Document for: Discussion/Decision

# Introduction

In Rel-18, a study item was approved for low-power wake-up signal and receiver for NR (WID in RP-222644 [1]), and it includes the following objectives.

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| * 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. |

This contribution summarizes the remaining proposals in RAN1#112b-e. Provide feedback directly to the Table

# Final check

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|  | **Support** | **Support with wording update** | **Not support because** |
| FL@Samsung, Intel: proposal applies to all schemes, please note “*and to modulate input signal of N SCs for other MC-ASK/FSK schemes*” in main bullet  FL@ALL: PAPR is controversial, I keep it FFS  ***FL5-Higher-Proposal-1a:*** *Study further methods to modulate input signal of the DFT/Least-Square block for OOK-4, and methods to modulate input signal of N SCs for other MC-ASK/FSK schemes*   * *study whether there is a need to additionally modulate input signal or it can be left up to gNB implementation* * *study methods with respect to*   + *improving frequency diversity by flattening the spectrum, frequency repetition and frequency hopping*   + *impact to dynamic range in frequency domain*   + *FFS: impact to PAPR of generated time domain modulated MC-ASK/FSK symbol*   + *improving robustness to timing error*   + *necessary spectrum adjustment for compatibility with CP-OFDM generation* | MTK, FW |  |  |
| @Samsung I am not so sure it would be the same, OOK-3 may be more complex to receive that OOK-1.  ***FL5-Lower-Proposal-1b***  **Observation**  For all studied waveform schemes, if different waveforms can be pre-generated and stored in thememory, the computational complexity at gNB to generate different waveforms (FFS: or at LP-WUR to decode different waveforms) is expected to be the same. | HW, ZTE, VIVO, FW, Apple, Intel, MTK | FW (not sure how pre-generating and storing waveforms at LP-WUR can help with decoding complexity of OOK waveforms) |  |
| FL: Regarding “new schemes/clarifications”, there is quite an opposition to update the last RAN1#112 agreement on waveforms.  P2: It was understood that 2 additional segments can be a known signal, i.e. synch signal modulated with FSK.  P3/4: It needs more study on how much information combination of OOK-4 and FSK-1/2 actually carry. We can continue in RAN1#113 where it will be easier to discuss F2F. For now we have agreement to study   * Study how to generate segment in time domain, e.g. OOK-1 or OOK-4   P5: It has been understood that information is generated by using sequences of different length within LP-WUS BW.  It has been understood that it can be received with already agreed receiver architecture. M baseband filters are needed as in FSK-2 to receive M bits.  Based on above companies should have enough understanding if they want to simulate this scheme. However, it would be hard to explicitly agree on the proposal.  P6: FSK1 could be updated so that pairs of segments are replaced with sets of segments which are FSK-2 this creating parallel FSK-2 modulations. It is understood that scheme is not precluded, but it may be hard to make explicit agreement. |  | FW: (1) For P2, we agree with a note indicating the 2 additional segments carrying a known signal.  (2) For P5, we are OK not to have an explicit separate agreement with details, but suggest amending the following note to FSK-2 scheme:  Note: N SCs of LP-WUS can be modulated to generate 2^M segments at BB of LP-WUR after self-mixing envelope detection. |  |
| FL has same understanding with Sony,sub-bullet 5 and 6 are for different type of GB, outer resp. inner GB.  FL: added MTK bullet which can be controversial  FL@Ericsson: I tried to clarify that Manchester is not the only coding that can be considered.  If we cannot agree on this it may serve as FL guidance for RAN1#113 meeting.  ***FL4-Lower-Proposal-2b:*** To focus simulation effort further, focus on answering at least the following:   * For each combination of waveform schemes and receiver architectures, the impact of timing and frequency error * For waveforms using segments, for different segment sizes in time/frequency, impact of frequency-selectivity, inter symbol interference and ~~[~~power boosting~~]~~ * What are sampling rate requirements and ADC dynamic range requirements for each waveform scheme. * Performance with and without Manchester coding or other coding * As function of in-band/out-of-band ACI and phase-noise, what size of guard-band (outside of LP-WUS). * In terms of frequency error, what guard-gap (between segments) is needed * Impact of BW choice * ~~(From MTK)~~Synchronization and RRM performance with the existing NR reference signal for each combination of waveform schemes and receivers | MTK: It is important to check how to benefit the always-on signal in the cellular network |  |  |
