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3GPP TSG RAN Meeting #102 RP-232979
Edinburgh, Scotland, December 11-15, 2023

Agenda Item: 9.1.1.6

Source: Spreadtrum Communications

Title: LP-WUS in Rel-19

Document for: Discussion and decision

Example of power consumption of LR and MR

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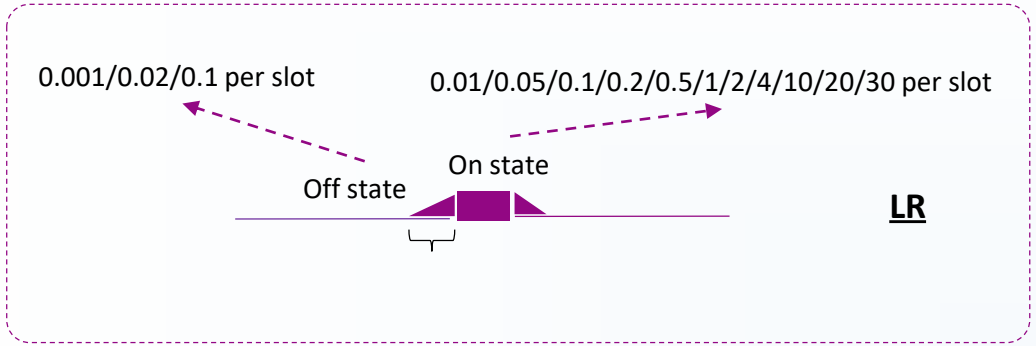
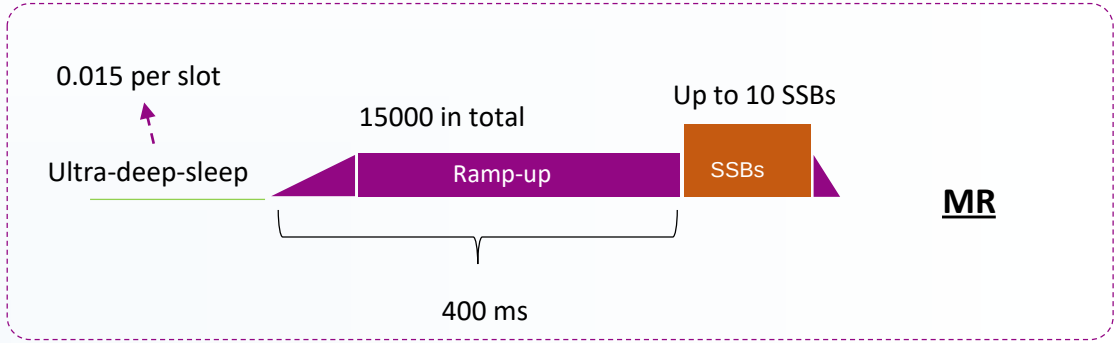
- R18 LP-WUS SI
  - TR 38.869

