



**3GPP TSG RAN Rel-19 workshop**

**RWS-230061**

**Taipei, June 15-16, 2023**

## **Work item on low-power Wake-up Signal and Receiver for NR Rel-19**

**Source: vivo**

**Document for: Discussion**

**Agenda Item: 5**

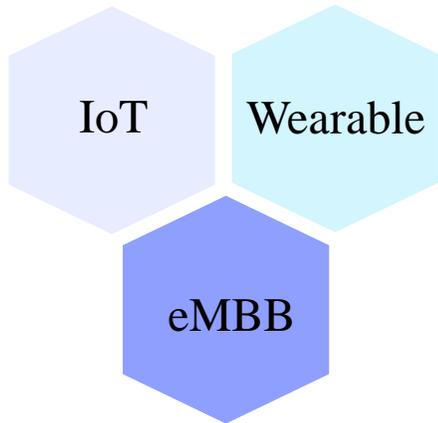
- **SI Status**
- **Overview of SI study**
  - Power saving gain: RRC idle/inactive, RRC connected (RAN1)
  - Coverage achievement (RAN1)
  - Network overhead and network energy consumption (RAN1)
  - Physical signal design and receiver architectures (RAN1, RAN4)
  - Procedures: RRC idle/inactive, RRC connected (RAN1, RAN2)
- **Potential R19 WID Scope**

# SI Status

RAN 1, 2, 4

	4Q'2022		1Q'2023	2Q'2023		3Q'2023	4Q'2023	
	10-Oct	14-Nov	27-Feb	17-Apr	22-May	21-Aug	9-Oct	13-Nov
Low power WUS (RAN1)	1	1	1	1	1	1		
Low power WUS (RAN2)				0.5	0.5	0.5	0.5	0.5
Low power WUS (RAN4) RF			0.25	0.5	0.5	0.5	0.25	0.25

## Agreed use cases for study



- In SI, performance evaluations are performed covering all use cases and RRC states

## Agreed RRC states for study

- RRC idle/inactive state
- RRC Connected state

WG	SI completion level
RAN1	80%
RAN2	30%
RAN4	50%
Overall	65%

Based on current progress, it is feasible to complete the study item on time, i.e.

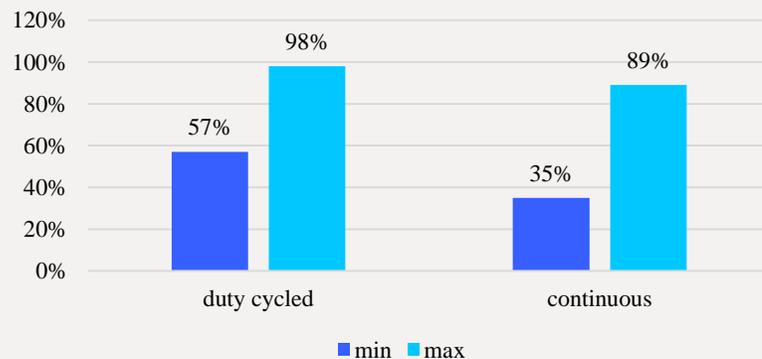
- RAN1 completion by Sept.
- RAN2/4 completion by Dec.

# RAN1 study: Power Saving Gain for IDLE/INACTIVE

## Power

- Compared to I-DRX with PEI, **power saving gain of LP-WUS** [1]:
  - WUS duty cycled monitoring: **57%~98%** (9 sources, LP-WUR “ON” power <10 units )
  - WUS continuous monitoring: **35%~89%** (6 sources, LP-WUR “ON” power <0.5 units )

