3GPP TSG RAN WG1#106-e R1-21XXXXX

E-meeting, August 16th- 27th, 2021

Source: Moderator (vivo)

Title: FL summary#1 of DCI-based power saving adaptation

Agenda Item: 8.7.2

Document for: Discussion and Decision

# Introduction

This contribution is a summary of the AI 8.7.2 after 2nd round discussion.

* Section 2 is a list of the issues to be discussed/decided.
* Section 3 is void.
* Section 4 is a summary of previous meeting agreements.
* Section 5 is a summary of proposals from companies’ contributions submitted.
* Section 6 is void.
* Section 7 is the decription of WI.
* Section 8 is the reference documents.
* Section 9 is the history of the FL summary.
* Section 10 is annex

# Issue list

## Issue 1: scheduling DCI based SSSG switching and/or PDCCH skipping

In RAN1#105-E, it is agreed that

Agreement:

* PDCCH schedules data and also indicates PDCCH monitoring adaptation by SSSG switching and PDCCH skipping for a duration is supported.
	+ At least DCI format(s) 1-1, 0-1, 1-2 and 0-2 can be used for the indication(s)

Agreement:

* ~~At least~~ one of  Alt 1 and Alt 2 is supported, to be decided in RAN1#106,
* Alt 1: Supporting SSSG  switching to emulate PDCCH skipping functionality,
	+ Alt 1-1: by an ‘empty’ SSSG which no SS set(s) is configured for the ‘empty’ SSSG, UE does not monitoring PDCCH on the ‘empty’  SSSG,
	+ Alt1-2: by a ‘dormant SSSG’ which may have associated SS sets, and monitored conditionally (e.g., depending on HARQ NACK or RTT/ReTx timers)
* Alt 2: PDCCH schedules data and also indicates PDCCH monitoring adaptation by PDCCH skipping for a duration is supported.
	+ FFS details, including
		- e.g., joint / separate indication of SSSG switching and PDCCH skipping
		- Determination of the duration(s) for PDCCH skipping, e.g.,
			* by RRC signaling,
			* by DCI indication
			* Implicitly, to the end of C-DRX active time

Agreement:

At least SSSG#0 and SSSG#1 switching is supported for Rel-17 SSSG switching indicated by PDCCH scheduling data and/or timer.

* FFS: support of more than 2 SSSGs

### Initial proposals

1. **Multiple levels of PDCCH monitoring adaptation**

Many companies proposed to introduce 3 or even more SSSGs, for which at least 3 ‘PDCCH monitoring behaviours is supported. [Samsung, NEC, Nordic, Qualcomm, CMCC, ETRI, DOCOMO, ASUSTeK,Nokia, Interdigital]

Many companies proposed to adopt skipping indication by DCI within a SSSG. Hence at least 2 ‘PDCCH monitoring behaviours exists within a SSSG. While considering at least 2 SSSGs are supported, it is expected that 3 or more ‘PDCCH monitoring behaviours will be supported.

Hence, it is suggested that at least 3 PDCCH monitoring behaviours (including PDCCH skipping like behaviour) can be adapted.

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| **[High] Proposal 1a:** * DCI-based PDCCH monitoring adaptation over at least 3 different monitoring behaviors (including PDCCH skipping, PDCCH monitoring by SSSG#0, PDCCH monitoring by SSSG#1) within an active BWP is supported in Rel-17.
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In order to supporting at least 3 ‘PDCCH monitoring pattern’, at least 2-bit is needed for a scheduling DCI for indication. How the 2-bit is indicating depends on the selection of Alt 1-1/1-2/2.

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| **[High] Proposal 1b:** * At least 2-bit field in scheduling DCIs (i.e., DCI format 1-1/0-1/1-2/0-2) can be configured for triggering the PDCCH monitpring adaptation
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1. **Number of SSSG groups**

In the last meeting,it is agreed that at least SSSG#0 and SSSG#1 switching is supported for Rel-17 SSSG switching indicated by PDCCH scheduling data and/or timer. More than 2 SSSG is for FFS.

* Up to 2 groups: Huawei/Hisilicon, ZTE/Sanchips, CATT, MediaTek, Ericsson
* More than 2 groups: Samsung, NEC, Nordic, Qualcomm, CMCC, ETRI, DOCOMO, ASUSTek, Nokia, Interdigital

Two groups of SS sets are supported by current specification. Companies have different understanding for introducing more than 2 SSSGs. Some pros and cons claimed are as follows,

* + (Pros)UE can achieve higher power saving gain if finer adaptation granularity and wider adaptation aspects can be supported. (x6901)
	+ (Cons) there will also introduce more complicate state transition design and error handling (x6481)(x7521)
	+ (Cons) Rel-16 only supports 2 SSSGs, and if Rel-17 supports 3 SSSGs, it is not possible to reuse the framework as much as possible, such as *searchSpaceGroupIdList-r16* need to be re-designed for Rel-17 SSSG switching. (x6481)

Considering slightly majority companies supporting more than 2 SSSGs, can we try to agree on the followings first? If not, it is recommended to conclude no more than 2 SSSGs should be supported.

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| **[High] proposal 1c:** * Up to 3 SSSGs is supported for Rel-17 SSSG switching in the active BWP.
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1. **Alt 1 vs Alt 2**

**Alt 1 (12 companies)**

* Alt 1-1: Samsung(\*), NEC(\*), Nordic(\*), Qualcomm(\*), CMCC(\*), ETRI(\*), Fraunhofer, DOCOMO(\*), ITRI, ASUSTeK(\*), Nokia(\*), Interdigital(\*)
* Alt 1-2: Nordic, Qualcomm, CMCC, Fraunhofer

Note:

* (\*): support more than 2 SSSGs can be configured.

**Alt 2 (12 companies)**

* Huawei/Hisilicon(\*), ZTE/Sanchips(\*), Spreadtrum, CATT(\*), Lenovo/Motorola Mobility(\*\*), OPPO(\*), LGE(\*), MediaTek(\*\*\*), Intel(\*), Panasonic(\*\*), Apple, Ericsson(\*\*\*)

Note:

* (\*): support to configure multiple candidate values of skipping duration by RRC signaling and use DCI to dynamically indicate one of the configured skipping durations
* (\*\*): support to configure by RRC a list of PDCCH monitoring adaptation behaviours, including which search space to be monitored with/without timer. DCI indicates which index in the list the UE should follow.
* (\*\*\*): skipping duration is configured by RRC

There isn’t clear majority for either Alt 1 or Alt2. And they are almost identical in terms of the functionality. Some pros and cons for Alt 1 and Alt 2 are as follows,

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| Alt 1 is better than Alt 2* PDCCH signalling commands for SSSG switching outperforms PDCCH skipping (x8124)
* In terms of codepoint mapping, Alt 1 is homogeneous, and Alt 2 is heterogeneous. Heterogeneous codepoint mapping is not found in Rel-15 and Rel-16 standards. (x7358)
 |
| Alt 2 is better than Alt 1* By Alt 2, the current configurations of SS set can be reused (x6481)
* The difference is that the existing timer to switch to SS group #1 -> #0 must be set 1 slot shorter than timer for PDCCH skipping. This due to applicable switching time currently specified (x7046)
* Explicit indication of PDCCH skipping for a duration can work for different SSSG configurations, e.g. larger skipping step with sparse SSSG configuration, or smaller skipping step with dense SSSG configuration.(x7601)
* With 2 SSSG, there is limited flexibility to dynamically switching between SSSG switching and skipping for Alt 1 (x7752).
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Proposal for Alt 1

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| **[High] proposal 1d-1:** * If alt 1 is supported,
	+ supporting SSSG  switching to emulate PDCCH skipping functionality by an ‘empty’ SSSG which no SS set(s) is configured for the ‘empty’ SSSG, UE does not monitoring PDCCH on the ‘empty’  SSSG
		- Y-bit is configured for scheduling DCIs (i.e., DCI format 1-1/0-1/1-2/0-2) indicating SSSG index.
		- FFS timers for switching between SSSGs
		- FFS: a ‘dormant SSSG’ which may have associated SS sets, and monitored conditionally (e.g., depending on HARQ NACK or RTT/ReTx timers)
 |

Proposal for Alt 2

If alt 2 is supported, the skipping duration can be indicated by DCI, RRC with one or multiple values. The proposals are as follows,

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| **[High] proposal 1d-2:** * If alt 2 is supported,
	+ PDCCH schedules data and also indicates PDCCH monitoring adaptation by PDCCH skipping for a duration is supported.
		- Y-bit to is configured for scheduling DCIs (i.e., DCI format 1-1/0-1/1-2/0-2),
			* Alt 1: 1 bit for PDCCH skipping adaptation (supported by MTK, Ericsson)
				+ Value ‘0’ to indicate PDCCH skipping is not activated
				+ Value ‘1’ to indicate PDCCH skipping for a duration

Determination of the duration(s) for PDCCH skipping, e.g., by RRC signaling, by specification* + - * + FFS: SSSG switching
			* Alt 2:more than 1-bit for PDCCH skipping adaptation
				+ Alt 2a: (supported by Huawei, ZTE,CATT,OPPO,LGE, Intel)

Value ‘0’ to indicate PDCCH skipping is not activatedMultiple candidate values of skipping duration configured by RRC signaling and use DCI to dynamically indicate one of the configured skipping duration* + - * + Alt 2b: (supported by Lenovo/MotM, Panasonic)

Y equals to the number of configured SSS or SSSGeach bit of the bitmap corresponds to a configured SSS or SSSG* + - * + FFS: SSSG switching
 |

Considering relatively infrequent occurrence, CONNECTED mode UEs should monitor Type0/0A/1/2-PDCCH CSS. Vivo and Nokia proposed the followings,

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| **[Medium]Proposal 1e:**Type0/0A/1/2-PDCCH CSS monitoring is not impacted by PDCCH monitoring adaptation |

### Companies views (1st round)

Companies are encouraged to provide comments in the table below.

