3GPP TSG RAN WG1#105-e R1-21XXXXX

e-Meeting, May 10th – 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.

* 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.

# Issue list

## Issue 1: SSSG switching and/or PDCCH skipping

In RAN1#104-E, it is agreed that

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:

* 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
  + Others not precluded

The followings are initial proposals.

### Initial proposals

Most companies support explicitly indication of SSSG switching by a scheduling DCI in the contributions,

* + Scheduling DCI Supporetd by Qualcomm, MTK, CMCC, Samsung, Nokia, , Huawei/HiSilicon, vivo, LGE, Panasonic, Apple, Fraunhofer HHI/Fraunhofer IIS, InterDigital (12)
  + some companies propose to support this with selected DCI formats: DOCOMO(format 0\_1 and 1\_1), , Ericsson (DCI format 1\_1, FFS : DCI format 0\_1), ZTE(UE-specific DCI format), OPPO(format 1\_1 and format 0\_1 as optional) (4)

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| **[High] proposal 1-1a:**   * PDCCH schedules data and also indicates PDCCH monitoring adaptation by SSSG switching is supported.   + At least DCI format(s) 1-1, 0-1, 1-2 and 0-2 is supported     - X-bit is added in the DCI for indicating SSSG switching       * X = [1]       * FFS details   + SSSG#0 and SSSG#1 is supported for Rel-17 SSSG switching indicated by PDCCH schedules data.     - FFS: more than 2 SSSGs |

In order to achive a common solution which support functionalities inclusive of both SSSG switching and PDCCH skipping, some companies propose that a ‘dormant search space set group’ is introduced in order to emulate PDCCH skipping by search space group switching(i.e. Alt 1), e.g.,

* To emulate PDCCH skipping with search space group switching, a dormant search space set group can be introduced, e.g., as group 2. [Qualcomm]
* A new ‘skipping’ SSSG group can be configured for scheduling DCI based SSSG switching. FFS whether and how the number of configured SSSG can be 2 or 3. [vivo]
* Support PDCCH skipping by enabling empty or non-empty SSGs which stay active for a configured time duration. [Fraunhofer]
* Support search space set group (SSSG) switching among more than two search space set groups, including empty SSSS group for PDCCH skipping. [Samsung]

While some companies think indicating PDCCH monitoring adaptation by PDCCH skipping for a duration within a SSSG is better (i.e. Alt 2), e.g.,

* Explicit PDCCH skipping function for UE and gNB; [ZTE]
* DCI indicating SSSG switching can indicate PDCCH monitoring periodicity for the target SSSG, i.e., PDCCH skipping duration. [NTT DOCOMO]
* Indicating skipping of PDCCH monitoring occasions is supported as PDCCH monitoring adaptation. [OPPO]

The pros of Alt 1 claimed are as follows,

* high flexibility in SS set group configuration [Samsung]

The cons of Alt 1 claimed are as follows,

* The configuration of a SSSG simulating an implicit PDCCH skipping by pure network implementation cannot provide gNB a straightforward information of a proper power saving configuration. It may result in low probability of deployment of this implicit PDCCH skipping function. [ZTE]
* UE power saving gain may be degraded for hardly configuring the implicit PDCCH skipping function by gNB.[ZTE]
* By configuring a SS set with a SSSG index and the SS set is not configured with any PDCCH MO, the SS set is always occupied for PDCCH skipping and the configurable SS sets used for PDCCH monitoring are reduced. [Huawei, HiSilicon]
* SSSG switching has the additional application delay during search space switching, which makes the SSSG switching not equivalent to the PDCCH skipping [CATT]

The pros of At 2 claimed are as follows,

* More flexibility, better power saving performance, less latency. [ZTE]

The cons of At 2 claimed are as follows,

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| **[High] proposal 1-1b:**   * Alt 1: Supporting SSSG configured as a ‘dormant’ SSSG,   + UE does not monitoring PDCCH on ‘dormant’ SSSG,     - * FFS: how to configure/indicate ‘dormant’ SSSG       * FFS: how UE switch out of ‘dormant SSSG’ , e.g., timer based.   **[High] proposal 1-1c:**   * Alt 2: PDCCH schedules data and also indicates PDCCH monitoring adaptation by PDCCH skipping for a duration is supported.   + DCI format(s) 1-1, 0-1, 1-2 and 0-2 is supported     - Y-bit, 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 specification       * Implicitly, to the end of C-DRX active time |