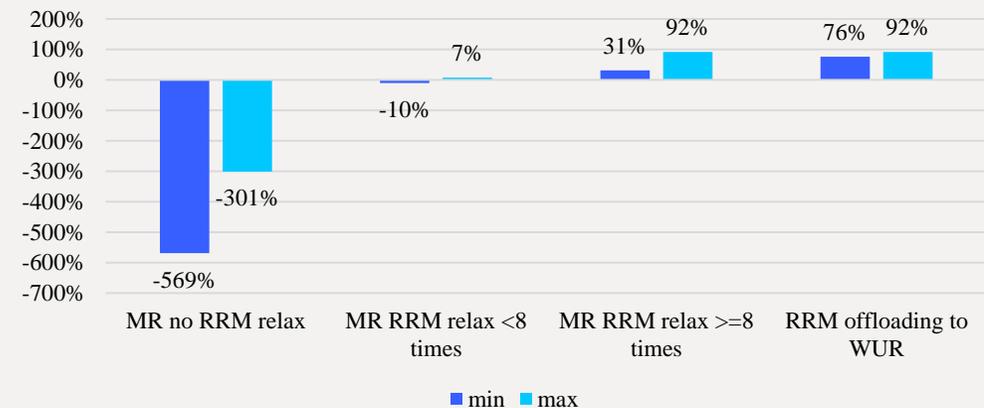
Power saving gain compared to I-DRX with PEI



## RRM

- Reduction of MR RRM measurement activities, power saving gain<sup>[3]</sup>:
  - MR no RRM relax : **no power saving** (2 sources)
  - MR RRM relax <8 times : **-10%~7%** (3 sources)
  - MR RRM relax >=8 times: **31%~92%** (7 sources)
  - RRM offloading to WUR: **76%~92%** (6 sources)

Power saving gain compared to I-DRX with PEI



## Latency

- Compared to eDRX with PEI, **latency reduction**<sup>[2]</sup>:
  - WUS can reduce the paging latency **up to 23 times**, with comparable UE power consumption

[1] R1-2305953, Summary of evaluation result (RAN1 feature lead)

[2] R1-2306129, Evaluation methodologies and results for LP-WUS/WUR, vivo

[3] 3GPP TSG RAN WG1#113, RAN1 Chair’s Notes

# SI Progress: Power Saving Gain, UPT Gain

## RRC connect mode

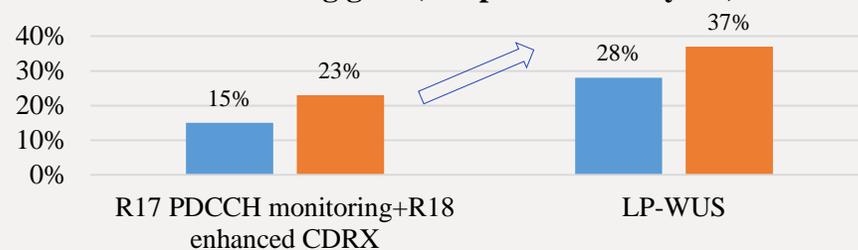
**XR traffic**

- Compared to R17/R18 power saving schemes<sup>[1-4]</sup>,
  - power saving gain: **up to 22%**
  - capacity loss: **0.4%**

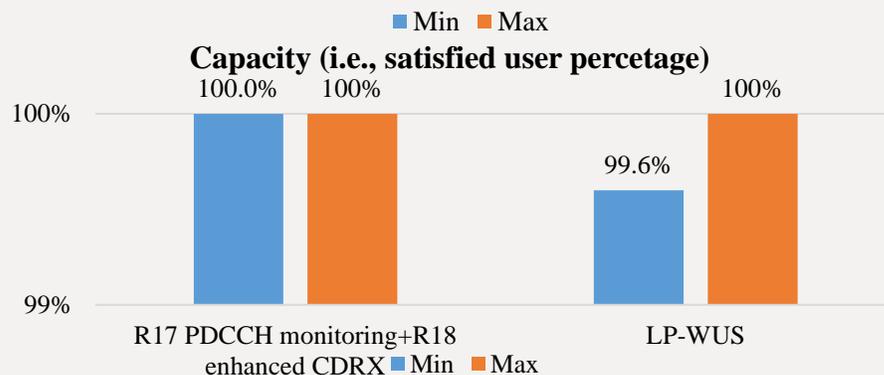
**FTP3 traffic**

- Compared to R15/R16/R17 power saving schemes<sup>[5-7]</sup>,
  - UPT gain: **up to 223%**
  - Power saving gain: **up to 62%**