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| **Company** | **Comment** |
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## Issue 2: non-scheduling DCI based SSSG switching and/or PDCCH skipping

### Initial proposals

Support of proposal 2a: Huawei/HiSilicon, Spreadtrum, Qualcomm, CMCC, ETRI, Intel, Apple, Nokia

Objec of proposal 2a: [TBC]

* It is important to know how to use the DCI field(s) to indicate. Companies’ proposals are appreciated. Details can be discussed and solved after Alt 1-1/1-2/Alt 2 in proposal 1d being down-selected.

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|  **[Medium] proposal 2a:** * PDCCH does not schedules data and indicates SSSG switching or PDCCH skipping for an active BWP in active time is supported by
	+ DCI Format 1\_1 (SCell dormancy case 2 like)
 |

For DCI format 2\_6, inside active time and outside active time are differentialed.

Support of proposal 2b:

* Outside active time: Lenovo/MotM, Qualcomm, LGE, Apple
* Inside active time: Huawei/HiSilicon, LGE, ETRI, Intel

Object of proposal 2b: [TBC]

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| **[Medium] proposal 2b:** * DCI format 2\_6 outside active time is supported to indicate SSSG switching or PDCCH skipping for an active BWP in active time when DRX is configured. (Supported by Lenovo/MotM, Qualcomm, LGE, Apple)
* DCI format 2\_6 being received in active time is supported to indicate SSSG switching or PDCCH skipping for an active BWP in active time when DRX is configured. (Supported by Huawei/HiSilicon, LGE, ETRI, Intel)
 |

### Companies views (1st round)

Companies are encouraged to provide comments in the table below.

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| **Company** | **Comment** |
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## Issue 3: implicit PDCCH monitoring adaptation

### Initial proposals

**Timer**

Most companies think for PDCCH monitoring adaptation for an active BWP in active time, timer-based SSSG switching is supported. It is beneficial so that during the inactivity the UE can based on timer expiry move to less frequent PDCCH monitoring without network to sending another PDCCH command when UE is not scheduled.

A list of related questions for timer is as follows,

* Q1: whether the timer is configured per SSSG, per BWP, or other approaches.
* Q2: whether multiple timer duration(s) can be configured by RRC, and DCI dynamically indicates a timer duration
* Q3: do we need to define default SSSGs and for what purpose?

Companies are encouraged to provides view on Q1, Q2 and Q3.

**SR/RACH**

At least for SSSG switching based PDCCH monitoring adaptation, switching to default SSSG based on UL scheduling request or RACH can reduce UL traffic latency when switching from power saving state to normal state.

Support of proposal 3a/3b Huawei/HiSilicon, Qualcomm, LGE, Nokia, CMCC, Ericsson (3a only)

Object of proposal 3a/3b: TBC

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| **[Medium] Proposal 3a:**For implicit indication of PDCCH monitoring adaptation , SSSG switching triggered by SR is supported.**[Medium] Proposal 3b:**For implicit indication of PDCCH monitoring adaptation , SSSG switching triggered by RACH is supported. |

Some companies think it is open for discussion and can be handled later for example after decision of framework.

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| [Medium] Proposal 3cFor UE configured with DRX, higher layer signaling can configure SSSG that a UE monitors when coming out of DRX to monitor an ON duration. |

### Companies views (1st round)

Companies are encouraged to provide comments in the table below.

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| **Company** | **Comment** |
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## Issue 4: interaction with HARQ/retransmission

In RAN1#104-E, it is agreed that,

Agreements:

* Further study whether and how to minimize the impact to data scheduling for new transmissions and retransmissions.
	+ FFS details
* Further study the application delay for PDCCH adaptation indication

Some companies pointed out that the SSSG switching/skipping should consider PDCCH monitoring behavior by considering interaction with data decoding and/or HARQ retransmission, in order to reduce service latency for retransmission. This can be useful for the following cases,

* PDCCH monitoring adaptation Alt 2: special handling of HARQ-retransmission when PDCCH skipping, e.g., UE suspends or stops PDCCH skipping . [OPPO][MediaTek][Ericsson][Apple][ZTE],
* PDCCH monitoring adaptation Alt 1-2: ‘dormant’ SSSG which may have associated SS sets, and monitored conditionally depending on HARQ NACK or RTT/ReTx timers. [Nordic, Qualcomm, CMCC, Fraunhofer]
* PDCCH monitoring adaptation Alt 1-1: switch from ‘empty’ SSSG to normal normal SSSG when retransmission occurs [vivo,Nokia]

Some specific examples are as follows,

MediaTek thinks UE should resume a short term PDCCH monitoring during the indicated PS duration, depending on the HARQ processing outcome. If HARQ processing outcome is valid (situation 1, about 90% of DL data scheduling), the UE does not have to wake up for the retransmission. If not (situation 2, about 10% of DL and UL data scheduling), the UE monitors the possible retransmission scheduling in a configured duration. As illustrated in Figure 5.



Figure 5. Illustration of UE power saving adaptation for retransmission handling

For PDCCH skipping, OPPO proposed a retransmission period can be introduced for the retransmission to allow a retransmission window. ***In the delay window for retransmission, PDCCH monitoring can be only after PDCCH-PDSCH-HARQ-ACK timing and in few consecutive monitoring occasions.***

Apple thinks that when PDCCH monitoring adaptation is triggered by DCI format 1-1 and 1-2, the switching or skipping command can be applied after ACK transmission. Also, when NACK is received by the gNB, the previous triggering commanded is cancelled, and the gNB needs to send another triggering commend with retransmissions scheduling DCI.

ZTE thinks that to serve the purpose of reducing UE power consumption, the UE does not need to monitor PDCCH scheduling an initial-transmission data during the PDCCH skipping period. When DRX is configured, the duration for monitoring PDCCH scheduling retransmission data (no initial transmission) can be determined by the *drx-RetransmissionTimerDL* and *drx-RetransmissionTimerDL*.

Vivo proposed the following alternatives,

The following additional mechanisms is supported for PDCCH switching/skipping when interaction with HARQ,

* UE switches to SSSG0 (from SSSG1),
	+ Alt 1-1: UE Tx NACK,
	+ Alt 1-2: *k* slot after UE Tx NACK
	+ Alt 2: after drx-RetransmissionTimer starts

And after UE successfully complete retransmission,

* UE Switching SSSG1,
	+ Alt 1: UE Tx an ACK which corresponds to the PDCCH indicates SSSSG switching from 0 to 1
	+ Alt 2: after drx-RetransmissionTimer expired

### Initial proposals

The following moderator recommendations are made.

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| **[High] proposal 4a:*** + After being indicated to skipping PDCCH monitoring and/or switched to ‘dormant’/’empty’ SSSG, the UE still performs PDCCH monitoring for HARQ retransmission at least during a ‘retransmission period’.
		- FFS How to perform PDCCH monitoring during the retransmission period, e.g.,
			* UE switch to another SSSG, e.g., default SSSG or a SSSG specially configured only for retransmission period .
			* UE suspends or stops PDCCH skipping.
			* UE performs discontinuously PDCCH monitoring according to the roundtrip and retransmission timers to receive any HARQ retransmissions
			* Others not precluded
		- FFS ‘retransmission period’
			* Alt 1: When triggered by DL DCI, the start and end of ‘retransmission period’ is defined as HARQ-ACK condition is satisfied
				+ FFS HARQ-ACK condition, e.g., the start of ‘retransmission period’ is when the UE transmit NACK
			* Alt 2: the start and end of ‘retransmission period’ is defined as the *start of drx-RetransmissionTimerDL(UL)* and expiration of *drx-RetransmissionTimerDL(UL)* respectively if DRX is configured.
			* others not precluded
 |

### Companies views (1st round)

Companies are encouraged to provide comments in the table below.

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| **Company** | **Comment** |
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## Issue 5: application delay

### Initial proposals

Before the UE starts to skip PDCCH/ switch SSSG, UE needs time to decode DCI carried the signaling. There were several minimum application delay studied in Rel-16,

* For Rel-16 cross-slot scheduling, the time needed for PDCCH processing was studied when specify the application delay for K0min/K2min indication
* For Rel-16 NRU, a UE can be provided by *searchSpaceSwitchingDelay-r16* a number of symbols $P\_{switch}$ where a minimum value of $P\_{switch}$ is provided in Table 10.4-1 in TS38.213 for UE processing capability 1 and UE processing capability 2 and SCS configuration $μ$. ZTE pointed out that the minimum value of application delay for PDCCH adaptation for μ=3 can be 25 symbols.

Also, several companies express their view that skipping command applies after PUSCH transmission if triggered by UL DCI or skipping commend applies after ACK/NACK transmission.

It is recommended that the application time can be futther finalized after decision of issue 1 and also together discussed with issue 4.

