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Type: Discussion

Discussion on Rel-19 LP-WUS WI

September 2023

LP-WUS SI results (based on TR38.869 v0.4.0)

	OOK	OFDM	Comment
Power saving gain	57%~99% (average 80%), P_{WURON}< 1 unit	29%~95% (average 66%), 5<=P_{WURON}<= 10 unit -79%~86% (average 16%),10<=P_{WURON}<= 20 unit	OOK has better PSG than OFDM, Note: Assuming (P_{WURON}<= 1 unit) for OOK and (P_{WURON} >4) for OFDM by author of this article
Coverage	0.9~17.28 MHz*Symbol/bit	0.31~4.32 MHz*Symbol/bit	• OFDM has clear advantage over OOK • Note: compare to Msg3 single transmission
LLS	Time error: up to 4us Frequency error: 390kHz	Time error: 4us depending on sliding window Frequency error: worse than OOK/FSK	OOK is better than OFDM in time and frequency error tolerance, but much worse in spectrum efficiency.

Active Power	• 0.05 ~ 1(8 sources),
	• 4(1 source)
		• Frequency-domain correlation
		  • 4 ~ 10/30 (5 sources)
		  • 1 (1 source)
		• Time-domain correlation only
		  • 5 ~ 10/30 (5 source)
		  • 1 ~5 (1 source)
		  • 0.15 (1 source)
			• Clear differences on active power.
			  • OOK has lower active power consumption over OFDM receiver.
			• Only IF/BB receiver for OOK is considered in the table.

LP-SS / SSB	• 0.4% for 320ms, 1 slot LP-SS • 0.3% for 1.28s, 3 slot LP-SS	Current SSB, no additional overhead	• Overhead is marginal
RRM accuracy	• X= [-9, -11] dB: AWGN, 90% accuracy of 3 or 5dB, (1 -20) symbols spreading over 1-3 periods is required	X= [-3, -6] dB: AWGN, 90% accuracy of 3dB, 1 OFDMA symbol in 1 period is required	• X denotes SNR target
NetPower	(0.06%~3.9%), (0.07%~2.716%), (0.388%~1.076%) for zero load, low load and medium load (1 slot LP-SS, 4 sources)	Current SSB, no additional Power	• network power consumption increase is marginal.

- **Observations 1:** OOK and OFDM receiver are tradeoff between power (i.e., active power, power saving gain) and link performance (coverage, measurement accuracy). Network power consumption and overhead is marginal

LP-WUS SI outcome (1)

Power consumption for different P_{WURON} for low traffic arrival rate and FAR (<=0.1%)

PSG	P_{WURON}<= 1 unit	4<P_{WURON}<=10	10 < P_{WURON} <= 30
[8A-3]	99%	95%, (5x) *	
[8A-13]	66%	29%, (2.2x)	-79% (5.3x)
[8A-17]	75%		
[8A-16]	97%	76%, (8x)	86% (4.6x)
[8A-11]	85%	64%, (2.4x)	42% (3.9x)
[8A-12]	84%		
[8A-4]	57%		

Note (*): 95% means the power saving gain is 95% compared to legacy, 5x means the power consumption is 5 times compared to P_{WURON}< 1 unit

- **Observations 2:**
  - If assuming (P_{WURON}<= 1 unit) for OOK and (P_{WURON} >4) for OFDM receiver
    - Almost all companies show significant power saving gain for OOK and OFDM receiver.
    - All companies shows OFDM receiver is 2.2x ~ 8x times power consumption than OOK receiver.
- **Proposal 1:**
  - Lower power consumption is essential for IoT devices. At least for IoT devices, OOK receiver should be considered.
  - For wearable and smartphone, OFDM receiver can be considered to further improve performance (carrying more information or better coverage) while still bringing large power saving benefits.

- For RRC CONNECTED mode
  - For FTP/IM
    - Trade-off between Power saving gain and UPT to replace DCP
    - For the usage of LP-WUS to trigger the UE MR PDCCH monitoring
      - Significant UE power saving gain (up to more than 60%) and moderate UPT improvement (up to more than 10%) when the UE MR enters deep sleep state during LR LP-WUS monitoring
- **Observation 3**: RRC CONNECTED LP-WUS has benefits for power saving

Potential scope for Rel-19 LP-WUS WI

- **LP-WUR based on waveform consideration**
  - LP-WUR support OOK only should be considered,
    - Targeting for low speed and with peak power consumption lower than 1 unit, and IoT traffics. Both duty-cycled and continuously monitoring(can be discussed in WI phase, larger CRC protection is not expected) can be considered.
  - LP-WUR supporting both OOK and OFDM can be considered as alternative LP-WUR receiver,
    - OFDM sequence(s) can be additionally modulated on top of OOK
    - Targeting for low speed and with peak power consumption larger than 4 unit and less than [20] unit, both eMBB and IoT traffic can be considered. Only duty-cycled monitoring is supported.
    - For wearable and smartphone, OFDM receiver can be considered to further improve performance (carrying more information or better coverage), details can be discussed in WI.
- **LP-SS based measurement for synchronization and RRM is supported**
  - MR RRM is further relaxed or offloaded to LP-WUR
  - For OOK receiver, same waveform for LP-SS and LP-WUS should be considered.
  - For OOK+OFDM receiver, reusing existing PSS/SSS measurement should be considered.
- **Targeting LP-WUS/LP-SS coverage comparable to NR bottleneck channel, e.g., PUSCH for msg3.**
- **Generation of OOK waveform by existing gNB implementation should be supported. Discuss and decide which OOK alternative is supported in WI.**
- **Necessary L1 and higher layer procedure to activate/deactivate LP-WUS monitoring, LP-SS measurement and wake-up/go-to-sleep MR should be supported.**
- **Forward compatibility to allow wake-up other system should be considered.**
- **Both RRC IDLE/INACTIVE/CONNECTED is considered.**

Thank you!