**The following proposals 1-2a~2c is related to non-scheduling DCI based PDCCH monitoring adaptation**

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| **[Medium] proposal 1-2a:**   * 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) |

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| **[Medium] proposal 1-2b:**   * PDCCH does not schedules data and indicates SSSG switching or PDCCH skipping for an active BWP in active time is supported by   + DCI format 2\_0 |

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| **[Medium] proposal 1-2c:**   * DCI format 2\_6 is supported to indicates SSSG switching or PDCCH skipping for an active BWP in active time when DRX is configured. |

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| **[Medium] proposal 1-3:**  When CA and Scell dormancy is configured, PDCCH which indicates Scell dormancy is also indicating SSSG switching for an active BWP in active time. |

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| **[Medium] proposal 1-4:**  When R16 cross-slot scheduling is configured, PDCCH which schedules data and indicates Rel-16 cross-slot indication is also indicating SSSG switching for an active BWP in active time. |

**The following proposals 1-5a~5e is related to implicit indication of PDCCH monitoring adaptation**

Timer-based PDCCH adaptation widely supported by many companies for SSSG switching, especially RRC configures a timer duration and after timer expired UE switches into another SSSG.

Besides that, following are some other proposals,

* Vivo propose DCI can dynamically indicate a timer duration for timer-based SSSG switching. [3]
* Similarly, Intel propose that DCI indicates a duration for the switched SSSG; UE switches back to previous/default SSSG after duration ends. [9]
* Nordic proposes to introduce DCI format 1\_1, 1\_2, 0\_1 and 0\_2 indicating, upon reception of such DCI format, initialize timer to value corresponding to end of C-DRX active time is also one alternative. [24]

For timer-based PDCCH skipping, please see **proposal 1-1c.**

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| **[High] proposal 1-5a:**  For implicit indication of PDCCH monitoring adaptation for an active BWP in active time, timer-based SSSG switching is supported,   * + A timer duration is configured by RRC, and UE switch back after timer expired.     - FFS timer duration is configured per SSSG or BWP.     - FFS multiple timer duration(s) can be configured by RRC, and DCI dynamically indicates a timer duration.     - FFS which SSSG UE switches to after the timer expired.     - FFS: the time duration is corresponding to end of C-DRX active time   **[High] proposal 1-5b:**  For timer-based SSSG switching , the following is considered after timer expired,   * + Alt 1: UE switches to SSSG#0 (i.e., default SSSG)   + Alt 2: UE switches to a SSSG configured by RRC |

SSSG switching triggered by scheduling request is proposed by many companies,

* Ericsson, Qualcomm, Nokia, Huawei, HiSilicon, CMCC, LGE, ITRI, Asia Pacific Telecom, FGI, ZTE

SSSG switching triggered by RACH is proposed by many companies,

* Nokia, Huawei, HiSilicon, CMCC, LGE, ITRI, Asia Pacific Telecom, FGI, ZTE(RACH due to out-of sync)

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| [Medium] Proposal 1-5c:  For implicit indication of PDCCH monitoring adaptation , SSSG switching triggered by SR is supported.  [Medium] Proposal 1-5d:  For implicit indication of PDCCH monitoring adaptation , SSSG switching triggered by RACH is supported. |

Some other implicit triggering mechanism such as follows,

* to guarantee that the UE will start monitoring using dense SSSG during the DRX on-duration, a default SS-set group that needs to be assumed at beginning of On-duration.[Ericsson]
* Beam failure detection [ZTE]

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| [Medium] Proposal 1-5e  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. |

### Companies views (1st round)

Companies are encouraged to provide comments in the table below.