**Power saving gain (compared to alwayson)**

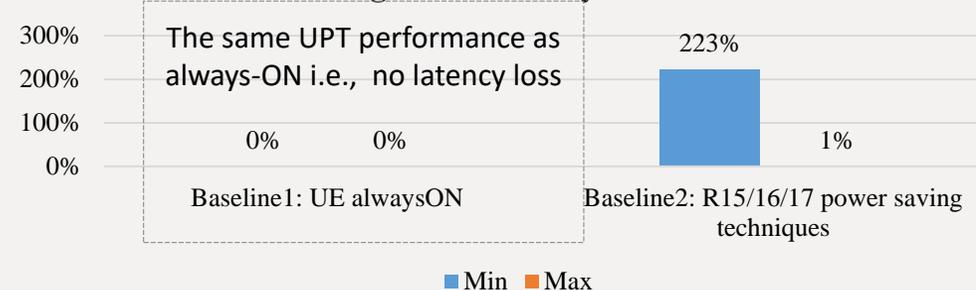


**Capacity (i.e., satisfied user percentage)**

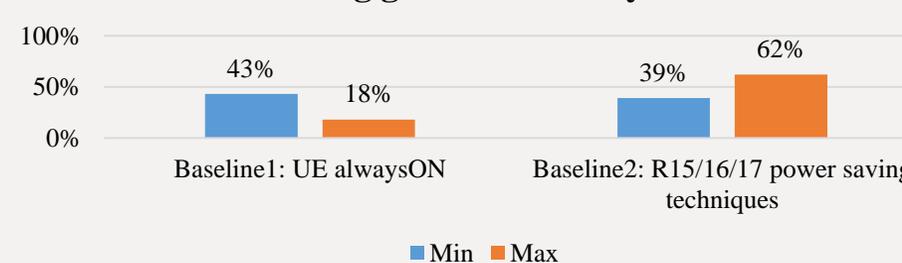


- UE MR enters micro, light or deep sleeps during LP-WUS monitoring
- The relative power of WUR ON state is assumed to be less than 1 unit.

**UPT gain achieved by LP-WUS**



**Power saving gain achieved by LP-WUS**



- UE MR enters micro, light or deep sleeps during LP-WUS monitoring
- The relative power of WUR ON state is assumed to be less than 1 unit.

# RAN1 study: LP-WUS coverage

## Target

- **Design Targets** for coverage of LP-WUS/LP-SS
  - Option 1: Broadcast PDCCH
  - Option 2: PUSCH Msg3
  - Other Channels, e.g., PUSCH eMBB

## Observation

LP-WUS can achieve **better coverage** than PUSCH eMBB and PUSCH Msg3 [1]

- For 1bit -WUS, required resource no more than 5MHz \* 4OFDM symbol (30KHz)
- For 12bit-WUS, required resource no more than 5MHz\* 7OFDM symbol (30KHz)

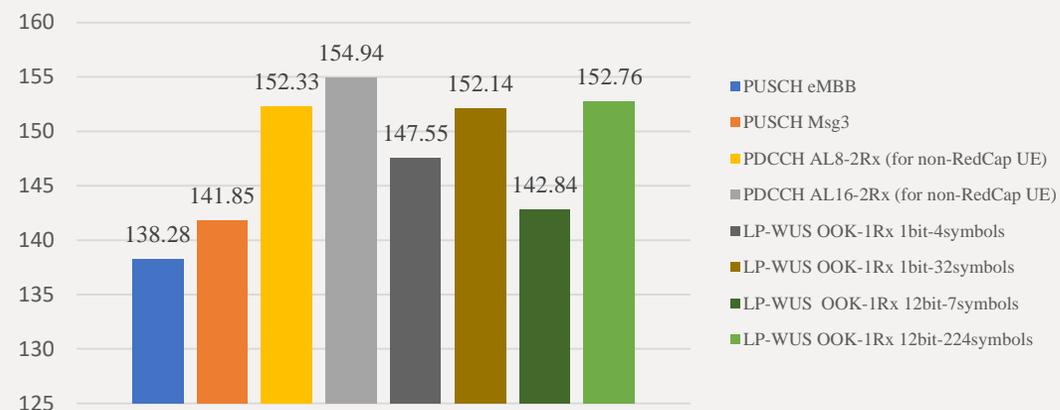
LP-SS can achieve **similar coverage** as LP-WUS based on same waveform design, e.g, OOK