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| **[High] proposal 5a:*** Further consider the following application delay for PDCCH adaptation,
	+ Option a: the application timelines provided in Table 10.4-1 in TS38.213 for search-space group switching for unlicensed band form is reused.
		- FFS: $P\_{switch}=[X] symbols$ for SCS configuration $μ=3$, FFS X = 25 or 39
		- FFS: $μ=5,6$
	+ Option b: the application delay needed for PDCCH processing for Rel-16 minimum application delay for K0min/K2min indication is reused/extended.
	+ Option c: PDCCH skipping command applies after PUSCH transmission if triggered by UL DCI
	+ Option d: PDCCH skipping command applies after ACK/NACK transmission.
	+ Option e: after successfully decoding TB.
	+ Option f: Application delay should be “ZERO” for PDCCH monitoring adaptation. PDCCH monitoring adaptation would be applied after UE receive the additional PDCCH monitoring adaptation control signaling bit(s) in DCI
	+ Others not precluded.
* FFS reference points for the application time
* FFS whether the same or different and howapplication delay(s) should be used for SSSG switching and PDCCH skipping functions
* FFS whether the same or different and how application delay for PDCCH monitoring adaptation indicated by DCI and timer expiration
 |

Another issue is that the UE behavior during the application time should be clear between gNB and UE. Hence, it is proposed that the UE should not receive different PDCCH monitoring adaptation indications during the application time, as proposed by some companies[21]. Surely it can be further discussed after a clear definition of the application time.

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| **[Medium] proposal 4-2:**UE should not receive different PDCCH monitoring adaptation indications during the application time |

### Companies views (1st round)

Companies are encouraged to provide comments in the table below.

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| **Company** | **Comment** |
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## Issue 6: Others

### Companies views (1st round)

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| **Company** | **Comment** |
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# Void

#  Summary of the previous agreements

*RAN1#102-e*

Agreements:

* Reusing power model in TR38.840 for evaluation of DCI-based power saving adaptation schemes.
	+ Note: company reporting additional power model for missing state or update is not precluded.

Agreements:

* Company should report assumptions used for periodic measurement activities for the Rel-17 DCI-based power saving adaptation evaluation.
	+ The periodic activities defined in TR38.840 can be reused.
	+ Measurement for RLM/BFD every C-DRX cycle can be optionally modelled

Agreements:

* The performance metrics described in TR38.840 section 8.2 is reused for power saving evaluation of Rel-17 DCI-based power saving adaptation during ActiveTime.
* The following Rel-15 / 16 features is recommended of the power consumption as reference for baseline. Company can report the feature(s) being used in the baseline.
	+ DRX
		- C-DRX cycle 40msec for VoIP
			* 10ms IAT, 8ms On-duration
			* Assume max two packets bundled
		- C-DRX cycle 160msec for FTP
			* Alt 1: 20 msec IAT, 8ms On-duration
			* Alt 2: short DRX
				+ 20 ms [or 40ms as optional] IAT, 8ms On-duration
				+ 20 ms for short DRX cycle, 4 cycles
			* Note: 100 msec IAT, 8ms On-duration can also be used with sufficient justifications that available Rel-15/16 Techniques being used to reduce UE power saving
	+ DCP for DRX adaptation,
		- DCP offset  to DRX ON = 2 ms, other values are not precluded
	+ Cross-slot scheduling adaptation
		- Minimum K0 can be adapted from 0 to 1 for FR1, 0 to [4] for FR2
	+ BWP switching, including
		- MIMO layer adaptation,
			* Max # of MIMO layer can be adapted from 4 layer to 2 layer for FR1, 2 layer to 1 layer for FR2
		- PDCCH monitoring period adaptation
			* PDCCH monitoring period can be adapted from per slot monitoring to X slot monitoring
				+ X = [2] for FR1 and [8] for FR2
		- Bandwidth adaptation
			* Bandwidth can be adapted from 100MHz to 20MHz for FR1,FFS for FR2
		- Note:
			* BWP transition time type 2 is assumed, BWP transition duration is
				+ 5 slot @ 30kHz SCS for FR1,
				+ 18 slot@120kHz SCS for FR2
				+ the slot-average power level for BWP transition duration is according to TR38.840
				+ BWP transition time type 1 can be optional modelled
			* BWP switching is Y (ms) after last packet/data burst.
				+ Y = [8], other values are not precluded
			* Whether BWP switching is modeled depends on the assumed UE capability and evaluated schemes.
	+ Scell dormancy assumption for CA capable UEs
		- FR1 & FR2: SCell dormancy with [160 ms] periodic CSI measurement and reporting
* Other settings
	+ CA assumption if configured for CA capable UEs
		- For FR1, FFS
		- For FR2, 4\*100MHz can be considered.
	+ Assumptions for scheduler
		- For FR1, no restriction on the beam assumptions being used in each slot
		- For FR2, up to each company, e.g., gNB equally schedule the slots for UEs targeting to different beams.
		- Note: the assumptions does not necessary mean to restrict or precluded any implementation. Other assumptions are not precluded and can be reported by companies.
	+ Company to report the used assumption for the interruption and also power savings impact due to presence/absence of interruptions .

Agreements:

Legacy traffic models in TR38.840 can be considered for Rel-17 DCI-based power saving adaptation evaluation, other traffic models can be optionally modelled and company report which traffic model(s) is used.

Draft LS is approved (with generic RAN2 action), with final LS in [R1-2007419](file:///C%3A/Users/wanshic/OneDrive%20-%20Qualcomm/Documents/Standards/3GPP%20Standards/Meeting%20Documents/TSGR1_102/Docs/R1-2007419.zip).

*RAN1#103-e*

Agreements:

Observation:

* Each of the following schemes is individually shown to be beneficial for UE power saving compared to the baseline.
	+ Dynamically switching search space set
	+ Dynamically skipping PDCCH monitoring for a certain duration or until next DRX ON
* At least the following Rel-15 and/or Rel-16 power saving solutions have been utilized for baseline,
	+ For eMBB traffic,
		- DRX setting(including using short DRX or long DRX with a short IAT or long IAT), Wake-up signal, Cross-slot scheduling, CA/Scell dormancy, MAC-CE skipping, BWP switching
	+ For VoIP traffic,
		- DRX setting(only long DRX cycle with a short IAT), Wake-up signal,  Cross-slot scheduling, MAC-CE skipping
	+ For IM traffic,
		- DRX setting(long DRX cycle [with a short IAT]), Wake-up signal
	+ For intensive eMBB traffic,
		- DRX setting(including using short DRX or long DRX with a short IAT), Wake-up signal, Cross-slot scheduling, [CA/Scell dormancy], MAC-CE skipping, BWP switching
		- Note: intensive eMBB traffic is optional and companies may use FTP model 3 with different packet size and mean data arrival time, e.g., 15ms, 30ms, 50ms or 100ms.
* Note 1: For Search space switching, switching from 1slot monitoring to 2, 4, 8, 10, 16 or 32 slot with 30kHz SCS (FR1) and 120kHz (FR2) is utilized.
* Note 2: For PDCCH skipping , skipping 2ms, 4ms, 5ms, 8ms, 15ms, 16ms, 32ms,  64ms or to next DRX cycle is utilized
* Note 3: the baseline assumed may vary across companies

Agreements:

* **Specify at least one of the following options for Rel-17 dynamic PDCCH adaptation ~~in time-domain~~ for active time,**
	+ **Option 1: Search space set group switching,e.g., ~~potential adjustments/enhancements for~~including explicit and implicit search spaceset group switching ~~specified in R16 for NR-U~~**
	+ **Option 2: PDCCH skipping for a certain duration / DRX cycle**
* **FFS: which option(s)~~(e.g. taking into account additional gain of option 1 over option 2, or vice-versa)~~**
* **Candidate DCI formats for dynamic PDCCH adaptation include DCI formats 1\_1(including scheduling and non-scheduling DCI), 0\_1, 1\_2, 0\_2, 2\_0, 2\_6.**
* **Note:**
	+ **Companies are encouraged to provide analysis on specification impact, power saving benefit and system impact (e.g., packet latency, system overhead)**
* **FFS: other schemes are not precluded for further study**

*RAN1#104-e*

Agreements:

* Strive for a common design for DCI based PDCCH monitoring adaptation in active time for an active BWP to support functionalities inclusive of both SSSG switching and PDCCH skipping for a duration.
	+ Details FFS

Agreements:

* Further study whether and how to minimize the impact to data scheduling for new transmissions and retransmissions.
	+ FFS details
* Further study the application delay for PDCCH adaptation indication

Agreements:

For DCI based PDCCH skipping in active time for an active BWP (if supported), the following can be further considered,

* Explicit indication of PDCCH adaptation
	+ Scheduling DCI
		- Format 1\_1
		- Format 0\_1
		- Format 0\_2/1\_2
	+ Non-scheduling DCI
		- Format 2\_6 in active time
		- Format 2\_0
		- Format 1\_1 (SCell dormancy case 2)
	+ additional indication mechanism
		- By reusing Rel-16 SCell dormancy indication when CA is configured, FFS details
		- By reusing Rel-16 cross-slot scheduling indication when R16 cross-slot scheduling is configured, FFS detailds
* DCI dynamically indicates a duration/periodic interval for skipping
	+ FFS: how to indicate the duration/period interval, e.g., number of slots or skipping current DRX
* PDCCH skipping for a duration indicated by minimum scheduling offset
* Others are not precluded