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| **Company** | **Comment** |
| NordicSemi | Based on contributions, we believe that there are two direction to be discussed here or in GTW  Alt 1: PDCCH schedules data and also indicates PDCCH monitoring adaptation by SSSG switching is supported.   * + At least DCI format(s) 1-1, 0-1, 1-2 and 0-2 is supported     - X-bit is added in the DCI for indicating SSSG switching       * X = [1]       * FFS details   + At least SSSG#0 and SSSG#1 is supported for Rel-17 SSSG switching indicated by PDCCH scheduling data     - FFS: support of more than 2 SSSGs     - FFS: explicitly or implicitly indicated timer value for a SSSG     - FFS: further monitoring restrictions within SSSG when group is active, e.g. monitoring only for re-tx, or only for UL grant, etc.     - …..     - Note: An SSSG may contain zero SS sets and UE does not monitor PDCCH during the time that SSSG is active.   Alt2: PDCCH schedules data and also indicates separately or jointly:   * PDCCH monitoring adaptation by SSSG switching   + - FFS: support of more than 2 SSSGs     - FFS: explicitly or implicitly indicated timer value for a SSSG     - FFS: further monitoring restrictions within SSSG when group is active, e.g. monitoring only for re-tx, or only for UL grant, etc.     - …..     - Note: An SSSG may contain zero SS sets and UE does not monitor PDCCH during the time the SSSG is active. * PDCCH skipping for a period of time   + FFS durations of skipping   + FFS one or more   + FFS configurable or indicated |
| CATT | We are OK with the common framework for SSSG switching and PDCCH skipping as agreed in RAN1#104-e. However, we don’t agree that the proposal is to support SSSG switching. We had listed the issues and drawback of SSSG switching as follows,   * The SSSG switching delay – this would have transition period that gNB can’t schedule any DL/UL transmission. This will incur additional UE power consumption * The HARQ operation interaction with SSSG switching – When scheduling DCI is used for SSSG switching, the effective time of SSSG would not be confirmed until the ACK is received from UE for DCI formats 1\_1/2\_1 and UL data is received for DCI formats 0\_1/0\_2. The handshaking between gNB and UE for DL and UL triggering might be quite different. Moreover, it would have concatenated effects of error propogation when miss-detection of DCI. * Traffic adaptation – the drawback of SSSG switching is the additional delay during switching. PDCCH monitoring adaptation is to reduce PDCCH monitoring during Active Time when gNB buffer is empty and Inactivity timer is running. The SSSG switching delay could not adjust UE PDCCH monitoring dynamically and quickly to align with traffic arrival and defy the purpose of PDCCH monitoring adaptation for the traffic arrival to achieve the power saving. |
| Apple | Proposal 1-1a, the proposal include only SSSG switching, but missed the PDCCH skipping. Suggest to change it to “PDCCH schedules data and also indicates PDCCH monitoring adaptation by SSSG switching and PDCCH skipping is supported.  Proposal 1-1b, we do not support this option. The cons have been listed as summarized. We would like to point out the current UE feature 3-1 has the limitation of “UP to 3 search space sets in a slot for a scheduled SCell per BWP”. This additional “Null” search space set will reduce the configurable SS sets for PDCCH monitoring, as Huawei commented.  Proposal 1-1c, we support this option. In addition to the cons listed above, “more flexibility, better power saving performance, less latency”, we would like to add that this approach does not have additional overhead, but can indicate more combinations. For example, when buffer is close the empty, gNB can use one DCI to trigger skipping for a duration, and use another SSSG after skipping using one commend. There is no cons listed above.  Proposal 1-2a: support this option. UE monitors USS for format 1-1 (Scell dormancy case 2 like) without the additional complexity.  Proposal 1-2b and 1-2c: Do not support these options. UE power saving adapation is based on UE specific traffic. There is no result that show the group based DCI format bring additional benefit.  Proposal 1-3: Do not support as it indicate SSSG switching only. Need clarification the difference between 1-3 and 1-2a.  Proposal 1-4: Do not support this proposal. Seems to be duplicate with 1-1.  Proposal 1-5a and 1-5b: The discussion of timer based adaption should based on both SSSG switching and PDCCH skipping. Do not see why only SSSG switching is discussed.  Proposal 1-5c and 1-5d: This is gNB implementation based on UE traffic. We do not see specification impact.  Proposal 1-5e: Open to discuss. |

## Issue 2: More number of SSSGs

Some companies pointed out to consider more than 2 SSSG for the following reasons, [Supported by Samsung, Ericsson, Nokia, Qualcomm, vivo]

* Support search space set group (SSSG) switching among more than two search space set groups, including empty SSSS group for PDCCH skipping. [samsung]
* For the unified design of PDCCH monitoring adaptation based on SSSG switching, the maximum number of configured SSSGs larger than two is considered. [Qualcomm]
* in order to emulate the function of PDCCH monitoring skip, which would not be well-supported with legacy SSSG switching, a new type of SSSG may need to be introduced.. [Qualcomm]
* Study further how to support SSSG-switching/skipping for multiple groups of cell(s). Details including number of groups FFS. [Ericsson]
* Increase the number of SS set groups from 2 to 3. [Nokia]

Some companies thinks Two groups of SS sets is enough to support both PDCCH skipping and SSSG switching.

