

Agenda Item: 7.2.9.1
Source: Ericsson
Title: Design of PDCCH-based power saving signal/channel
Document for: Discussion and Decision

1 Introduction

In RAN#83, a new WI on UE power savings for NR was agreed with the objectives as highlighted below for power saving signal/channel power saving techniques.

- 1) Specify power saving techniques with UE adaptation with focus in RRC_CONNECTED mode [RAN1, RAN4]
 - a) Specify the power saving techniques with power saving signal/channel
 - i) Specify the PDCCH-based power saving signal/channel triggering UE adaptation in RRC_CONNECTED
 - ii) Note: this objective shall not duplicate DRX operation and impact to DRX is studied at RAN2
 - iii) Note: Any change of PDCCH channel coding and payload interleaver is not in the scope
 - b) Specify the procedure of cross-slot scheduling power saving techniques
 - i) Note: The procedure is in addition to Rel-15 cross-slot scheduling procedure

In this document, we discuss design details for PDCCH-based power savings signal/channel.

2 Power Saving Signal/Channel

The main objective is to design a PDCCH-based power saving signal/channel, without duplicating DRX operation. Furthermore, changing PDCCH channel coding and payload interleaver is not in scope. Thus, if a DCI based scheme is used, then it should reuse the coding chain specified in Rel-15, including the CRC payload interleaver. In Rel-15, DCI with smaller number of information bits was discussed and handled through the following principle, captured in 38.212, subclause 7.3.1.

If the number of information bits in a DCI format is less than 12 bits, zeros shall be appended to the DCI format until the payload size equals 12.

Thus, Rel-15 PDCCH channel coding and payload interleaver can already handle the case when the number of information bits in a DCI is less than 12 bits, by appending zeros until the payload size is 12. Subsequently, a 24-bit CRC is attached with a 16-bit RNTI masking. The UE could improve the detection performance by taking the additional information (regarding zero padding bits and trading off the 24 bits of CRC for error correction, etc) into the Polar SSCL decoding. With this background we discuss some aspects related to the detailed design of power saving signal/channel.

2.1 Design Details

As a minimum the PDCCH based power saving signal needs to indicate 'wake-up' based on which the UE can decide to decode/not decode subsequent PDCCH monitoring occasion(s). For this case, the UE can detect presence of power saving signal/channel addressed for it using CRC masked by RNTI. This option (shown in Figure 1 below) allows the power saving

signal/channel to be detected by a correlation-based receiver or by using a regular PDCCH decoder. From a robustness perspective this would be the most robust option as it has the smallest amount of information (i.e. On/Off or 1 bit).

Fixed/known bits (12bits)	CRC masked by UE specific RNTI (24bits)
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Figure 1 – WUS option with smallest possible amount of information.

A more flexible option is to have a small number of bits of information in the DCI payload. This can allow the power saving signal to control more actions than just wakeup as shown in Figure 2.

Power savings information (N bits)	Fixed/known bits max (0,12-N) bits	CRC masked by UE specific RNTI (24bits)
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Figure 2. Flexible power saving signal/channel.

Next, we evaluate the required SNR vs number of information bits in DCI for various aggregation levels (1/2/4/8/16) and target BLERs of 1% and 0.1%. These are assuming TDL-C, 100ns DS, 3kmph UE speed.

Table 1 Required SNR for PDCCH based WUS BLER 1% and 0.1 % for different payload sizes and ALs

Payload size	AL	SNR for 1% BLER	SNR for 0.1% BLER
1	1	7.8 dB	11.5 dB
	2	3.5 dB	6.5 dB
	4	-2.4 dB	0.7 dB
	8	-5.7 dB	-3.7 dB
	16	-8.1 dB	-6.4 dB
2	1	8 dB	11.5 dB
	2	3.5 dB	6.5 dB
	4	-2.3 dB	0.3 dB
	8	-5.7 dB	-3.7dB
	16	-8.1 dB	-6.5 dB
4	1	8.3 dB	11.8 dB
	2	4 dB	6.8 dB
	4	-2 dB	0.6 dB
	8	-5.6 dB	-3.5 dB
	16	-8 dB	-6.2 dB
8	1	9 dB	12.8 dB
	2	4.7 dB	8 dB
	4	-1.7 dB	1 dB
	8	-5 dB	-4.4 dB
	16	-7.8 dB	-6.2 dB
16	1	10.7 dB	15 dB
	2	5.9 dB	9.2 dB
	4	-1.2 dB	1.7 dB
	8	-4.7 dB	-2.8 dB
	16	-7.4 dB	- 5.7 dB
32	1	16.2 dB	>20 dB
	2	9 dB	12.8 dB
	4	0.3 dB	3 dB
	8	-3.7 dB	-1.9 dB
	16	-6.3 dB	-5.2 dB

From the results, if only one DCI size and one aggregation level is used for power saving signal/channel, at least sixteen CCEs (and smaller payload size) are needed to achieve

0.1% BLER at cell-edge scenario e.g. ~ -6 dB SNR. Such a design may be unviable to due to large resource overhead. A more reasonable approach would be configuring the power saving signal/channel only for some UEs in the cell and allow link adaptation similar to PDCCH to reduce overhead.