## Coverage enhancement techniques

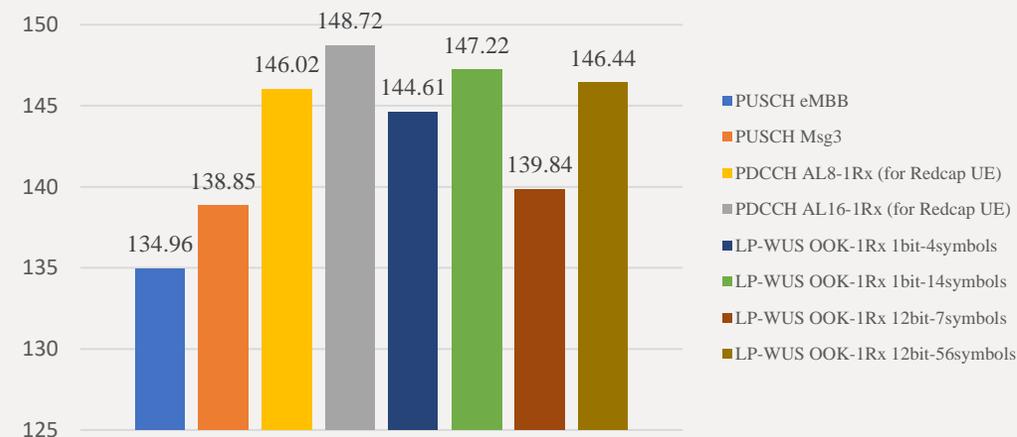
To reduce the MIL gap between LP-WUS and NR PDCCH, considering coverage enhancement schemes, e.g.

- Power boosting;
- Channel coding;
- more time/frequency resources.

MIL performance of WUS(Urban 2.6GHz,non-RedCap UEs)



MIL performance of WUS(Urban 2.6GHz, RedCap UEs)



[1] R1-2306129, Evaluation methodologies and results for LP-WUS/WUR

# RAN1 study: Resource Overhead and Network Energy Consumption

**Resource overhead**

- **RRC IDLE/INACTIVE** in 100MHz system BW :
  - LP-WUS: <1%
  - LP-SS: < **0.065%** with 320ms periodicity
- **RRC Connected** in 100MHz system BW :
  - LP-WUS: < **6%** (XR: 10 users per cell, maximum capacity)
  - LP-WUS: < **0.5%** (FTP3: 10 users per cell)

**Network Energy Consumption**

- **LP-SS FDM with SSB/SIB 1** across difference network loads:
  - LP-SS: < **0.075%** with 320ms periodicity
- **LP-SS TDM with SSB/SIB 1** across difference network loads:
  - LP-SS: < **1.725%** with 320ms periodicity

T-F resources used for resource overhead and network energy calculation

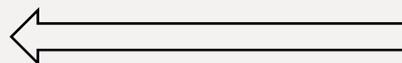
	LP-WUS	LP-SS
# OFDM symbols (WUS BW 5MHz @30kHz)	<ul style="list-style-type: none"> <li>• RRC Idle/inactive:               <ul style="list-style-type: none"> <li>▪ Comparable to or better than <b>Msg 3 coverage</b>: <b>4 symbols</b> carrying 1 bit &amp; <b>7 symbols</b> carrying 12 bits</li> <li>▪ Comparable to <b>PDCCH AL8-2Rx coverage</b>: <b>14 symbols</b> carrying 1 bit</li> </ul> </li> <li>• RRC connected mode:               <ul style="list-style-type: none"> <li>▪ Comparable to <b>PDCCH AL2-4Rx coverage</b>: <b>14 symbols</b> carrying 1bit &amp; <b>56 symbols</b> carrying 12 bits</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• RRC Idle/inactive:               <ul style="list-style-type: none"> <li>▪ Comparable to <b>PDCCH AL8-2RX coverage</b>: <b>14 OFDM symbols</b> carrying 1 bit</li> </ul> </li> <li>• RR Connected: LP-SS is not needed</li> </ul>