| FL: I removed controversial FFS bullets, if this not flying FL suggests dropping this proposal in RAN1#112b-e  @Apple: Proposal to me sounds stronger than what was agreed so far  “Agreement RAN1#112: *When comparing waveforms of LP-WUS, consider the impact to gNB for each of the waveform generation schemes. Consider whether there is impact to PAPR and a need for additional hardware for WUS.*”  @Sony: If feasibility to reuse existing hardware is too strong, we could re-word with “possibility”?  **FL5-Higher-Proposal-22** Consider the following qualitative aspects in addition to agreed KPI in selection of waveform(s). For example   * [~~feasibility~~/possibility] to generate waveform at gNB using existing hardware. * ~~FFS: capability to be received with one or more the agreed receiver architectures e.g. energy detection and time domain correlation.~~ * FFS: capability to support flexible bitrate per within fixed TF resource. * ~~FFS: complexity of reception of waveform.~~ * ~~FFS: complexity of generation of waveform~~. * ~~FFS: feasibility to receive waveform using existing hardware (or at least part of the existing hardware).~~ * FFS: capability to support the agreed use cases, e.g., IoT, wearable, and eMBB in IDLE/INACTIVE and RRC CONNECTED. * ~~FFS: Capability to coexist with NR common signals such as SSB in NR bands of 5MHz.~~ * Other aspects can be further discussed. | MTK |  |  |
| @MTK, I prefer not to add FFSes at this point, this can trigger more FFS at this point.  ***FL5-Lower-Proposal-3:*** *Study how the CP is handled for OOK-4 atthe transmitter and at the receiver.*  *Note: There is no intention to change CP-OFDMA generation at the transmitter.* | HW, ZTE, VIVO, HW, IDC, Apple, MTK, FW |  | CATT  We need to define the waveform generation for OOK-4 before studying CP |
| FL@Xiaomi: support of mixed SCS has not been much seen in field so far, and the reason is the complexity. 😊  FL@ALL: It seems that some companies have issue with O4, while other would not except proposal without O4.  FL@Sony: Clarified “guard-band (with NR signals)”  Let’s try to go with Alt2.  ***FL5-Higher-Proposal-4***  For a case of LP-WUS SCS is different to SCS used for other NR transmissions in CP-OFDM symbol overlapping in time with LP-WUS transmission agree on the following observations.   * **O1:** If higher data rate is expected to be supported, SCS of LP-WUS should be higher than SCS of NR transmissions in FR1. * **O2:** NR specification supports FDM and TDM multiplexing of signals/channels generated with different SCS. It may be feasible from specification point of view to support the case. * ~~Alt1: HW, ZTE, VIVO, FW, Samsung, Oppo, ///, Apple, [Sony]~~   + **~~O3:~~** ~~The case may require additional guard-bands (with NR signals) due to spectral leakage. Spectral leakage can be alleviated partially by pulse shaping performed at gNB. Larger guard-band (with NR signals) will negatively impact spectral efficiency. Spectral leakage will negatively impact performance of legacy UEs.~~   + **~~O4:~~** ~~complexity at gNB may increases and gNB may require new hardware.~~ * **Alt2:** ZTE, VIVO, FW, HW (2nd preference), Samsung, Intel, ///, Nokia, Apple, [Sony]   + the case may will increase complexity at gNB and may require new hardware, pulse shaping, or additional guard bands. | MTK, FW (there is a typo in Alt2, may followed by will) |  |  |
| FL: improved FFS wording based on Samsung input  ***FL5-Higher-Proposal-6***  *At least for IDLE/Inactive mode*   * *at least one BW-size <=5MHz is recommended to be supported for FR1*    + *if additional BW-size(s) are recommended to be supported, BW-size can be up to 20MHz*   + *FFS: LP-WUS size (including guard-bands) is an integer number of PRBs* | HW, ZTE, VIVO, Samsung, Apple, Intel, MTK, FW, CATT |  | Ericsson wants to leave this to WID |