* When PDCCH skipping is introduced, the duration of PDCCH skipping can be flexibly configured. Different levels of UE power saving is obtained by supporting both PDCCH skipping and SSSG switching. It is not necessary to introduce more than 2 SSSGs to further increase UE complexity [Huawei]

### Initial proposals

The following moderator recommendations are made.

**[High] proposal 2-1:**

* Up to 3 SSSGs is supported for Rel-17 SSSG switching in the active BWP.

### Companies views (1st round)

Companies are encouraged to provide comments in the table below.

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| **Company** | **Comment** |
| NordicSemi | This is one way to resolve FFS in Alt 1 proposal |
| CATT | We only support 1 SSSG for PDCCH monitoring adaptation with dynamic skipping. |
| Apple | Do not support. As discussed in 1-1, many cons are listed for this approach. |

## Issue 3: 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. [OPPO][MTK][Ericsson][Apple][ZTE][vivo]

MediaTek states that skipping PDCCH monitoring not only achieves power saving but also impacts the flexibility of data scheduling. As long as the skipping indication of network is not align with the behaviour of a UE, the impact to data scheduling becomes larger. For example, the UE will switch to power-saving setting as it receives DCI that indicate PDCCH monitoring reduction. However, if the HARQ outcome is invalid, gNB cannot schedule UE during the period of power-saving setting as illustrated in Figure 1 in [R1-2105388].

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 if the UE is only allowed to perform PDCCH skipping after the data of all the HARQ process are received successfully, it may beyond the gNB’s prediction ability and degrades the UE power saving benefits. On the contrary, if the UE does not monitor the PDCCH scheduling retransmission data during skipping period, the latency for the retransmission data may increase significantly. ZTE proposed that the UE should monitor PDCCH for retransmission data, but it does not monitor PDCCH for an initial-transmission data during the PDCCH skipping period.

Ericsson thinks while the indication can also be included in the uplink DCI format i.e. 0\_1, it can become a bit cumbersome to manage uplink HARQ retransmissions. This aspect needs to be studied a bit further.

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 3-1:**   * + The UE performs ‘intensive PDCCH monitoring for retransmission’ for retransmission data during a ‘retransmission period’, and it performs normal PDCCH monitoring for an initial transmission data as explicit/implicit indicated by network.     - FFS the following is considered for the UE when entering ‘intensive PDCCH monitoring for retransmission’, e.g.,       * UE stays in default SSSG.       * UE stops PDCCH skipping.     - 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       * 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 |

### Companies views (1st round)

Companies are encouraged to provide comments in the table below.

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| **Company** | **Comment** |
| NordicSemi | We think intensive monitoring has not much common with power saving, because after NACK/failed-PUSCH, it takes some time for gNB to process HARQ-ACK and to rescheduled PDSCH/PUSCH transmission.  In this case it is better to define low-frequent monitoring SS-set (corresponding to gNB RTT) and define a period for which UE monitors re-tx, after that UE may stop monitoring in that SSSG completely for a period of time. |
| CATT | We don’t agree with Moderator’s proposal. Since the additional control bits in DCI format for PDCCH monitoring adaptation would be transmitted at each DL/UL DCI, the triggering of PDCCH monitoring adaptation should be “right away” without intensive PDCCH monitoring for retransmission. If the PDCCH monitoring adaptation without search space change, the DCI indication and the associated NDI could be used to indicate the number of slots for UE to skip the PDCCH monitoring at the initial transmission of last TB in the buffer. gNB could schedule the retransmission at the next indicated slot of UE PDCCH montiroing after receives HARQ-ACK feedback from UE. If search space does not change, there is no issue of PDCCH monitoring adaptation during HARQ operation. |
| Apple | Do not support this proposal. We do not see why intensive PDCCH monitoring for retransmission is needed when drx-RetransmissionTimerDL/UL is running. We also do not see the need to define another set of timer for this “retransmission period” as there is already set of HARQ timer for retransmission purpose. |
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## Issue 4: application time

### 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 where a minimum value of is provided in Table 10.4-1 in TS38.213 for UE processing capability 1 and UE processing capability 2 and SCS configuration . 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 3.