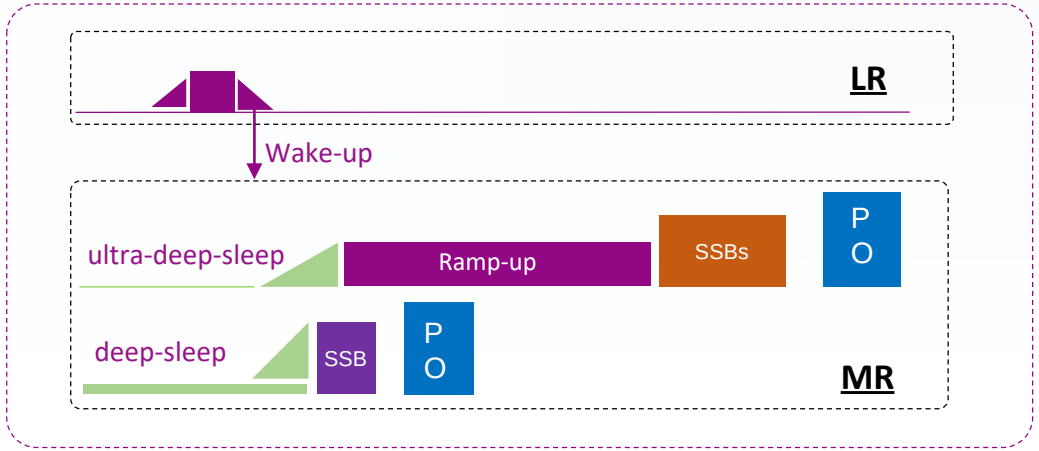
Power model for LR



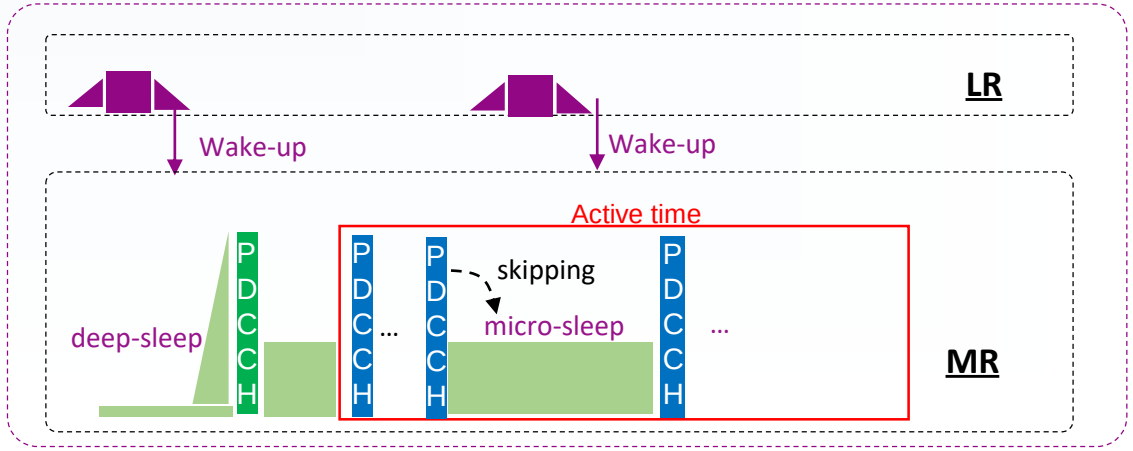
Power model for ultra-deep-sleep for MR



Example of power consumption for RRC IDLE/INACTIVE state



Example of power consumption for RRC CONNECTED state



KPIs for LP-WUS (1/2)

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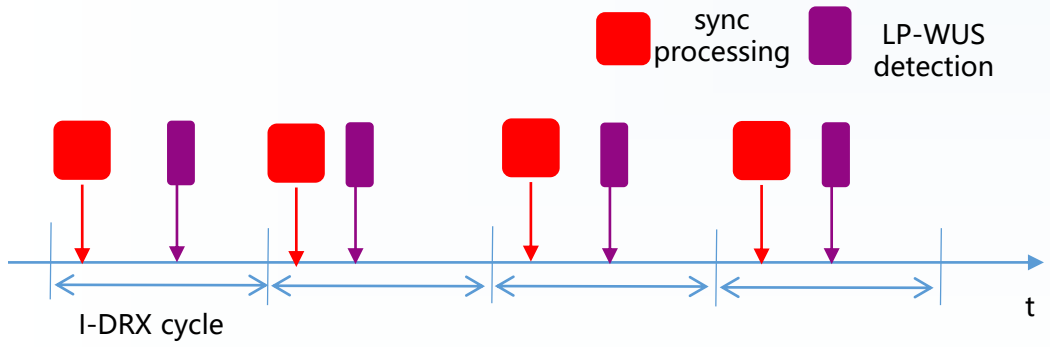
KPIs for UE in RRC IDLE/INACTIVE state