Agreements

* For DCI based SSSG switching in active time for an active BWP (if supported), the following can be further considered,
	+ Explicit indication of PDCCH adaptation
		- Scheduling DCI based
			* Format 1\_1,
			* Format 0\_1,
			* Format 0\_2/1\_2
			* ~~Format 1\_0~~
		- Non-scheduling DCI ~~supported by vivo, Samsung~~
			* Format 2\_6 in active time
			* Format 2\_0
			* ~~Format 1\_0~~
			* Format 1\_1 (SCell dormancy case 2)
		- additional indication mechanism
			* By reusing Rel-16 SCell dormancy indication when CA is configured, FFS details
			* By associating Rel-16 cross-slot scheduling indication when R16 cross-slot scheduling is configured, FFS detailds
		- DCI dynamically indicates a duration ~~period~~ for the switched SSSG, UE switch back to previous/default SSSG after duration ends~~timer expried~~
	+ Timer-based SSSG switching, including RRC configured a timer, UE switch back after timer expired.
	+ SSSG activation/deactivation
	+ FFS: Implicit SSSG switching
		- SSSG switching triggered by SR
		- SSSG switching triggered by RACH
		- Default SSSG that a UE monitors when coming out of DRX to monitor an ON duration.
* FFS: whether/how to support SSSG switching for multiple groups of cell(s).
* FFS: whether/how to support SSSG switching in active time with DCP outside active time
* FFS: whether / how to support more than 2 SSSGs,
	+ FFS: number of SSSGs
* FFS: a search space set group to emulate PDCCH skipping
* Others are not precluded

Agreements:

* The following alternatives can be considered for DCI based PDCCH monitoring adaptation in active time for an active BWP for power saving
	+ Alt 1: Enhancement of Rel-16 SSSG switching to support PDCCH monitoring adaptation including skipping for a duration
	+ Alt 2a: Enhancement of DCI(s) utilized for Rel-16 power saving adaptation for supporting both skipping PDCCH monitoring for a duration and SSSG switching
	+ ~~Alt 2b: Enhancement of DCI(s) utilized for Rel-16 power saving adaptation for supporting both skipping PDCCH monitoring for a duration and PDCCH monitoring periodicity adaptation~~
	+ Others not precluded

*RAN1#105-e*

Agreement:

* PDCCH schedules data and also indicates PDCCH monitoring adaptation by SSSG switching and PDCCH skipping for a duration is supported.
	+ At least DCI format(s) 1-1, 0-1, 1-2 and 0-2 can be used for the indication(s)

Agreement:

* ~~At least~~ one of  Alt 1 and Alt 2 is supported, to be decided in RAN1#106,
* Alt 1: Supporting SSSG  switching to emulate PDCCH skipping functionality,
	+ Alt 1-1: by an ‘empty’ SSSG which no SS set(s) is configured for the ‘empty’ SSSG, UE does not monitoring PDCCH on the ‘empty’  SSSG,
	+ Alt1-2: by a ‘dormant SSSG’ which may have associated SS sets, and monitored conditionally (e.g., depending on HARQ NACK or RTT/ReTx timers)
* Alt 2: PDCCH schedules data and also indicates PDCCH monitoring adaptation by PDCCH skipping for a duration is supported.
	+ FFS details, including
		- e.g., joint / separate indication of SSSG switching and PDCCH skipping
		- Determination of the duration(s) for PDCCH skipping, e.g.,
			* by RRC signaling,
			* by DCI indication
			* Implicitly, to the end of C-DRX active time

Agreement:

At least SSSG#0 and SSSG#1 switching is supported for Rel-17 SSSG switching indicated by PDCCH scheduling data and/or timer.

* FFS: support of more than 2 SSSGs

# Proposals from companies’ submitted contributions

## Huawei, HiSilicon

1. **R1-2106481 Extensions to Rel-16 DCI-based power saving adaptation for an active BWP Huawei,** **HiSilicon**

***Observation 1: The existing specification does not support to configure empty SSSG.***

***Observation 2:*** ***It is complicated for UE implementation and for specification to introduce dormant SSSG.***

***Observation 3: If the number of SSSG is more than 2 by Alt 1, the complicated state transitions should be discussed and specified.***

***Observation 4: Alt 2 provides the flexibility for gNB to indicate both SSSG switching and PDCCH skipping depending on configuration, meanwhile Alt 1 needs to rely on more than two SSSGs and complicated state transitions to achieve the same purpose.***

***Observation 5: Alt 2 provides good forward compatibility, e.g., combination of PDCCH skipping and Rel-18 network energy saving.***

***Observation 6：PDCCH monitoring adaptation indicated by group common DCI format is beneficial，e.g., DCI format 2\_6 inside DRX active time, if there is no data transmission.***

***Observation 7: Two groups of SS sets is enough to support both PDCCH skipping and SSSG switching.***

***Proposal 1: Specify directly indicating PDCCH skipping for a duration, i.e., do not use SSSG switching to emulate PDCCH skipping functionality.***

***Proposal 2: Reuse/extend dormancy indication field in scheduling DCI to indicate PDCCH monitoring adaptation.***

***Proposal 3: Extend MCS/NDI/RV/HARQ process number/antenna port/DMRS sequence initialization field used for SCell dormancy case 2 to indicate PDCCH monitoring adaptation.***

***Proposal 4: Support group common DCI, e.g. DCI format 2\_6 inside DRX active time, to indicate PDCCH skipping and SSSG switching.***

***Proposal 5: Support different application delay for SSSG switching and PDCCH skipping：***

* *If DCI indicates the UE switching to another SSSG, UE applies the DCI after HARQ-ACK feedback for DCI with DL grant or PUSCH transmitting for DCI with UL grant;*
* *If DCI indicates the UE to skip PDCCH monitoring, the application delay is max(applicable K0min, Z), after which the UE stops monitoring PDCCH in a duration.*

***Proposal 6: Explicitly configure the duration(s) of PDCCH skipping by RRC signaling.***

***Proposal 7: After being indicated to skipping PDCCH monitoring and/or switching to ‘empty’ SSSG, if the HARQ feedback for PDSCH is NACK, the UE still performs PDCCH monitoring for HARQ retransmission when drx-RetransmissionTimerDL is running.***

***Proposal 8: For different SSSG, the skipped duration(s) may be different to match the PDCCH monitoring periodicity.***

***Proposal 9: Support SSSG switching or stop PDCCH skipping triggered by SR and RACH.***

## ZTE, Sanechips

1. **R1-2106524 Extension to Rel-16 DCI-based power saving adaptation during DRX Active Time ZTE, Sanechips**

**Observation 1: The emulation of an implicit PDCCH skipping via SSSG switching by pure network implementation cannot give gNB a straightforward information of a proper power saving configuration.**

**Observation 2: For Alt 1, there will be low probability to deploy the implicit PDCCH skipping function if the UE power saving gain from the common design is degraded.**

**Observation 3: According to Rel-16 specification, the latency of data processing will be increased if DCI-based indication of SSSG switching is not supported with Alt 1.**

**Observation 4: For Alt 2, UE can perform PDCCH skipping right after the triggering DCI with data scheduling and the UE can fall in a deep sleep during the skipping duration.**

**Observation 5: For PDCCH adaptation, the processing time for responding DL SPS PDSCH release needs to be considered.**

**Observation 6: When cross-slot scheduling is applied for the UE, the delay for applying the PDCCH adaptation does not need to consider the minimum scheduling offset.**

**Proposal 1: Alt 2 should be supported for the common design of SSSG switching and PDCCH skipping for the following advantages:**

* **explicit PDCCH skipping function for UE and gNB;**
* **more flexibility;**
* **better power saving gain;**
* **less latency.**

**Proposal 2: Supporting two SSSGs for Rel-17 SSSG switching.**

**Proposal 3: It should support to configure multiple candidate values of skipping duration by RRC signaling and use DCI to dynamically indicate one of the configured skipping durations.**

**Proposal 4: For SSSG switching of Alt 2, timer-based triggering mechanism for SSSG switching can be reused to simplify the specification work.**

**Proposal 5: A skipping timer used for PDCCH adaptation from SSSG monitoring to PDCCH skipping should be considered in the cases of PDCCH adaptation without DCI indication.**

**Proposal 6: UE should switch to a default SSSG after the end of PDCCH skipping duration, wherein the default SSSG should be configured by RRC signaling to adapt to various traffic models.**

**Proposal 7: The UE should monitor PDCCH for retransmission data, but it does not monitor PDCCH for an initial transmission data during the PDCCH skipping period.**

**Proposal 8: The UE should monitor PDCCH according to all of search space sets configured in the DL active BWP or search space sets in a default SSSG when the following events occur during a skipping duration.**

* **SR indicated by the UE,**
* **beam failure detection, or**
* **random access procedure in RRC connected mode due to out-of sync, etc.**

**Proposal 9: The application delay for PDCCH adaptation for μ=0/1/2 can reuse that of SSSG switching in Rel-16. The minimum value of application delay for PDCCH adaptation for μ=3 can be 25 symbols.**

## vivo

1. R1-2106610 Discussion on DCI-based power saving adaptation in connected mode vivo

**Proposal 1: a new ‘empty’ SSSG group can be configured for scheduling DCI based SSSG switching.**

**Proposal 2**

* **If Alt 1 (i.e. Supporting SSSG switching to emulate PDCCH skipping functionality) is supported, maximum 3 SSSGs should be supported for Rel-17 SSSG switching in the active BWP.**
* **If Alt 2 (i.e. PDCCH schedules data and also indicates PDCCH monitoring adaptation by PDCCH skipping for a duration.) is supported, more than 2 SSSGs is NOT supported.**