Proposal 1 Link adaptation for power saving signal/channel is supported using a similar mechanism as PDCCH (e.g. blind decoding for different ALs).

Next, we consider DCI size/format for PDCCH-based wakeup signal (WUS). If the power saving signal/channel is expected to be always monitored separately (e.g. X slots before DRX On duration) from scheduling PDCCH monitoring, the DCI size/format for the power saving signal/channel can be independent of existing DCI format sizes. This allows using a more compact and robust DCI size.

Proposal 2 DCI format size for power saving signal/channel is independent (e.g. smaller) of scheduling DCI format size(s), at least for the case where the power saving signal/channel is expected to be always monitored separately from scheduling PDCCH monitoring (e.g. X slots before DRX On duration).

However, for the case of a more flexible power savings signal/channel which can be sent both separately, and along with scheduling DCI, the DCI size should be aligned with existing DCI formats to avoid running into blind decoding budgeting issues.

Next, we consider configuration signalling related to power saving signal/channel. This can largely reuse the coreset and search space configurations used for configuring PDCCH monitoring for the UE. One additional aspect is the offset between the WUS monitoring occasions and corresponding DRX On duration(s). This can be part of e.g. the DRX configuration of the UE or a separate WUS configuration.

Proposal 3 UE-specific configuration of the power saving signal/channel includes the following: RNTI, Coreset configuration, search space configuration (e.g. including BDs and monitoring occasions) and if needed, offset from DRX On duration.

Next, we discuss the use of power saving signal/channel for addressing a group of UEs. As shown in Figure 3 below, this can be done using approach similar to TPC-PUXCH-RNTI where WUS for multiple UEs is sent in one PDCCH with each UE assigned specific DCI bit(s) for its corresponding wake-up indication e.g. UE is assigned bit4 for its wakeup indication in below figure. This option can reduce overhead especially for cases where per-UE payload is small.

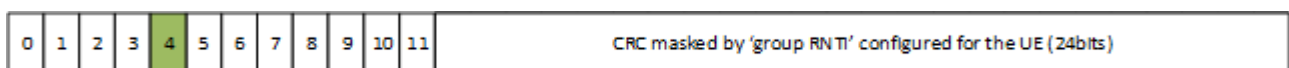


Figure 3 – Group-based power saving signal/channel option.

Proposal 4 RAN1 should develop power saving signal/channel such that a group of UEs can be addressed using one PDCCH.

Next, we discuss further details on the use of power saving signal/channel for WUS. PDCCH based WUS can be related to C-DRX adaptation (RAN2 study), i.e., if a WUS is detected in a WUS monitoring occasion, the UE should wake-up for the ON duration(s) associated with the WUS monitoring occasion.

If WUS is not detected in a WUS MO, this can be due to NW not sending wakeup command or UE missing the WUS. For the former case, UE should skip monitoring the associated ON duration(s). However, the case of missed WUS can increase latency significantly. Also,

configuring WUS for a UE should not result in adverse NW impact such as increased link failures. To avoid such situations, it should be possible to adapt WUS monitoring based on fluctuating channel conditions and also as a fall-back UE should monitor some search spaces/PDCCH On durations even when WUS is not detected.

Proposal 5 When the power saving signal/channel is used as WUS, UE monitors WUS in WUS monitoring occasions configured by the NW and upon WUS detection, UE should wake-up during On Duration(s) associated with the WUS monitoring occasion.

Proposal 6 Mechanisms to avoid and quickly recover from WUS misdetection should be specified e.g. adapting WUS monitoring based on fluctuating channel conditions, fallback search spaces/PDCCH On durations that are always monitored independent of WUS detection, etc.

Conclusion

In section 2, the following observations and proposals were made:

Proposal 1 Link adaptation for power saving signal/channel is supported using a similar mechanism as PDCCH (e.g. blind decoding for different ALs).

Proposal 2 DCI format size for power saving signal/channel is independent (e.g. smaller) of scheduling DCI format size(s), at least for the case where the power saving signal/channel is expected to be always monitored separately from scheduling PDCCH monitoring (e.g. X slots before DRX On duration).

Proposal 3 UE-specific configuration of the power saving signal/channel includes the following: RNTI, Coreset configuration, search space configuration (e.g. including BDs and monitoring occasions) and if needed, offset from DRX On duration.

Proposal 4 RAN1 should develop power saving signal/channel such that a group of UEs can be addressed using one PDCCH.

Proposal 5 When the power saving signal/channel is used as WUS, UE monitors WUS in WUS monitoring occasions configured by the NW and upon WUS detection, UE should wake-up during On Duration(s) associated with the WUS monitoring occasion.

Proposal 6 Mechanisms to avoid and quickly recover from WUS misdetection should be specified e.g. adapting WUS monitoring based on fluctuating channel conditions, fallback search spaces/PDCCH On durations that are always monitored independent of WUS detection, etc.

References

- [1] RP-181463, "New SID: Study on UE Power Saving in NR", CATT, CMCC, vivo, CATR, Qualcomm, MediaTek, 3GPP TSG RAN Meeting #80
- [2] RP-181763, "Views on the Progress of UE Power Saving for NR", CATT, 3GPP TSG RAN Meeting #81