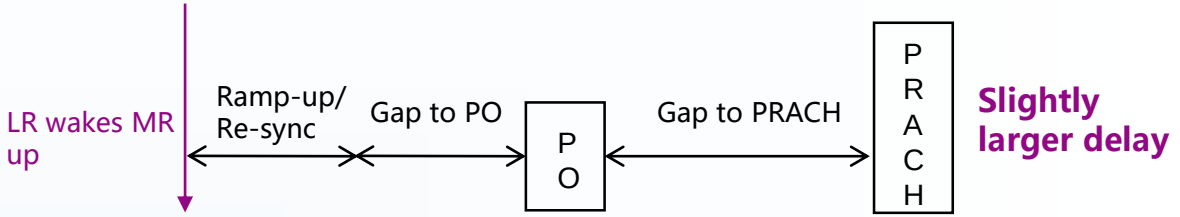
Power saving gain

- Power saving gain is significant compared to R17 PEI solution in our evaluation for both ultra-deep-sleep and deep-sleep
- Power saving gain mainly comes from
  - RRM measurement relaxation of MR
  - Time/frequency-error tolerance of LR (i.e. reception with presence of large time/frequency error)
  - 1 Rx of LR
  - Low power consumption of processing in LR than that of MR, e.g. without FFT/equalizer/decoder and other modules



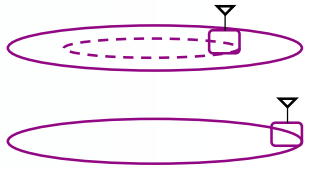
Latency

- Latency is slightly larger than that of legacy paging for normal I-DRX, since PO should be monitored in general cases



Coverage target

- Discontinuous coverage: PUSCH for Msg.3
- Continuous coverage: Paging PDCCH
  - UE does not need to turn on MR at cell edge
  - NW does not need to aware of UE turning on MR



System overhead

- System overhead depends on coverage target and LR complexity
- LP-WUS can replace DCI format 2_7 (PEI)

Observation 1: Power saving gain is promising in RRC IDLE/INACTIVE state, at least for normal I-DRX

KPIs for LP-WUS (2/2)

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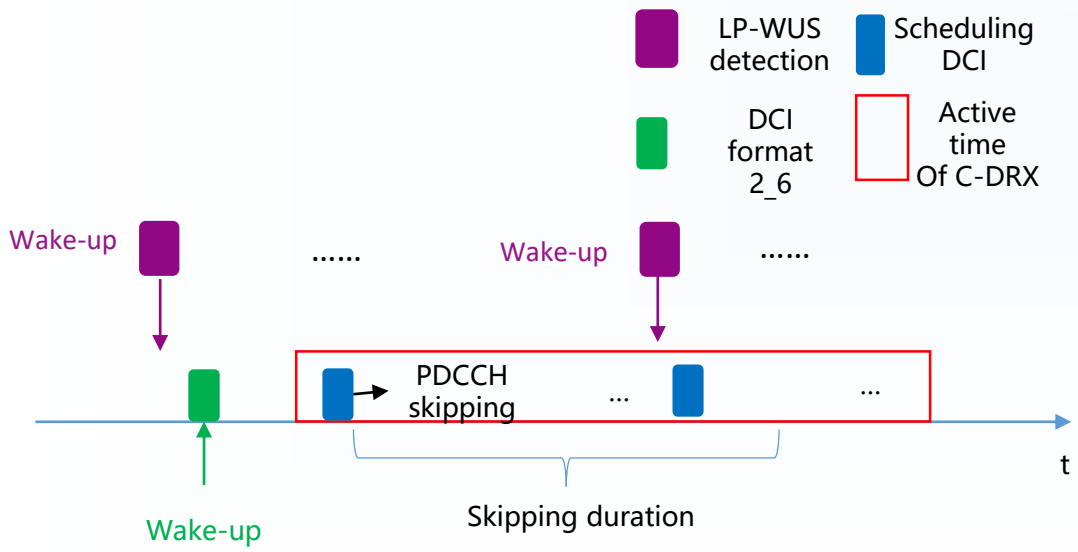
◻ KPIs for UE in RRC CONNECTED state

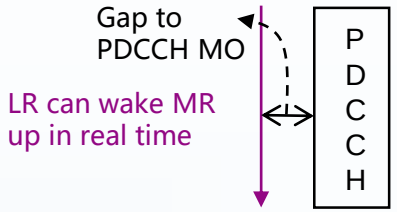
Power saving gain

- Power saving gain may come from
  - PDCCH monitoring reduction at MR through real-time wakeup due to monitoring with dense duty cycle
- May be sensitive to power consumption for LR on state due to monitoring with dense duty cycle