| FL: Leaving feasibility FFS for offloading neighbor cell measurements matches to what was contributed to RAN1#112b-e  At least Intel is not OK to put neighbor-cell RRM relaxation on the same bar as serving cell  Apple would not be OK with precluding study of neighbor cell RRM measurements offloading to LP-WUR  ***FL5-Higher-Proposal-9:***  *For Idle/Inactive mode, study offloading of RRM measurements of serving cell to LP-WUR and relaxation of RRM measurements of serving cell (neighbor cell with second priority) in MR considering*   * *periodic reference signal(s) is/are used for measurements.*   + *FFS: reference signal(s) to measure, e.g. PSS/SSS/PBCH DMRS, LP-WUS-waveform based sequence (LP-SS)*   + *FFS: periodicity, content, e.g. cell ID in case SSB is not used* * *FFS: periodic reference signal(s) is/are cell dependent.* * *MR performs serving cell and (neighbor cell with second priority) measurements*    + *Alt1: with relaxed periodicity if RRM measurement in MR is relaxed.*   + *~~Alt2a: only when reference signal(s) based measurements~~*      - *~~are below a threshold if RRM measurement is offloaded to LP-WUR. FFS threshold based on LP-WUS metric.~~*   + *Alt2b: only when reference signal(s) based measurements by LP-WUR satisfy certain condition(s), e.g. are below threshold.*      - *FFS threshold.*     - *Note: the case where serving cell measurements are always performed by LP-WUR even if MR is ON, e.g. WUR and MR coverage is equal case, is not precluded.*   + *Other alternatives are not precluded*   *~~Opt1: Note: RRM measurements of neighbor cells by LP-WUR is not precluded by this agreement and can be further studied.~~*  *Opt2: FFS: Feasibility of RRM measurements of neighbor cells by LP-WUR* | MTK, IDCC | Intel ([FFS: neighbor])  FW (what is the difference between “• *FFS: periodic reference signal(s) is/are cell dependent*.” and having “cell ID” under the first bullet?) | CATT (more progress on LP-WUS design needed)  There are different levels of LP-WUR receiver sensitivities. We need to agree whether the LP-WUR would have same coverage as those of NR channels/signals first before discussing RRM aspects. |
| FL does not see reason why LP-SINR or Detection rate could not be further studied.  N is controversial, we need to see how the resource is defined first, may not necessarily reuse legacy definition. It is left FFS, including the case N=1.  If proposal is not agreed, companies can focus next meeting on how to define resource for LP-RSSI, LP-RSRP, etc…  ***FL5-Higher-Proposal-10:***  *For at least RRM serving cell measurement performed by LP-WUR based on reference signals(s), RAN1 identified at least the following metrics for further study and evaluation*   * *LP-RSSI or Energy detection: linear average of received power over a RSSI resource.*   + *FFS RSSI resource.* * *LP-RSRP: linear average of received power of resource of reference signal(s) or signal(s) parts.*    + *FFS resource of reference signal(s) or signal(s) parts* * *~~FFS:~~ LP-SINR = LP-RSRP/(power of interference and noise)*   + *FFS how to define “power of interference and noise”* * *LP-RSRQ= [N x] LP-RSRP/LP-RSSI*   + *~~Alt1: N = size of resource of reference signal(s) or signal(s) parts / size of RSSI resource and~~*   + *Alt2: FFS: N, if any* * *~~FFS:~~ Detection rate of always ON periodic reference signal(s) or LP-WUS*   + *FFS how to calculate/define detection rate*   *FFS: Feasibility of different receiver architectures to support the above metrics. e.g. need for ADC, AGC, with different reference signal(s).*  *Note: Reference signal for performing measurements can be e.g. SSB (PSS/SSS/PBCH DMRS), LP-WUS-waveform sequence (LP-SS)* | MTK, FW |  | CATT  The RSSI, RSRP, RSRQ, and SINR measurements would be defined when the waveform and LP-WUS or other LP-SS transmission are defined. All measurements also require time domain filtering to ensure the confidence of the statistic measure. |
| @Xiaomi, indeed occasions could be for different beams, like we have for paging, nothing precluded at this point.  @MTK, I captured your input a bit differently, OK?  “FFS: LP-SS transmission pattern …” seems to be too much detail at this stage, more of WID aspect, FL would suggest to remove  ***FL5-Higher-Proposal-11:***  *At least for LP-WUR architectures that cannot receive existing OFDMA-based NR signals for synchronization, at least periodic synchronization signal used by LP-WUR (LP-SS) is required. Study further*   * *required periodicity of LP-SS.* * *waveform used for LP-SS, and whether it should be the same or can be different as used for LP-WUS, assuming that LP-WUR can receive both.* * *structure of LP-SS*   + *Alt1: sequence based only*   + *Alt2: sequence + message with encoded bits*   + *FFS: sequence* * *supporting additionally aperiodic synch signal for fine synchronisation* * *feasibility of time/frequency estimation/correction for different waveforms/receivers architectures* * *~~[FFS: LP-SS transmission pattern, e.g. multiple transmissions of LP-SS within each period, e.g. DRX window, beam sweeping window]~~* * *FFS: whether can be used as reference signal(s) for RRM measurements as well and vice versa.