**Proposal 3: Type0/0A/1/2-PDCCH CSS monitoring is not impacted by Rel-17 PDCCH monitoring adaptation**

**Proposal 4, Rel-17 supports the following mechnisms for SSSG swithing**

* **Scheme 1: for scheduling DCI triggered SSSG switching**
	+ **SSGS bit(s) in a UE specific DCI (such as DCI format x\_1/x\_2)**
		- **‘0’: starts monitoring PDCCH according to SSSG#0 and stop monitoring SSSG#1**
		- **‘1’: starts monitoring PDCCH according to SSSG#1 and stop monitoring SSSG#0**
		- **FFS: more bits for extending more than 2 SS set groups**
* **Scheme 2: A duration indicated by scheduling DCI**
	+ **UE switch from SSSG#1 to SSSG#0 after a last symbol of a remaining duration from timer1 indicated by scheduling DCI**
* **Scheme 3: RRC configured timer for switching**
	+ **Timer0 for switching from SSSG#0 to SSSG#1**
		- **UE switches from SSSG#0 to SSSG#1 at the beginning of the first slot that is at least** $P\_{switch}$ **symbols after a slot where the timer0 expires**
			* **timer1 is configured by RRC**
	+ **Timer 1 for switching from SSSG#1 to SSSG#0**
		- **UE switches from SSSG1 to SSSG0 at the beginning of the first slot that is at least** $P\_{switch}$ **symbols after a slot where the timer1 expires**
			* **timer1 is configured by RRC**
* **Scheme 4: Non-scheduling DCI triggered SSSG switching, e.g.**
	+ **Any non-scheduling DCIs with C-RNTI scrambled.**
	+ **Format 1\_1 (SCell dormancy case 2)**

**Proposal 5, the following additional mechanisms is supported for PDCCH switching/skipping when interaction with HARQ in case UE receives the PDCCH in SSSG 0 indicating SSSG switching from 0 to 1,**

* **UE switches to SSSG#1 after decoding the PDCCH,**
* **UE switches to SSSG#0 (from SSSG1), if**
	+ **Alt 1-1: UE Tx NACK,**
	+ **Alt 1-2: *k* slot after UE Tx NACK**
	+ **Alt 2: after *drx-RetransmissionTimer* starts**

**And after UE successfully complete retransmission,**

* **UE switches to SSSG#1 (from SSSG0),**
	+ **Alt 1: UE Tx an ACK which corresponds to the PDCCH indicating SSSG switching from 0 to 1**
	+ **Alt 2: after *drx-RetransmissionTimer* expires**

## Spreadtrum Communications

1. R1-2106710 Discussion on power saving techniques for connected-mode UEs Spreadtrum Communications

Rel-17 SSSG switching technique

***Proposal 1: The wakeup indication for Rel-17 SSSG switching technique should be down prioritized.***

***Proposal 2: The state machine for Rel-17 SSSG switching technique should be down prioritized, or simplified as much as possible.***

***Proposal 3: The application delay for Rel-17 SSSG switching technique can be defined.***

Rel-17 PDCCH skipping technique

***Proposal 4: The wakeup indication for Rel-17 PDCCH skipping technique is not supported.***

***Proposal 5: The state machine for Rel-17 PDCCH skipping technique is not supported.***

***Proposal 6: The application delay for Rel-17 PDCCH skipping technique is zero.***

Scheduling DCI

***Proposal 7: Select Alt 2 to support PDCCH skipping technique, i.e. PDCCH schedules data and also indicates PDCCH monitoring adaptation by PDCCH skipping is supported.***

***Proposal 8: Consider the following DCI fields for PDCCH that schedules data and also indicates PDCCH monitoring adaptation by SSSG switching and PDCCH skipping.***

* ***New DCI field***
* ***Reusing the Rel-16 indication of cross-slot scheduling***
* ***Reusing the Rel-16 Indication of SCell dormancy***

Non-scheduling DCI with C-RNTI scrambling

***Proposal 9: Support the non-scheduling DCI with C-RNTI scrambling that indicates PDCCH monitoring adaptation by SSSG switching and PDCCH skipping.***

## Samsung

1. R1-2106901 Discussion on DCI-based power saving techniques Samsung

**Observation 1: One PDCCH skipping state associated with a PDCCH skipping time duration is sufficient to achieve UE power saving from PDCCH skipping.**

**Proposal 1: Support more than 2 SSSG for PDCCH monitoring adaptation in a finer adaptation granularity and wider adaptation aspects.**

**Proposal 2: Support an “empty” SSSG associated with a RRC configured time duration for PDCCH skipping.**

**Proposal 3: Support application delay for PDCCH monitoring adaptation triggered by scheduling DCI format, based on one of the following alternatives:**

* **Alt1: configured by higher layer**
* **Alt2: after HARQ-ACK feedback**

**Propose 4: Support UE assistance information for PDCCH monitoring adaptation, including**

* **preferred search space set group,**
* **PDCCH skipping duration.**

**Proposal 5: Support PDCCH skipping for a duration indicated by minimum scheduling offset.**

## CATT

1. R1-2106986 PDCCH monitoring adaptation CATT

***Observation 1: SSSG switching has the additional application delay during search space switching, which can decrease the power saving gain.***

***Observation 2: For SSSG switching, the flexible PDCCH adaptation would need large Search Space Set overhead.***

***Observation 3: Although the SSSG switching is enhanced by using UE-specific indication, e.g. scheduling DCI, the catastrophe could be created when DCI is miss-detected and large search space set overhead.***

***Observation 4: The PDCCH skipping can obtain the higher power saving gain than the SSSG switching.***

***Proposal 1: The SSSG switching cannot create the exact function of the PDCCH skipping to achieve UE power saving for its non-negligible drawbacks, especially for the additional switching delay, miss detection of HARQ-ACK and large search space set overhead.***

***Proposal 2: The Alt 2: PDCCH schedules data and also indicates PDCCH monitoring adaptation by PDCCH skipping for a duration should be supported.***

***Proposal 3: The PDCCH monitoring adaptation can dynamically indicate UE to reduce the PDCCH monitoring without any changes of SearchSpace configuration.***

## NEC

1. R1-2107017 Discussion on DCI-based power saving adaptation NEC

**Proposal 1: Support more than 2 SSSGs for PDCCH monitoring adaptation by SSSG switching.**

**Proposal 2: Maximum number of simultaneously monitored search space set groups may be configurable.**

**Proposal 3: Introduce a bitmap in DCI for dynamic indication of SSSG switching.**

## Nordic Semiconductor ASA

1. R1-2107046 On PDCCH monitoring adaptation Nordic Semiconductor ASA

***Observation-1:*** *PDCCH skipping can be achieved according to R16 specification by configuration of an empty SSG#1*

***Proposal-1:*** *To enable user-specific PDCCH skipping for a duration, add SS group switching field to DCI format 1\_1 and 1\_2. Support Alt 1.*

* *Adopt the correspond TP in Appendix*

***Observation-2:*** *SS group switching with additional re-transmission behavior may achieve the same as PDCCH skipping with less DL control overhead.*

***Proposal-2:*** *Support a dormancy SSS group, a SS group configured with sparse MOs, where monitoring of all or subset of group’s search-space sets is conditional on a pending re-transmission.*

***Observation-3:*** *Support of 3rd SS group does not result in large specification changes.*

***Proposal-3:*** *Consider support of 3rd SS group*

***Proposal-4:*** *If more than one timer values is configured, DCI format 1\_1,1\_2 or 2\_0 contains additional field indicating which timer value applies.*

* *Initialize timer to value X*
* *Initialize timer to value Y*
* *…..*

***Proposal-5:*** *Reuse the existing timelines for search-space group switching form sub-clause 10.4 of TS 38.213. For switching to and from empty SSG, timelines are up to UE implementation.*

## Lenovo, Motorola Mobility

1. R1-2107184 Enhanced DCI based power saving adaptation Lenovo, Motorola Mobility

**Observation 1: Rel-16 search space set group configuration may result in an unnecessary high signalling overhead.**

**Proposal 1: In Rel-17, support configuring more than one value for a subset of search space configuration parameters in a given search space configuration.**

**Proposal 2: Rel-17 NR supports search space set adaptation when starting an ON duration timer in every DRX cycle based on DCI format 2\_6. Further, Rel-17 NR supports small-scale search space set adaptation within a DRX cycle based on scheduling DCI.**

**Proposal 3: Support scheduling-DCI based PDCCH skipping indication. Reuse the Rel-16 application delay for K0,min/K2,min indication as an application delay for PDCCH skipping.**

**Proposal 4: If there is no active UE-specific search space set excluding a UE-specific search space set indicated by an PDCCH skipping indication, UE applies PDCCH skipping for the indicated UE-specific search space set as follows:**

* **not earlier than the application delay after the end of PDCCH including the indication, and**
* **for DL DCI format(s) of the UE-specific search space set, upon expiration of *drx-RetransmissionTimerDL* if *drx-HARQ-RTT-TimerDL* or *drx-RetransmissionTimerDL* is running, and**
* **for UL DCI format(s) of the UE-specific search space set, upon expiration of *drx-RetransmissionTimerUL* if *drx-HARQ-RTT-TimerUL* or *drx-RetransmissionTimerUL* is running.**

## OPPO

1. R1-2107255 DCI-based power saving adaptation solutions OPPO

***Proposal 1: No further DCI format other than 1\_1, 0\_1, 1\_2 and 0\_2 is used for triggering PDCCH monitoring adaptation.***

***Proposal 2: Directly indicating skipping of PDCCH monitoring occasions is supported as PDCCH monitoring adaptation:***

***PDCCH skipping is based on number of slots.***

***2bits indication in DCI format is introduced to support for non-skipping, 4-slot skipping, 8-slot skipping, 16-slot skipping.***

***Proposal 3: Introduce a delay window in the PDCCH skipping indication, which is based on PDCCH-PDSCH-HARQ-ACK timing and re-scheduling timing.***

***Proposal 4: In the delay window for retransmission, PDCCH monitoring can be only after PDCCH-PDSCH-HARQ-ACK timing and in few consecutive monitoring occasions.***

***Proposal 5: Indicate PDCCH search space group sets by the PDCCH skipping indication bits.***

***Proposal 6: When multiple PDCCH search space groups are switchable, autonomous PDCCH monitoring adaptation is triggered by timer.***

***Proposal 7: The search space group switching indication states in the DCI can also trigger cross-slot scheduling states.***

***The application delay can be also applicable to the search space group switching.***

## Qualcomm Incorporated

1. R1-2107358 DCI-based power saving adaptation during DRX ActiveTime Qualcomm Incorporated

Proposal 1: For the common design of PDCCH monitoring adaptation in Rel-17, Alt 1 (RAN1 #105-e agreement) is adopted.