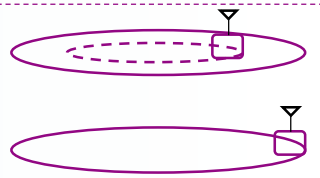
Latency

- Latency is smaller than that of R16/17 PDCCH adaptation and WUS for C-DRX due to monitoring with dense duty cycle



Coverage target

- Discontinuous coverage: PUSCH for Msg.3
- Continuous coverage: Paging PDCCH
  - UE does not need to turn on MR at cell edge
  - NW does not need to aware of UE turning on MR



System overhead

- System overhead depends on target coverage and LR complexity
  - High-precise sync can be provided by MR
- LP-WUS can replace DCI

Observation 2: Power saving gain and/or UPT improvement can be achieved in RRC CONNECTED state

RAN discussion

RP-232745, Summary for RAN Rel-19 Package: RAN1/2/3-led, RAN#102, RAN Chair

- 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

RAN discussion

RP-232616, Moderator's summary of Rel-19 LP-WUS WI, RAN#101, Moderator (CMCC)

Only Q1 and Q2 are discussed, 4 directions are identified. And also the number of supporting companies are listed. In order to facilitate scoping the WI, moderator suggests to choose one of the direction for further discussion.

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.

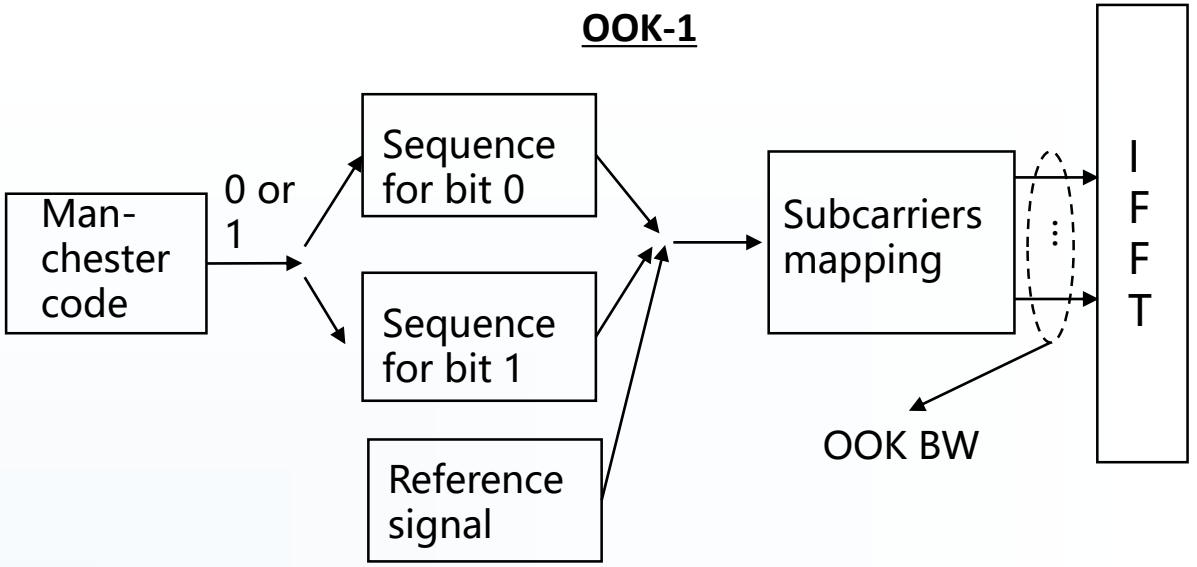
Direction 3(Number of supporting companies:2)
- Waveform-option-3: Harmonized design that accommodates OOK-1/OOK-4 and OFDM waveform, i.e., specified overlayed OFDM sequences over OOK symbol
- Waveform-option-2: standalone OFDM-based sequences,
- For RRC IDLE/INACTIVE, in addition to existing PSS/SSS, 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 4(Number of supporting companies:2)
- **Waveform-option-5:** Harmonized design that accommodates FSK-2 and OFDM waveform
- 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.

