3GPP TSG RAN Meeting #102
Edinburgh, Scotland, December 11 - 15, 2023

RP-233164

Source: Apple
Agenda Item: 9.1.1.6

Views On Low-Power Wake-up Signal/Receiver in R19

Apple

Background

- The LP WUS/WUR SI is now completed in RAN1/2/4.
- Preliminary discussion on the WI scope was discussed in RAN#101 and summarized in RP-232616.
- For the **waveform down-selection**, the guideline is to focus on the following two directions:
  - Direction 1 (Number of supporting companies:13):
    - 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.
  - Direction 2 (Number of supporting companies:13):
    - 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.

Waveform Down-Selection for LP WUS

- Comparison between OOK-1/OOK-4 and the waveform with overlayed sequence specified
  - Pure OOK-1/4 waveform is intended for an OOK-based receiver, while the waveform with overlayed sequences specified can also be received by a receiver with I/Q branches and sequence detection capability (either in time-domain or frequency-domain).
  - The two types of receivers presents a tradeoff between power consumption/complexity and performance (coverage/overhead/mobility support).
  - Each of them is more suitable for a different set of use cases.
    - OOK-1/OOK-4 is beneficial for very power sensitive IoT use cases.
    - OFDM-based sequence is beneficial for less power sensitive uses cases that have higher performance requirements, especially the ones that have wide-area deployment and requires good mobility support.
  - It is important to allow the flexibility in UE implementation to choose the right type of receiver for the targeted use case.
- Among the 2 directions, **our preference is Direction 2 (Waveform-option-3)**.
  - Direction 1 requires further discussion on OOK-1/4 and the harmonized design, in terms of further down-selection or mandatory/optional discussion.
  - Direction 2, with the harmonized design, can accommodate both OOK-based receiver and a receiver with I/Q branches and sequence detection capability.
    - The only additional work is to specify the sequence(s) used for OOK waveform generation.
      - Note that this is beneficial for performance guarantee even without considering the receiver flexibility, compared to completely leaving the OOK waveform generation to gNB implementation.

Proposal 1: Specify LP-WUS using a harmonized design that can accommodate both OOK-based receiver and a receiver with I/Q branches and sequence detection capability, by specifying the overlayed time-domain or frequency-domain sequence(s) used to generate OOK-based waveform.

Other Considerations (1/2)

- For idle/inactive UEs, the design should support UE MR going into deep sleep state.
  - The evaluation in the SI showed that MR going into deep sleep state also provides significant power saving gain, with much smaller latency impact compared to ultra-deep sleep state.
  - The specification of delay between LP-WUS and paging monitoring should consider both deep sleep state and ultra-deep sleep state for the MR.

Proposal 2: For UEs in RRC_IDLE/RRC_INACTIVE state, the design should also support the main radio going into deep sleep state instead of ultra-deep sleep state.

- Sufficient mobility support should be provided.
  - Procedure of activation/deactivation of LP-WUR should be defined to handle the potential mismatch between the LP-WUS coverage and PSS/SSS coverage.
  - RRM measurement enhancements should be specified at least for serving cell measurement, to allow UE power saving and support mobility.

Proposal 3: Sufficient mobility support is provided by specifying RRM measurement enhancements and considering the potential mismatch between the LP-WUS coverage and PSS/SSS coverage.

- LP-SS should be specified to support time/frequency synchronization and RRM measurement.
  - It should use the same waveform as LP-WUS, and can be received by both OOK-based receiver and a receiver with I/Q branches and sequence detection capability.

Proposal 4: LP-SS uses the same waveform as LP-WUS, which can be received by both OOK-based receiver and a receiver with I/Q branches and sequence detection capability.

Other Considerations (2/2)

- There are multiple moving targets(e.g., target SNR, target accuracy, target time delay or sample number) to specify the LP-WUR based RRM requirement. The criteria for requirement design shall be decided before the requirement design.
  - Alternative 1: Firstly fix the target accuracy performance to be equivalent to the existing RSRP/RSRQ measurement accuracy, and then decide the target SNR and sample number for LP-WUR based RRM requirement.
  - Alternative 2: Firstly fix the target SNR side condition to be equivalent to the existing SNR side condition in current RSRP/RSRQ measurement requirement (e.g., -6dB or -4dB), and then decide the target accuracy and sample number for LP-WUR based RRM requirement.
  - Alternative 3: Firstly fix the target coverage performance of LP-WUR to be equivalent to the existing MR (i.e., new target SNR = (existing target SNR) – (extra noise figure)), and then decide the target accuracy and sample number for LP-WUR based RRM requirement.

Proposal 5: A study phase is preferable from beginning of R19 WI for RAN4 to decide which criteria shall be used for RRM requirement design, and then to evaluate the RRM performance based on:
- Different SNR side condition
- Different samples/symbols for both LP-SS and SSS
- Measurement accuracy and measurement delay
- Coverage

Rel-19 WI on Low Power WUS/WUR

- **Objectives**
  - Specify LP-WUS using a harmonized design that can accommodate both OOK-based receiver and a receiver with I/Q branches and sequence detection capability [RAN1]
    - Specify the time-domain or frequency-domain sequence(s) used to generate OOK-based waveform
    - Common waveform design is applied to RRC_IDLE/RRC_INACTIVE and RRC_CONNECTED states.
  - Specify synchronization signal for low power receiver to support both synchronization and serving cell RRM measurement [RAN1, RAN4]
    - The same waveform as LP-WUS is used for synchronization signal.
  - Specify LP-WUS related physical layer and higher layer procedures [RAN1, RAN2]
    - For RRC_IDLE/RRC_INACTIVE state
      - Specify LP-WUS configuration, subgrouping for LP-WUS, duty-cycled operation for LP-WUS monitoring;
      - Specify LP-WUS to control paging and/or PEI monitoring;
      - Specify the entry and exit conditions for using LP-WUS.
      - Note: the design should also support the main radio going into deep sleep state instead of ultra-deep sleep state.
    - For RRC_CONNECTED state
      - Specify the procedures for network to configure/activate/deactivate LP-WUS monitoring;
      - Specify the procedures for LP-WUS to control PDCCH monitoring with/without C-DRX.
  - Specify LP-WUS related RRM measurement enhancements for UEs in RRC_IDLE/RRC_INACTIVE state [RAN4, RAN1, RAN2]
    - Study the criteria for RRM requirement design (e.g., to achieve a target accuracy, or a target coverage, or a target SNR) and evaluate the RRM measurement performance based on the determined criteria
      - If the above criteria is decided and performance is verified, specify the corresponding serving cell RRM measurement on the low power receiver;
    - Specify the time domain relaxation of serving cell and neighbor cell RRM measurements on the main radio.

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