Proposal 2: To emulate PDCCH skipping with search space group switching (Alt 1), a dormant search space set group is introduced (Alt 1-2):

* To enable HARQ retransmissions during the dormant search space set group, only discontinuous PDCCH monitoring according to RTT and Retransmission timers is allowed, if configured.
* The UE switches back to a non-dormant search space set group when a dormancy timer associated with the dormant SSSG expires.

Proposal 3: For the common design of PDCCH monitoring adaptation based on SSSG switching (Alt 1), the maximum number of configured SSSGs larger than two is considered.

Proposal 4: For explicit indication of PDCCH monitoring adaptation, in addition to scheduling DCI formats 0\_1/1\_1/0\_2/1\_2, non-scheduling DCI formats are also considered:

* DCI format 1\_1 (similar to Case 2 SCell dormancy indication) and DCI format 2\_6 (outside active time).

Proposal 5: For implicit indication of PDCCH monitoring adaptation, the following candidates are considered:

* **Configured timer: per-non-default SSSG (including dormant and non-dormant SSSGs), if more than two SSSGs are supported,**
* **Transmission of SR and PRACH: transition from a dormant SSSG to a non-dormant SSSG after transmitting a scheduling request or a PRACH preamble.**

Proposal 6: For the application delay of PDCCH monitoring adaptation, combination the application delays of Rel-16 minimum scheduling offset restriction and Rel-16 SSSG switching is considered:

* **Different application delays are used for indication types (explicit or implicit) and SSSG types (dormant and non-dormant).**
* **Different application delays are used depending on whether the PDCCH monitoring adaptation is jointly configured with Rel-16 minimum scheduling offset restriction or not.**

Proposal 7: In the CA scenario, for the joint adaptation across CCs, carrier-group-based PDCCH monitoring adaptation is considered.

Observation 1: In terms of codepoint mapping, Alt 1 is homogeneous, and Alt 2 is heterogeneous. Heterogeneous codepoint mapping is not found in Rel-15 and Rel-16 standards.

Observation 2: During the application delay, the UE does not expect to receive another indication of power saving adaptation different from the previous indication.

## CMCC

1. R1-2107416Discussion on PDCCH monitoring reduction during DRX active time CMCC

**Proposal 1: Alt 1 is adopted for R17 PDCCH monitoring adaptation, that is supporting SSSG switching to emulate PDCCH skipping functionality.**

**Proposal 2: Alt1-2 can be supported for SSSG switching, e.g. to emulate PDCCH skipping functionality by a ‘dormant SSSG’ which may have associated SS sets, and monitored conditionally (e.g., depending on HARQ NACK or RTT/ReTx timers).**

**Proposal 3: More than 2 SSSGs can be supported for Rel-17 SSSG switching and the PDCCH skipping duration of dormant SSSG(s) are configured by RRC.**

**Proposal 4: UE should switch to the last non-dormant SSSG used before current dormant SSSG when the PDCCH skipping duration expires.**

**Proposal 5: A default SSSG can be configured and applied for the following cases,**

* **SSSG switching triggered by SR**
* **SSSG switching triggered by RACH**

**Proposal 6: Format 1\_1 (SCell dormancy case 2) is supported as non-scheduling DCI indication for SSSG switching in active time for an active BWP.**

## LG Electronics

1. R1-2107455 Discussion on DCI-based power saving adaptation during DRX ActiveTime LG Electronics

***Proposal 1: Discuss explicit definition of PDCCH skipping with regard to a DRX functionality, especially on Type0/0A/1/2-PDCCH CSS sets.***

***Observation 1: Supporting SSSG switching to emulate PDCCH skipping functionality, i.e. Alt 1, cannot be possible if PDCCH skipping shut down UE’s monitoring PDCCH candidates for a DCI with CRC scrambled by RNTIs controlled by a DRX functionality.***

***Proposal 2: Support Alt 2 for a common design for DCI-based monitoring adaptation.***

***Proposal 3: Consider supporting the following design for DCI-based PDCCH monitoring adaptation:***

* + - ***1-bit flag distinguishing between PDCCH skipping and SSSG switching***
		- ***UE behavior corresponding to each state configured by RRC signaling***
			* ***FFS: details including the number of bits required.***

***Proposal 4: Consider PDCCH monitoring adaptation indicated by a DCI format 2\_6 inside/outside DRX Active Time.***

* + - ***Discuss whether and how to define the monitoring window for DCI format 2\_6 inside DRX Active Time.***

***Proposal 5: Study how to handle missing case of DCI indicating SSSG switching.***

***Proposal 6: Discuss different application delay for two cases:***

* + - ***Command applied after UE’s UL transmission (PUSCH or ACK) if monitoring adaptation is indicated by a DCI with scheduling information.***
		- ***Time-based application delay if monitoring adaptation is indicated by a DCI without scheduling information.***

***Proposal 7: Consider supporting implicit PDCCH monitoring adaptation triggered by SR and RACH***

* + - ***Discuss whether and how to define a monitoring window for a UL grant regarding SR***

## ETRI

1. R1-2107476 DCI-based power saving adaptation during DRX active time ETRI

**Observation 1: Noting that Alt. 2 needs a new DCI field to indicate PDCCH skipping and also noting that Alt. 2 may have an issue addressed in Table 1, taking Alt. 1 may result in less specification change.**

**Proposal 1: Support Alt. 1, i.e., SSSG switching to emulate PDCCH skipping functionality.**

**Proposal 2: For Alt. 1, support up to three SSSGs.**

**Proposal 3: PDCCH which does not schedule data and indicate SSSG switching or PDCCH skipping for an active BWP in active time is supported by DCI Format 1\_1 (SCell dormancy case 2 like)**

**Proposal 4: DCI format 2\_6 is supported to indicate SSSG switching or PDCCH skipping for an active BWP in active time when DRX is configured.**

**Proposal 5: For UE configured with DRX, higher layer signaling can configure SSSG that a UE monitors when coming out of DRX to monitor an ON duration.**

**Proposal 6: At least for the case where ACK/NACK for the DCI is present, application time of SSSG switching or PDCCH skipping is configured to be after the HARQ-ACK transmission timing + some margin for gNB’s HARQ-ACK decoding processing time.**

**Proposal 7: Application time of SSSG switching or PDCCH skipping is configured to be after the potential retransmission period, i.e., time period while DRX retransmission timer for PDSCH/PUSCH is running.**

## MediaTek Inc.

1. R1-2107521On enhancements to DCI-based UE power saving during DRX active time MediaTek Inc.

**Observation 1: At least three PDCCH monitoring behaviours are needed for Rel-17 power saving adaptation.**

* **Per-slot monitoring: The default monitoring behaviour during scheduling of data packets**
* **PDCCH skipping for a duration: Switch to this behaviour after the last TB scheduling**
* **Periodical PDCCH monitoring: Switch to this behaviour when there is potential timing critical data scheduling (e.g., for AR/VR UL traffic)**

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**Figure 1. The Rel-17 PDCCH adaptation for reducing PDCCH monitoring**

**Observation 2: In Alt 1, to support at least 3 monitoring behaviours, at least 1 additional SSSG is needed. However, there will also introduce more complicate state transition design and error handling.**

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**Figure 2. The state machine of Alt 1 becomes complex after adding one SSSG**

**Observation 3: Alt 2 requires minimum extension to Rel-16 SSSG switching and addition of simple PDCCH skipping behaviour.**

**Proposal 1: Support Alt 2 for reusing 2 SSSG framework and skipping for one duration.**

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**Figure 3. The state machines of Alt 2**

**Proposal 2: To avoid blocking retransmission scheduling during the skipping duration, UE should resume a short term PDCCH monitoring during a configured duration, depending on the HARQ processing outcome.**

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**Figure 5. Illustration of UE power saving adaptation for retransmission handling**

**Proposal 3: The configured time duration for DL/UL can be set to the sum of RTT and retransmission timer of DRX configuration.**