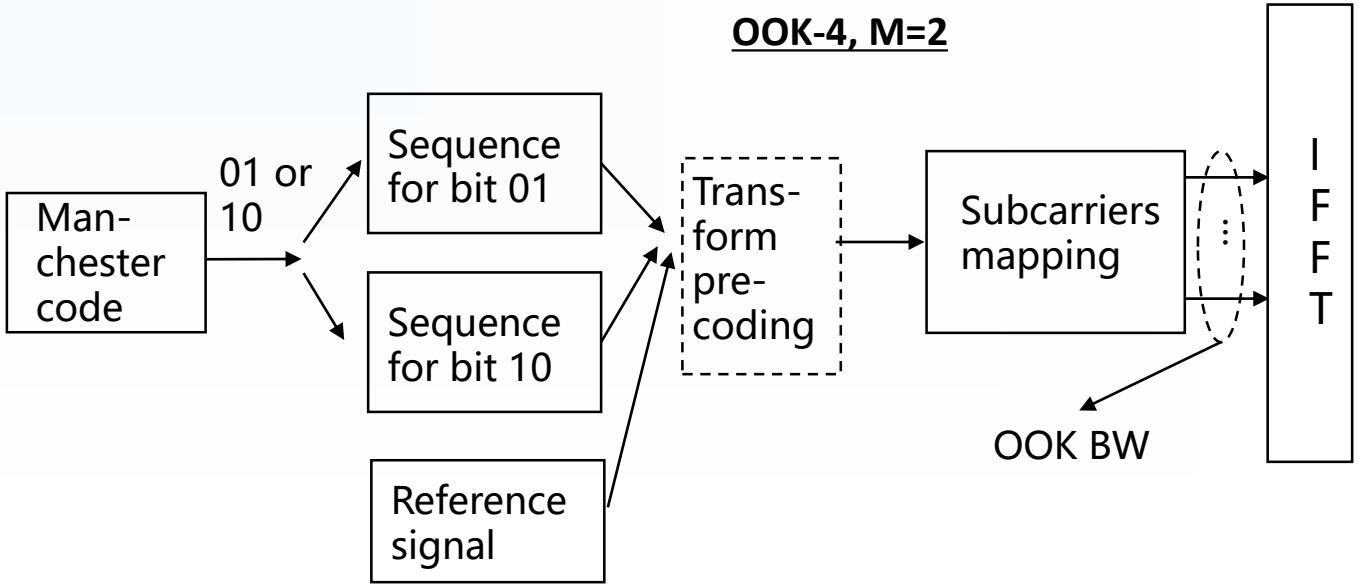
Preferred LP-WUS WI Objectives

- **LP-WUS physical design (RAN1)**
  - Waveform Direction-2: OOK-1/4 with OFDM sequence
    - OOK-1: QPSK/QAM sequence generation and mapping to subcarriers for 1 bit for one OFDM symbol
    - OOK-4: QPSK/QAM sequence generation and mapping to subcarriers for M bits (2<=M<=4) for one OFDM symbol
      - Transform precoding may or may not specified
  - Manchester code
    - Power boosting within an OFDM symbol is support, but power imbalance across OFDM symbols is avoided
    - OOK-1: code length = 2
    - OOK-4: code length = M
  - CRC is configurable
    - If information is carried by encoded bits, CRC is attached
    - If information is carried by sequences, CRC is not necessary
  - Reference signal (e.g. preamble) can be configured in LP-WUS
- **LP-WUS physical procedures (RAN1, RAN2)**
  - Duty-cycled monitoring is baseline
- **High layer procedures for LP-WUS (RAN2, RAN3, RAN1)**