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| **[High] proposal 4-1:**   * Further consider the following application delay for PDCCH adaptation indication,   + 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: for SCS configuration   + Option b: the application delay needed for PDCCH processing for Rel-16 minimum application delay for K0min/K2min indication was reused.   + 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.   + Others not precluded. |

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** |
| NordicSemi | I believe reference point for scheduling PDCCH should be slot of HARQ-ACK/PUSCH and Option a can be reused . If non-scheudling DCI is supported, Option a can be reused directly. |
| CATT | Option f: Application delay should be “ZERO” for PDCCH monitoring adaptation to achieve higher UE power saving. PDCCH monitoring adaptation would be applied after UE receive the additional PDCCH monitoring adaptation control signaling bit(s) in DCI since DCI would control signaling bits at each DCI. |
| Apple | Proposal 4-1: Option c for UL scheduling DCI and Option d for DL schecheduling DCI.  For DL scheduling DCI, when NACK is transmitted, the gNB does not know whether the UE missed DCI itself, or failed PDSCH decoding. There can be misalignment between the UE and the gNB on PDCCH monitoring occasion. To handle this problem, 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 |

## Issue 5: Others

**UAI**

*Support UE assistance information of preferred search space set group. [Samsung]*

*Support PDSCH processing time relaxation based on minimum scheduling offset [Samsung]*

**Multi-cell operation**

*Forexample, having an indication on another cell e.g. by reusing Rel16 SCell dormancy indication, wherein PCell DCI format controls the SSSG-switching functionality for multiple groups of cells. Details including number of groups FFS. [Ericsson]*

### Companies views (1st round)

Companies are encouraged to provide comments in the table below.

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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:/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

# Proposals from companies’ submitted contributions

## ZTE, Sanechips

1. **R1-2104224 Extension to Rel-16 DCI-based power saving adaptation during DRX Active Time ZTE, Sanechips**

**Observation 1:** **For Alt 2a, 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 2:** **For Alt 1, the configuration of a SSSG simulating an implicit PDCCH skipping by pure network implementation cannot provide gNB a straightforward information of a proper power saving configuration. It may result in low probability of deployment of this implicit PDCCH skipping function.**

**Observation 3: For Alt 1, UE power saving gain may be degraded for hardly configuring the implicit PDCCH skipping function by gNB.**

**Observation 4:** **For Alt 1, in the case that PDCCH skipping implemented by SSSG switch is triggered by the timer-based mechanism, the latency of data processing can be increased when DCI-based indication of SSSG switching is not supported according to Rel-16 specification.**

**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 2a should be supported for the common design including SSSG switching and PDCCH skipping for the following advantages:**

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

**Proposal 2**: **For SSSG switching of Alt 2a, DCI-based and timer-based triggering mechanism for Rel-16 SSSG switching can be reused to simplify the specification work.**

**Proposal 3: To adapt to various UEs’ data traffic, UE-specific DCI format can be used to trigger PDCCH adaptation.**

**Proposal 4: A skipping timer used for PDCCH adaptation from SSSG monitoring to PDCCH skipping for a duration should be considered for the cases of PDCCH adaptation without DCI indication.**

**Proposal 5**: **For the case of switching PDCCH skipping to a default SSSG after the end of skipping duration, the default SSSG can be configured by RRC signaling to adapt to various traffic models.**

**Proposal 6**: **Multiple candidate values of skipping duration configured by RRC signaling should be adopted for RRC connected-mode UE**.

**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 are happened 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 NR-U. The minimum value of application delay for PDCCH adaptation for μ=3 can be 25 symbols.**

## Huawei, HiSilicon

1. **R1-2104253 Extensions to Rel-16 DCI-based power saving adaptation for an active BWP Huawei,** **HiSilicon**

***Observation 1: According to the current specification, SSSG switching framework cannot achieve the target of skipping PDCCH monitoring.***

***Observation 2: By configuring a SS set with a SSSG index and the SS set is not configured with any PDCCH MO, the SS set is always occupied for PDCCH skipping and the configurable SS sets used for PDCCH monitoring are reduced .***

***Observation 3: Alt 2a provides the flexibility for gNB to indicate both SSSG switching and PDCCH skipping, meanwhile Alt 1 cannot simultaneously support PDCCH skipping and switch to another SSSG.***

***Observation 4：PDCCH monitoring adaptation indicated by group common DCI format is helpful if there is no data transmission.***

***Observation 5: Two groups of SS sets is enough to support both PDCCH skipping and SSSG switching.***

***Proposal 1: specify different codepoint of DCI field to indicate SSSG switching and/or PDCCH skipping for a duration.***

***Proposal 2: Reuse dormancy indication filed to indicate PDCCH monitoring adaptation.***

***Proposal 3: Reuse 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: Explicitly configure the duration(s) of PDCCH skipping by RRC signaling.***

***Proposal 5: Different skipping duration(s) can be used for different SSSG to match with the PDCCH monitoring periodicity in the current SSSG.***