* ***drx-HARQ-RTT-TimerDL* + *drx-RetransmissionTimerDL* for downlink scheduling.**
* ***drx-HARQ-RTT-TimerUL* + *drx-RetransmissionTimerUL* for uplink scheduling.**
* **Note: UE is not required to monitoring PDCCH during the first RTT timer**
* **FFS: UE behaviour when receiving DL and UL indications of different configured time durations**

**Proposal 4: Application delay is only one slot for PDCCH skipping, aiming for the minimum specification change.**

**Proposal 5: Application delay for SSSG switching triggered by scheduling DCI should be further discussed since the scheduling DCI can also trigger cross-slot scheduling adaptation.**

## Fraunhofer HHI, Fraunhofer IIS

1. R1-2107533DCI-based Power Saving Enhancements Fraunhofer HHI, Fraunhofer IIS

**Proposal 1: Use the SSG switching mechanism as a starting point for a unified design.**

**Proposal 2: Adopt SSG switching using the minimum offset signaling to trigger a switch.**

**Proposal 3: Support PDCCH skipping by enabling empty or dormant SSGs which stay active for a configured time duration.**

**Proposal 4: The PDSCH processing time shall be adaptable based on certain parameters, e.g., the minimum scheduling offset or the currently active SS group.**

## Intel Corporation

1. R1-2107601 Discussion on DCI-based UE Power Saving Schemes during active time Intel Corporation

**Observation 1:**

* **PDCCH monitoring adaptation can be potentially triggered by both scheduling and non-scheduling DCI formats and it is expected that unified approach is taken regarding start of the adaptation**
* **Impact to HARQ retransmission due to PDCCH monitoring adaptation can be avoided by gNB implementation**

**Proposal 1: Support Alt 2: PDCCH schedules data and also indicates PDCCH monitoring adaptation by PDCCH skipping for a duration is supported.**

* **Duration for PDCCH skipping can be RRC signaled or indicated by DCI**
* **FFS: joint / separate indication of SSSG switching and PDCCH skipping**

**Proposal 2: Support indication of PDCCH monitoring adaptation by following ways.**

* **Use explicit bit field in DCI formats 1-1, 1-2, 0-1, 0-2 when they schedule data**
* **DCI Format 1\_1 (SCell dormancy case 2) when not scheduling data.**
* **DCI Format 2\_6 during active time.**

**Proposal 3: PDCCH monitoring adaptation should not be dependent on HARQ outcome or PUSCH transmission**

* **Monitoring adaptation does not start before Z slots from the slot where DCI is received, and Z is given by (1, 1, 2, 2) for DL SCS of (15, 30, 60, 120) KHz, respectively.**

## Panasonic

1. R1-2107624 Potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime Panasonic

Proposal 1: Support Alt 2 to specify a unified framework supporting SSSG switching and PDCCH skipping by RRC configuration + DCI indication. Following design is considered:

* gNB configures by RRC a list of PDCCH monitoring adaptation behaviours, including which search space to be monitored with/without timer. DCI indicates which index in the list the UE should follow.

## Apple

1. R1-2107752 Enhanced DCI-based power saving adaptation Apple

***Proposal 1: Alt 2 should be supported to enable PDCCH monitoring adaptation.***

***Proposal 2: When DCI format 0-1, 0-2, 1-1 and 1-2 is used to trigger PDCCH monitoring adaptation, the adaptation is applied to all CCs within a CC group.***

***Proposal 3: For PDCCH based adaptation using non-scheduling DCI, enable DCI format 1-1 with triggering bits per cell group.***

***Proposal 4: For PDCCH based adaptation using non-scheduling DCI, enable DCI format 2-6 monitoring in DRX-ON duration.***

***Proposal 5: When PDCCH monitoring adaptation is triggered by non-scheduling DCI, application delay for SSSG switching is 25 OFDM symbols for*** $μ=0,1,2$***, and 39 OFDM symbols for*** $μ=3$***.***

***Proposal 6: When PDCCH monitoring adaptation is triggered by non-scheduling DCI, application delay for PDCCH skipping is 11 OFDM symbols for*** $μ=0,1,2$***, and 25 OFDM symbols for*** $μ=3$***.***

***Proposal 7: When PDCCH monitoring adaptation is triggered by DCI format 1-1 and 1-2, application delay applies after the last OFDM symbol of ACK transmission. Application delay can 1 slot considering gNB ACK decoding time and UE processing time to apply the new configuration.***

***Proposal 8: When PDCCH monitoring adaptation is triggered by DCI format 0-1 and 0-2, application delay applies after the last OFDM symbol of PUSCH transmission when drx-RetransmissionTimerUL is not configured or longer than a threshold.***

***Proposal 9: When PDCCH monitoring adaptation is triggered by DCI format 0-1 and 0-2, application delay applies after drx-RetransmissionTimerUL expires if drx-RetransmissionTimerUL is configured and less than a threshold.***

## InterDigital, INC.

1. R1-2107808 PDCCH monitoring reduction in Active Time InterDigital, Inc.

**Proposal 1: Support configuration of codepoints per SSSG to indicate SSSG switching and/or PDCCH skipping.**

**Proposal 2: Support indication of skipping a subset of SSs in a SSSG.**

**Proposal 3: PDCCH skipping indication (including monitoring the PDCCH according to a null SSSG) is not applied in an interval when the DL retransmission timer is running.**

**Proposal 4: PDCCH skipping indication (including monitoring the PDCCH according to a null SSSG) is not applied in an interval when the UL retransmission timer is running.**

## NTT DOCOMO, INC.

1. R1-2107871 Discussion on extension to DCI-based power saving adaptation NTT DOCOMO, INC.

**Observation 1: If ‘empty’ SSSG which no SS set(s) is configured, only when switching to ‘empty’ SSSG, the application delay can be as short as possible to cover PDCCH processing time.**

**Proposal 1: For PDCCH skipping functionality, SSSG switching should be used.**

**Proposal 2: More than 2 SSSGs should be considered for flexible monitoring periodicity and PDCCH skipping functionality.**

**Observation 2: PDCCH skipping along with cross-slot scheduling can maximize the benefit of cross-slot scheduling.**

**Proposal 3: It should be considered that the duration of PDCCH skipping is equal to or longer than the applicable minimum scheduling offset.**

## Ericsson

1. R1-2108001 Design of active time power savings mechanisms Ericsson

[Observation 1 Allowing NW to have control on which SSSG the UE needs to monitor PDCCH after the skipping duration ends can be beneficial.](#_Toc79165169)

[Observation 2 UE PDCCH monitoring behavior during PDCCH monitoring adaptation application delay should be clear to avoid different understanding between NW and UE.](#_Toc79165170)

[Proposal 1 Support following as a common solution for SSSG switching and PDCCH skipping:](#_Toc79168505)

[- DCI indicates one of the following states to the UE](#_Toc79168506)

[i. switch to SSSG0](#_Toc79168507)

[ii. switch to SSSG1](#_Toc79168508)

[iii. skip PDCCH monitoring for duration X (X configured by RRC)](#_Toc79168509)

[iv. no change to PDCCH monitoring](#_Toc79168510)

[Proposal 2 Use the baseline application delay from Rel. 16 SSSG-switching feature.](#_Toc79168511)

[- FFS: the baseline application delay for 120 kHz SCS .](#_Toc79168512)

[Proposal 3 HARQ retransmissions should not be delayed due to PDCCH monitoring adaptation and mechanisms to avoid this should be supported e.g., a configurable timer-based application delay or HARQ ACK-based application of the PDCCH monitoring adaptation command.](#_Toc79168513)

[Proposal 4 PDCCH monitoring adaptation for Rel. 17 should not entail an interruption to UE transmission/reception on any serving cell.](#_Toc79168514)

[Proposal 5 For UE configured with DRX, higher layer signaling can configure SSSG that a UE monitors when coming out of DRX to monitor an ON duration.](#_Toc79168515)

[Proposal 6 UL scheduling request can be used as a trigger to stop skipping and/or to switch between SS-set groups. The SS-set group that UE monitors after transmitting an UL scheduling request is configurable by NW.](#_Toc79168516)

[Proposal 7 For a transition between SSSG1 and SSSG0, a similar mechanism with Rel. 16 SSSG-switching timer-based feature is adopted.](#_Toc79168517)

[Proposal 8 The SSSG that a UE monitors after skipping duration ends is explicitly configured by RRC or is indicated by the PDCCH monitoring adaptation bitfield in the DCI.](#_Toc79168518)

[Proposal 9 Indication for PDCCH monitoring adaptation (by SSSG switching and PDCCH skipping for a duration) is supported only via DCI formats 1-1/1-2/0-1/1-1.](#_Toc79168519)

[Proposal 10 For self-scheduling, PCell’s scheduling DCI format 1\_1/0\_1/1\_2/0\_2 can indicate SSSG-switching/skipping for the primary cell.](#_Toc79168520)

[Proposal 11 For self-scheduling, an SCell’s scheduling DCI format 1\_1/0\_1/1\_2/0\_2 can indicate SSSG-switching/skipping for the SCell.](#_Toc79168521)

[Proposal 12 Study further how to support SSSG-switching/skipping for multiple groups of cell(s). Details including number of groups FFS.](#_Toc79168522)

## ITRI

1. R1-2108014 Discussion on DCI-based power saving adaptation ITRI

**Observation:**

SSSG switching may impact on PDCCH monitoring after UE transmit SR or PRACH.

**Proposal 1:**

Supporting SSSG switching to emulate PDCCH skipping functionality by an ‘empty’ SSSG which no SS set is configured for the ‘empty’ SSSG, UE does not monitoring PDCCH on the ‘empty’ SSSG.

