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Views on LP-WUS/WUR for Rel-19

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Motivations for Rel-19 LP-WUS/WUR

- UE energy saving is a key aspect, especially for battery-powered devices (e.g., smartphone, wearables, etc.), even within a 5G network.
  - The Rel-18 LP-WUS/WUR study item (SI) investigated ultra-low-power mechanisms capable of improving low latency, e.g., surpassing the performance of existing DRX operations.

The study item includes the following objectives [1]

- 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.

[1] RP-222644, “Revised SID: Study on low-power Wake-up Signal and Receiver for NR”, Vivo, RAN#97e, Sept. 12-16, 2022

Discussion for prioritization

- Based on research findings from the LP-WUS/WUR SI outcome, it is highly desired to specify further UE power saving enhancements in Rel-19 Work Item (WI)
  - Essential area should only be specified for reasonable standardization workload

- Outline of Rel-19 LP-WUS/WUR WI scope
  - LP-WUS physical design
  - L1 procedure
  - Synchronization and RRM measurement

LP-WUS/WUR WI

- References: RWS-230488, RP-231540, RP-232616
- Potential objectives:
  - Waveform & LP-SS support
    - Waveform-option-1 + waveform-point-3, or waveform-point-3 only → Further downselection
      - Waveform-option-1: OOK-1 and/or OOK-4, as described in section 7.2.1.1 (A)(D) in TR38.869.
      - Waveform-option-3: Harmonized design that accommodates OOK-1/OOK-4 and OFDM waveform, i.e., specified overlayed OFDM sequences over OOK symbol
    - For RRC IDLE/INACTIVE, in addition to existing PSS/SSS, LP-SS (, i.e., OOK-1 and/or OOK-4 waveform with/without overlayed OFDM sequences with potential further down selection in WI phase) for LP-WUR that cannot receive existing PSS/SSS, is supported for synchronization and/or RRM for serving cell.

- For IDLE/INACTIVE operation, specify
  - UE serving cell RRM measurement offloaded from MR to LR
  - Further time domain relaxation (at least X times) of UE MR RRM measurement for both serving and neighbor cell measurement
    - X to be determined in the WI phase
- Note: For CONNECTED mode, UE RRM/RLM/BFD/CSI measurements are performed by MR
- To specify an LP-WUS design commonly applicable to both IDLE/INACTIVE and CONNECTED modes
- For IDLE/INACTIVE mode, to specify procedures to allow UE MR paging monitoring triggered by LP-WUS
- For CONNECTED mode, to specify procedures to allow UE MR PDCCH monitoring triggered by LP-WUS
- At least duty-cycled monitoring for LP-WUS is supported
- Note: LP-WUS shall be able to reach at least the coverage of PUSCH for message3

Overview of Rel-18 SI

- **LP-WUS physical design**
  - The LP-WUS waveform was extensively discussed, considering the following options:
    - » MC-ASK waveform, including option OOK-1/2/3/4
    - » FSK waveform, including option FSK-1/2
    - » OFDM waveform, such like existing OFDM-based sequences (e.g., CSI-RS, SSS)

  → Based on TR38.860, OOK-1/4 provides better performance, particularly in terms of time and frequency error tolerance

  → Support OOK-1 and/or OOK-4 waveform
    - » The overlaying of OFDM sequences on top of OOK waveform requires further study in WI phase

  - Fundamental design and procedure of LP-WUS (e.g., indication mechanism to wake up PDCCH monitoring) can be commonly specified across all RRC states
    - » Significant power saving gain can be achieved for RRC IDLE/INACTIVE mode rather than RRC CONNECTED mode
    - » However, LP-WUS/WUR for RRC CONNECTED mode brings power/latency saving benefits for smart phones and XR/smart glasses, i.e., major devices on the market today

  → Strive for a unified design and mechanisms of LP-WUS/WUR across all RRC states

Overview of Rel-18 SI

- **L1 procedures**
  - The following L1 procedures upon LP-WUS detection are recommended for WI phase
    - » Legacy paging procedure for IDLE/INACTIVE mode
    - » PDCCH monitoring for CONNECTED mode (e.g., LP-WUS with similar functionality as R16 DCP)

  - The following alternatives for LP-WUS monitoring scheme are studied in SI phase
    - » Alt.1: Duty-cycled monitoring
    - » Alt.2: Continuous (Always-on) monitoring
    - » Alt.3: Support both Alt.1 and Alt.2

  → In TR38.860, duty cycled monitoring (Alt.1) provides biggest gain for IDLE/INACTIVE mode, however further comparative study is required even for CONNETED mode, taking into account commonalities across all RRC states.

- **RRM measurements**
  - At least for LP-WUR that cannot receive existing PSS/SSS, periodic synchronization signal (i.e., LP-SS) is beneficial both for RRM measurements and coarse time synchronization by LP-WUR

  - Both RRM measurement offloading from MR to LR and RRM relaxation are essential for achieving substantial UE power saving gain

Proposed WI scope

- Based on the discussion, following WI scope is proposed

- Specify LP-WUS/LP-SS physical design, including OOK-1 and/or OOK-4 waveform, channel coding, preamble generation, and payload contents [RAN1, RAN4]
  - » OFDM sequence may be potentially overlayed over OOK symbol for increasing LP-WUR implementation flexibility
  - » Performance requirements for new waveform, if any

- Specify L1/L2 procedures for LP-WUS/WUR both for IDLE/INACTIVE mode and CONNECTED mode
  - » Synchronization procedure for LP-WUR [RAN1, RAN4]
  - » UE behavior and procedure for LP-WUS monitoring [RAN1, RAN2]
  - » UE behavior after LP-WUS detection [RAN1, RAN2]
  - » Activation/deactivation mechanism of LP-WUS monitoring [RAN1, RAN2, RAN4]

- Specify RAN4 requirements related to LP-WUS/WUR [RAN4, RAN1]
  - » RRM requirements for synchronization procedure and LP-WUS monitoring
    - – SNR side conditions
    - – Number of measurement samples
    - – Measurement accuracy
  - » RRM measurement offloading to LP-WUR and RRM measurement relaxation
  - » RF requirements based on decided waveform
    - – Specifying at least the REFSENS, ACS and ASCS requirements with consideration of possible new methodology
    - – Impacts of different architecture on RF requirements, if any
    - – Specific guard RBs for ACS and ASCS cases
    - – Study and specify BS power boosting value/range for LP-WUS
    - – Specific IMT operating band(s) for LP-WUS if necessary
    - – Possible testability issues