* * FFS: which architectures are not able to receive existing OFDMA-based NR signals.   *Note: LP-WUR for* OFDMA-based LP-WUS may also receive LP-SS. |  | MTK: We still have concerns on using “architectures”. Most of the agreed architectures can support receiving existing OFDMA-based NR signals by UE implementations (e.g., pre-stored to memory for cross-correlation). We suggest removing architectures to make it general.  ***FL5-Higher-Proposal-11:***  *At least for LP-WUR ~~architectures~~ that cannot receive existing OFDMA-based NR signals for synchronization, at least periodic synchronization signal used by LP-WUR (LP-SS) is required. Study further*  FFS: whether the support of receiving existing OFDMA-based NR signals can up to UE implementation | CATT  The characteristic of the LP-WUS and LP-SS waveform needs to be agreed for different LP-WUR architecture. |
| @HW, and chance you can except FFSes? Seems majority is fine to keep the last FFS  @Intel: clarified that FFS is on type of encoding scheme.  ***FL5-Higher-Proposal-13:*** *Study further following alternatives to carry the LP-WUS information using:*   * *Alt 1: by sequence(s) selection*    + *FFS sequence type* * *Alt 2: by encoded bits*    + *FFS: what type of encoding scheme*   + *FFS: with or without CRC/FCS* * *FFS: LP-WUS need to be preceded by known one or more sequence(s).* | MTK, FW |  |  |
| @Below FFS from MTK, for FL OK to keep, but already not clear to Ericsson  **FL5-Higher-Proposal-21a:**   * *Study techniques/mechanisms to enhance coverage performance of LP-WUS, in case enhancement is deemed needed, focus at least on*    + *reducing payload size of LP-WUS*   + *power boosting*   + *time domain solutions: repetition in time, interleaving in time*   + *frequency domain solutions: repetition in frequency, frequency-hopping*   + *channel coding*   + *code domain solutions: CDM between LP-WUSs*   + *FFS: increased number of receive antennas*   + *FFS: improve synchronization by reusing the existing NR reference signal* * *For above, 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 is insufficient ~~would be designed with coverage smaller than the coverage of NR~~*   + *Study fallback mechanisms where the Main Radio switches to legacy operation in case the channel condition of are not sufficient, e.g. below threshold.* | MTK: For LPWUR only uses LPSS for synchronization, it is possible to further enhance by using the existing NR RS additionally. | FW (- we do not see the relationship between synchronization improvement and coverage enhancement, - we understand that interleaving in time might be relevant only if channel coding is considered.) | CATT (coverage target defined first?) |
| FL: prefer not to discuss new added FFS in SID, moreover, we did not yet agree on LP-SS.  ***FL2-Higher-Proposal-16:***   * *It is recommended to define LP-WUS transmission occasion(s) with a periodicity, where a LP-WUS can ~~only~~ be transmitted by gNB only in those occasion(s) within each period.*    + *FFS: periodicity of configured occasion(s)*   + *FFS: granularity of starting location, e.g. symbol/slot*   + *~~FFS: monitoring conflict to periodic LPSS or SSB (PSS/SSS/PBCH)~~*   + *~~FFS: there is one or more corresponding transmission occasion within a periodicity for a UE~~* | MTK |  |  |
| FL: seems we need to progress more with other aspects first, proposal is dropped in RAN1#112b-e. We can use this as starting point in future.  ***~~FL5-Lower-Proposal-17:~~***   * *~~Regarding procedures for MR, upon wake-up from ultra-deep-sleep~~****~~,~~*** *~~for~~**~~“Option 1: perform PO monitoring, and afterwards follow legacy procedures”, study whether a support of dynamic PO, i.e. PO outside of regular paging frame could reduce latency.~~* * *~~FFS: Study whether the case where LP-WUS monitoring is configured together with PEI monitoring is beneficial to be supported.~~* |  |  |  |
| FL: I would drop this one in RAN1#112b-e. Next meeting companies could focus on whether any of these aspects should be still discussed in Study phase.  ***~~FL5-Lower-Proposal-18:~~*** *~~From RAN1 point of view, LP-WUS monitoring can be activated semi-statically and/or dynamically through MR.~~*   * *~~FFS broadcast or UE-specific signalling~~* * *~~FFS need for UE confirmation of gNB activation~~* * *~~FFS activation by gNB based on UE request~~* * *~~FFS: UE being able to autonomously decide whether to monitor PO or LP-WUS~~*   + *~~FFS: need for informing gNB about change of monitoring~~* * *~~FFS: UE following criteria to determine whether PO or LP-WUS is monitored.~~* * *~~FFS: need for informing gNB about change of monitoring~~* |  |  |  |