**Proposal 2:**

Further study the SSSG switch impacts over multi-cell operation and cross-carrier scheduling.

**Proposal 3:**

Further study the SSSG switch impacts over PDCCH monitoring.

## ASUSTeK

1. R1-2108048 A common framework for SSSG switching and PDCCH skipping ASUSTeK

**Observation1: Rel-16 SSSG switch is well-specified in Rel-16 and could provide a good frame work for both Rel-17 SSSG switch as well as PDCCH skipping.**

**Proposal 1: RAN1 considers Rel-16 SSSG switch as a starting point for power saving adaptation during Active Time and makes further required adjustment which fits needs of Rel-17 power saving better.**

**Observation 2: time duration could be variant, e.g. indicating by DCI to fit the needs of power saving.**

**Observation 3: SSSG activation deactivation may not fit the case of PDCCH skipping.**

**Proposal 2: RAN1 considers the following adjustment to Rel-16 SSSG switch to support both Rel-17 SSSG switch and PDCCH skipping:**

* **Variant time duration indicated by DCI**
* **DCI format triggering the SSSG switch**
* **More than two SSSGs**

## Nokia, Nokia Shanghai Bell

1. R1-2108124 UE power saving enhancements for Active Time Nokia, Nokia Shanghai Bell

In Section 2 were present the evaluation of signalling overhead related to the PDCCH monitoring adaptation considering SSSG switching and PDCCH skipping:-

**Observation:** *SSSG switching has lower signalling overhead than PDCCH skipping for most of the evaluated traffic scenarios.*

In the continued discussion in RAN1#105e it was agreed that SSSG switching at least with 2 SSSGs wil be supported in Rel-17 for PDCCH monitoring adaptation and the method to introduce stopping the PDCCH monitoring, will be either introduced as a part of the SSSG frame work or as a separate functionality. Based on this we made following observations and proposals in Section 3:-

**Observation**: A field indicating the target SSSG index could be added to the scheduling DCI.

**Proposal:** Support Rel-17 SSSG switching, in addition to scheduling DCIs also for DCI format 2\_0. For multi cell operation consider introducing similar mechanism as for Scell dormancy e.g. via DCI format 1\_1 (SCell dormancy case 2).

**Proposal:** Increase the number of SS set groups at least from 2 to 3.

**Proposal:** Support timer-based UE autonomous SS set group switching for active time power saving.

**Observation:** Through use of timer based SSSG switching and proper configuration of SS set stopping of PDCCH monitoring for a duration can be achieved.

**Proposal:** Supporting SSSG switching with ‘empty’ SSSG to embed PDCCH skipping functionality to SSSG framework.

**Proposal:** Procedures such as SR transmission, BSR or beam failure recovery should result UE to stop PDCCH monitoring adaptation and resume normal PDCCH monitoring.

**Observation:** In case of C-DRX, timer-based SSSG switching could be applied during the inactivity and SSSG would be switched if UE is scheduled during On Duration.

**Proposal:** Support configuring a default SS set group that is applied during On Duration, at least when DCP is configured.

**Proposal:** PDCCH monitoring adaptation should not be applied to Type0/0A/1 or 2 PDCCH CSS. For Type3-PDCCH CSS adaptation could be considered, but the monitoring should not be stopped completely.

**Proposal:** Use the application delay timeline introduced in Rel-16 for SSSG switching.

**Observation:** For PDCCH monitoring adaptation case, where UE still continues to monitor PDCCH, albeit at reduced rate, there may not be any need to have special handling of HARQ re-transmissions scheduling, but scheduling can follow the applied SS set(s).

**Observation:** Special handling of HARQ re-transmissions is only needed when UE stops the PDCCH monitoring for extended time.

**Proposal:** For stopping PDCCH monitoring based on {empty} SSSG or PDCCH skipping, define timers similarly as in C-DRX operation to enable configuring time windows for handling the open re-transmissions.

**Observation:** Associating minimum cross-slot scheduling restriction to certain SSSGs could be considered.

# Void

# Work Item Description

*NR\_UE\_pow\_sav-Core; WID in* [*RP-200938*](http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_88e/Docs/RP-200938.zip)*. The objectives are as follows*

|  |
| --- |
| 1. Specify enhancements for idle/inactive-mode UE power saving, considering system performance aspects [RAN2, RAN1]
	1. Study and specify paging enhancement(s) to reduce unnecessary UE paging receptions, subject to no impact to legacy UEs [RAN2, RAN1]
* NOTE: RAN1 to check and update, if needed, evaluation methodology in RAN1 #102-e meeting
	1. Specify means to provide potential TRS/CSI-RS occasion(s) available in connected mode to idle/inactive-mode UEs, minimizing system overhead impact [RAN1]
* NOTE: Always-on TRS/CSI-RS transmission by gNodeB is not required
1. Study and specify, if agreed, enhancements on power saving techniques for connected-mode UE, subject to minimized system performance impact [RAN1, RAN4]
	1. Study and specify, if agreed, extension(s) to Rel-16 DCI-based power saving adaptation during DRX Active Time for an active BWP, including PDCCH monitoring reduction when C-DRX is configured [RAN1]
* NOTE: Rel-15 and Rel-16 available power saving solutions should be supported by the UE and included in the evaluation. RAN1 will ask the confirmation from RAN2 that Rel-15 and Rel-16 available power saving solutions are properly utilized.
	1. Study the feasibility and performance impact of relaxing UE measurements for RLM and/or BFD, particularly for low mobility UE with short DRX periodicity/cycle, and specify, if agreed, relaxation in the corresponding requirements [RAN4]
* NOTE: Supplementary RAN2 work, if needed, can be triggered by RAN4 LS
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# Reference

**The following contributions are submitted in RAN1#106-E in AI 8.7.2,**

1. R1-2106481 Extensions to Rel-16 DCI-based power saving adaptation for an active BWP Huawei, HiSilicon
2. R1-2106524 Extension to Rel-16 DCI-based power saving adaptation during DRX Active Time ZTE, Sanechips
3. R1-2106610 Discussion on DCI-based power saving adaptation in connected mode vivo
4. R1-2106710 Discussion on power saving techniques for connected-mode UE Spreadtrum Communications
5. R1-2106901 Discussion on DCI-based power saving techniques Samsung
6. R1-2106986 PDCCH monitoring adaptation CATT
7. R1-2107017 Discussion on DCI-based power saving adaptation NEC
8. R1-2107046 On PDCCH monitoring adaptation Nordic Semiconductor ASA
9. R1-2107184 Enhanced DCI based power saving adaptation Lenovo, Motorola Mobility
10. R1-2107255 DCI-based power saving adaptation solutions OPPO
11. R1-2107358 DCI-based power saving adaptation during DRX ActiveTime Qualcomm Incorporated
12. R1-2107416 Discussion on PDCCH monitoring reduction during DRX active time CMCC
13. R1-2107455 Discussion on DCI-based power saving adaptation during DRX ActiveTime LG Electronics
14. R1-2107476 DCI-based power saving adaptation during DRX active time ETRI
15. R1-2107521 On enhancements to DCI-based UE power saving during DRX active time MediaTek Inc.
16. R1-2107533 DCI-based Power Saving Enhancements Fraunhofer HHI, Fraunhofer IIS
17. R1-2107601 On PDCCH Monitoring Adaptation during DRX active time Intel Corporation
18. R1-2107624 Potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime Panasonic
19. R1-2107752 Enhanced DCI-based power saving adaptation Apple
20. R1-2107808 PDCCH monitoring reduction in Active Time InterDigital, Inc.
21. R1-2107871 Discussion on extension to DCI-based power saving adaptation NTT DOCOMO, INC.
22. R1-2108001 Design of active time power savings mechanisms Ericsson
23. R1-2108014 Discussion on DCI-based power saving adaptation ITRI
24. R1-2108048 A common framework for SSSG switching and PDCCH skipping ASUSTeK
25. R1-2108124 UE power saving enhancements for Active Time Nokia, Nokia Shanghai Bell

**Other references:**

1. RP-200938, “Revised WID: UE Power Saving Enhancements for NR”, MediaTek Inc., RAN#88-e

# History

1. R1-2007065 FL summary of potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime RAN1#102-E Moderator (vivo)
2. R1-2007117 FL summary#2 of potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime RAN1#102-E Moderator (vivo)
3. R1-2007225 FL summary#3 of potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime RAN1#102-E Moderator (vivo)
4. R1-2007400 FL summary#4 of potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime RAN1#102-E Moderator (vivo)
5. R1-2009501 FL summary#1 of power saving for Active Time RAN1#103-E Moderator (vivo)
6. R1-2009655 FL summary#2 of power saving for Active Time RAN1#103-E Moderator (vivo)
7. R1-2009656 FL summary#3 of power saving for Active Time RAN1#103-E Moderator (vivo)
8. R1-2009804 FL summary#4 of power saving for Active Time RAN1#103-E Moderator (vivo)
9. R1-2101893 FL summary#1 of power saving for Active Time RAN1#104-E Moderator (vivo)
10. R1-2101894 FL summary#2 of power saving for Active Time RAN1#104-E Moderator (vivo)
11. R1-2106040 FL summary#1 of power saving for Active Time RAN1#105-E Moderator (vivo)
12. R1-2106041 FL summary#2 of power saving for Active Time RAN1#105-E Moderator (vivo)