# RAN1/4 study: Physical Signal and Receiver Architecture

## Waveform, Signal design and Receiver architecture

**Low Power-Wake Up Signal (LP-WUS):**  
waking up UE,  
on-demand transmission

Sync/measurement  
information



**Low Power-Synchronization Signal(LP-SS):**  
synchronization, RRM measurement,  
periodical transmission

Waveform: <b>OOK /FSK are generated via OFDM generator</b> → No hardware impact at gNB side.			Receiver architecture	Power consumption <sup>[1]</sup>
OOK	OOK-1	1 OOK chip per 1 OFDM symbol, higher data rate requires larger SCS	<ul style="list-style-type: none"> <li><b>OOK Type 1</b>-RF envelope detection</li> <li><b>OOK Type 2</b>-Heterodyne architecture with IF envelope detection</li> <li><b>OOK Type 3</b>-homodyne/zero-IF architecture with baseband envelope detection</li> </ul>	<ul style="list-style-type: none"> <li>WUR 'ON' : 0.01-1 unit</li> <li>WUR 'OFF': 0.001 unit</li> </ul>
	OOK-2	Parallel M-bit OOK in frequency domain, requires parallel receiver		
	OOK-3	Multi-tone single-bit OOK, requires I-Q branch based receiver		
	OOK-4	M OOK chip/1 OFDM symbol, spectrum flattening is needed due to DFT/LS operation		
FSK	FSK-1	M pairs of segments to carry M bits	<ul style="list-style-type: none"> <li><b>FSK Type 1</b>-parallel receiver architectures</li> <li><b>FSK Type 2</b>-frequency to amplitude conversion</li> </ul>	<ul style="list-style-type: none"> <li>WUR 'ON' : 0.1-1 unit</li> <li>WUR 'OFF': 0.001 unit</li> </ul>
	FSK-2	2 <sup>M</sup> segments to carry M bits		
OFDM	OFDM	Legacy signal, e.g., PSS, SSS	<ul style="list-style-type: none"> <li><b>OFDM receiver</b></li> </ul>	<ul style="list-style-type: none"> <li>WUR 'ON' : 0.15-35 unit</li> <li>WUR 'OFF': 0.001-0.5 unit</li> </ul>
<p><b>Observation: There is good consensus on low power consumption for WUR targeting OOK/FSK-based LP-WUS , however, the view on OFDM is quite divergent.</b></p>				

[1] LP-WUR architecture analysis results collection by FL, Apple

# RAN1 study: RRM measurement offloading to WUR

## Necessity

- **No power saving gain** if MR performs legacy RRM measurement without sufficient relaxation
- **Higher UE power saving gain** if RRM measurement can be offloaded from MR to WUR.

## Measurement metric

- RAN 1 agree to study the following measurement metrics for WUR based on LP-SS
  - LP-RSSI
  - LP-RSRP
  - LP-RSRQ
  - LP-SINR

## Evaluation

- For OOK-based LP-SS, **accuracy of LP-RSRP** at SNR = -3dB, -6dB:
  - Similar measurement accuracy as MR SS-RSRP can be achieved at SNR=-6dB <sup>[1][2]</sup>.
  - +/-2 dB delta RSRP relative to genie RSRP can be achieved at 90%-percentile and SNR=-3 dB and realistic clock model <sup>[3]</sup>.
- For OOK-based LP-SS, **accuracy of LP-SINR**:
  - The gap between the measured SINR and theoretical SINR is marginal <sup>[2]</sup>.