OOK-1



OOK-4, M=2

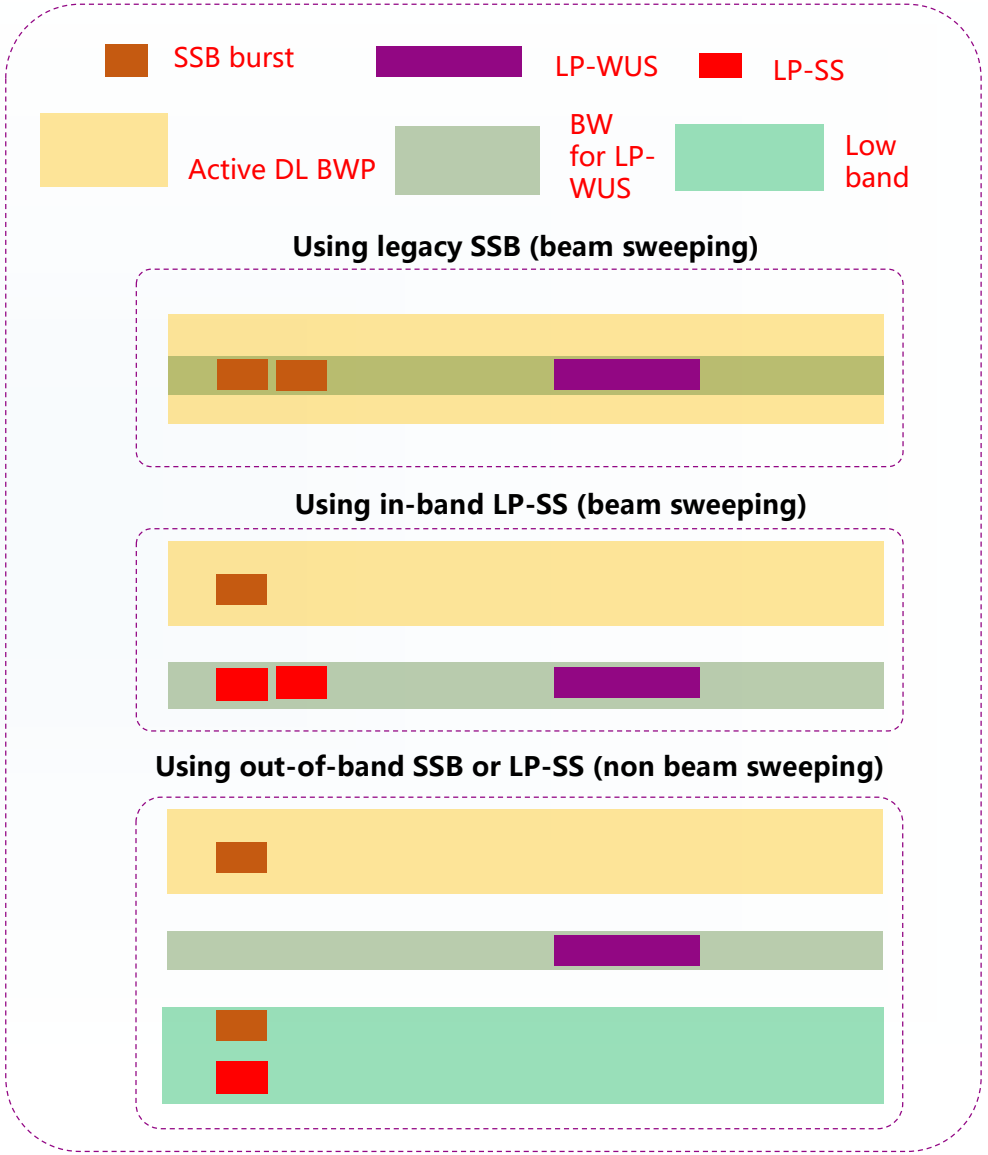


Preferred LP-WUS WI Objectives

- **Synchronization/RRM measurement (RAN4, RAN1)**
  - Offloading synchronization/RRM measurement to LR in idle/inactive state
  - Make RRM measurement relaxation of MR feasible
  - Alt-1: Legacy SSB
    - Beam sweeping
      - How can LR keep tracking time index in PBCH DMRS?
        - 1) Filtering out PBCH DMRS in time domain
        - 2) Tracking time position of PSS/SSS in short periodicity
    - Non beam sweeping
      - Using SSB in a band without beam sweeping, e.g. low band
  - Alt-2: LP-SS
    - Beam sweeping
      - LR can detect time index in LP-SS
    - Non beam sweeping
      - LR does not need to detect time index in LP-SS

- **Note: Strive common design for idle/inactive and connected states**

Illustration of frequency locations for LP-WUS and LP-SS



Thanks

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