## Observation

OOK based LP-WUS and LP-SS provide promising power saving gain and support RRM measurement with promising accuracy.

[1] R1-2305577, Ericsson

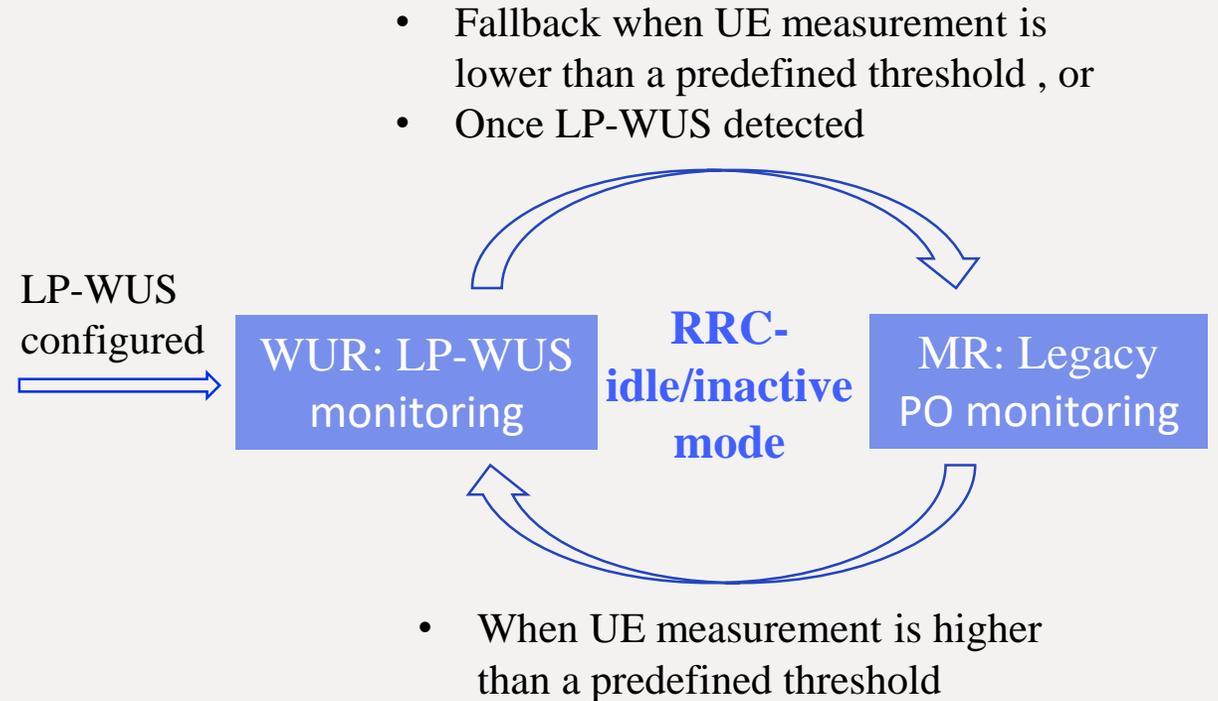
[2] R1-2306013, vivo

[3] R1-2305360, Qualcomm

# RAN1/2 study: Procedures for IDLE/INACTIVE

For RRC idle/inactive, RAN1 and RAN 2 agree to study the following:

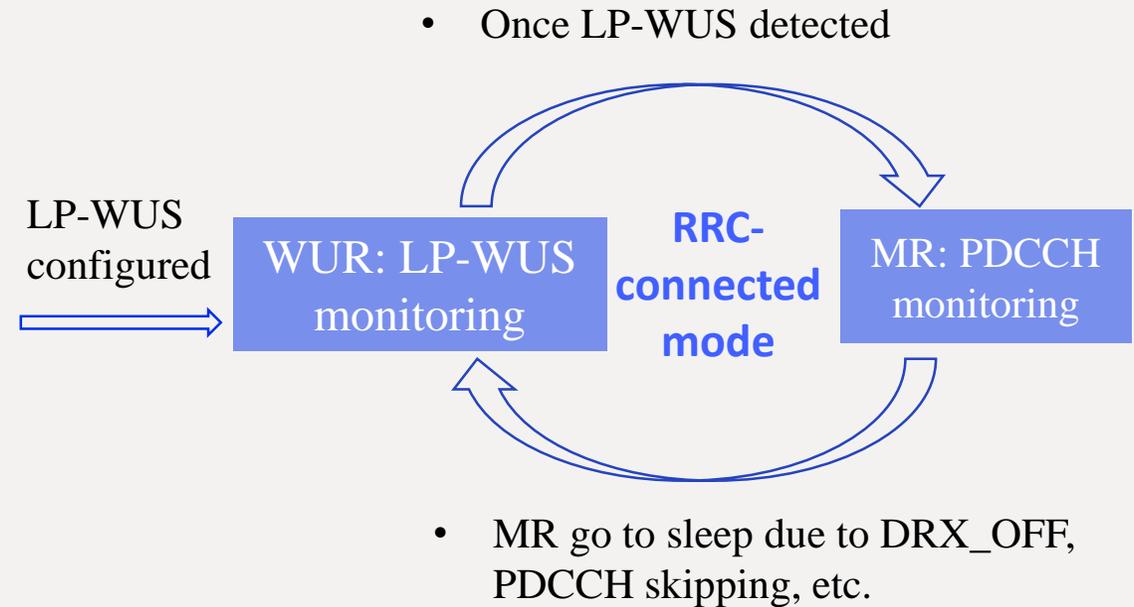
- **Activation and deactivation** of LP-WUS monitoring
- **Fallback** to legacy operation after exiting LP-WUS monitoring
- UE performs PO monitoring after detecting LP-WUS



# RAN1/2 study: Procedures for CONNECTED

For RRC Connected, RAN1 and RAN 2 agree to study the following:

- WUR can monitor LP-WUS during MR in sleep
- LP-WUS to trigger start/resume of MR PDCCH monitoring
- RRM/RLM/BFD/CSI performed by MR
- **Interaction** between LP-WUS and legacy UE power saving techniques e.g., C-DRX, DCP, R17 PDCCH skipping /SSSG switching



# Potential Rel-19 WID Scope

- Specify an OOK (OOK-1 and/or OOK-4) based LP-WUS that can be detected by LP-WUR and applicable for both IDLE/INACTIVE and CONNECTED mode usage (RAN1)
  - Information payload carried by LP-WUS is [1~12]bits
  - LP-WUS shall be able to reach the coverage of existing Msg3 PUSCH with no repetition
  - It shall be possible to generate the OOK based LP-WUS with no hardware impact from gNB transmitter perspective
- For IDLE INACTIVE modes,
  - Specify necessary procedures to allow UE MR (Main receiver) paging monitoring triggered by LP-WUS including the mechanisms to activate/deactivate the LP-WUS monitoring (RAN1, RAN2)
  - Specify an OOK (OOK-1 and/or OOK-4) based periodic LP-SS for synchronization and serving cell measurement performed by LP-WUR, with its coverage target no worse than LP-WUS and periodicity no less than [320ms] (RAN1, RAN4, RAN2)
    - It shall be possible to generate the OOK based LP-SS with no hardware impact from gNB transmitter perspective
  - Specify further RRM relaxation of UE MR for both serving and neighbor cell measurements, including the possibility of offloading MR serving cell measurement(s) to LP-WUR (RAN4, RAN2, RAN1)
- For CONNECTED mode, specify necessary procedure to allow LP-WUS monitoring by LP-WUR when MR is in sleep mode(s) except for ultra-deep sleep, and MR PDCCH monitoring triggered by LP-WUS (RAN1, RAN2)
  - No change on existing RRM/RLM/BFD/CSI measurements for MR
- UE RF core and RRM performance requirements (RAN4)

THANK YOU.

谢谢。