***Proposal 6: For the application delay for PDCCH monitoring adaptation:***

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

***Proposal 7: Consider SSSG switching triggered by detecting a scheduling DCI format.***

***Proposal 8: Support SSSG switching or stop PDCCH skipping triggered by SR or RACH.***

## vivo

1. R1-2104374 Discussion on DCI-based power saving adaptation in connected mode vivo

**Proposal 1. Rel-17 supports scheduling DCI dynamically indicates PDCCH monitoring adaptation within an active BWP, e.g., switching SS set group(s)**

**Proposal 2. Rel-17 supports scheduling DCI dynamically indicates PDCCH skipping for a certain duration.**

**Proposal 3: a new ‘skipping’ SSSG group can be configured for scheduling DCI based SSSG switching. FFS whether and how the number of configured SSSG can be 2 or 3.**

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

* **Scheme 1: 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#1 and SSSG#0**
    - **‘1’: starts monitoring PDCCH according to SSSG#0 and SSSG#1**
    - **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 switch from SSSG#1 to SSSG#0 after a last symbol of a remaining duration from timer1 indicated by scheduling DCI**
* **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,**

* **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**

## Spreadtrum Communications

1. R1-2104434 Discussion on power saving techniques for connected-mode UEs Spreadtrum Communications

***Observation 1: For enhancement of Rel-16 SSSG switching, for explicit indication, DCI format 2-0 may not be suitable.***

***Observation 2: The purpose of SSSG switching for Rel-16 NR-U is different from that of SSSG switching for Rel-17 power saving.***

***Observation 3: For enhancement of DCI(s) utilized for Rel-16 power saving adaptation, the following methods are feasible:***

* ***Reusing the up to 5 bits SCell dormancy indication in DCI format 2-6 or scheduling DCI***
* ***Reusing the 1 bit minimum scheduling offset indication***

***Proposal 1: For enhancement of Rel-16 SSSG switching, implicit triggering is prioritized.***

***Proposal 2: For skipping PDCCH monitoring for a duration, when the drx-RetransmissionTimerDL is running, UE should perform PDCCH monitoring even if UE is in a skipping duration.***

***Proposal 3: For enhancement of DCI(s) utilized for Rel-16 power saving adaptation, reusing SCell dormancy and/or cross-slot scheduling indication are prioritized.***

***Proposal 4: For enhancement of DCI(s) utilized for Rel-16 power saving adaptation, for reusing cross-slot scheduling indication, the application delay can be K0min.***

***Proposal 5: New DCI field can be considered as new signaling different from enhancement of Rel-16 SSSG switching and enhancement of DCI(s) utilized for Rel-16 power saving adaptation.***

## CATT

1. R1-2104535 PDCCH monitoring adaptation CATT

The observations are summarized as follows:

***Observation 1: SSSG switching has the additional application delay during search space switching, which makes the SSSG switching not equivalent to the PDCCH skipping.***

***Observation 2:*** ***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.***

The proposals are summarized as follows:

***Proposal 1: The PDCCH skipping should be co-existed with the enhanced SSSG switching for PDCCH adaptation enhancement.***

***Proposal 2: The SCell dormancy indication field in existing DCI formats 0\_1 and 1\_1 in Rel-16 could be reused for PDCCH monitoring adaptation for PCell without any introducing additional information field.***

***Proposal 3: The PDCCH adaptation would be performed after the slot of HACK-ACK of the last retransmission is sent from the UE.***

## CMCC

1. R1-2104624 Discussion on PDCCH monitoring reduction during DRX active time CMCC

**Proposal 1: Support Alt 1: Enhancement of Rel-16 SSSG switching to support PDCCH monitoring adaptation including skipping for a duration.**

**Proposal 2: Three SSSGs can be defined to support PDCCH monitoring adaptation including skipping for a duration.**

**Proposal 3: a default SSSG can be configured and applied for the following cases,**

* **SSSG switching triggered by SR**
* **SSSG switching triggered by RACH**
* **When the timer for SSSG2 expires.**

**Proposal 4: Both scheduling DCI and non-scheduling DCI can be supported for dynamic PDCCH monitoring adaptation in active time.**

**Proposal 5: For scheduling DCI based SSSG switching in active time for an active BWP, DCI format 1\_1 and 0\_1 can be supported for explicit indication.**

**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.**

## Qualcomm Incorporated

1. R1-2104684 DCI-based power saving adaptation during DRX ActiveTime Qualcomm Incorporated

Observation 1: SSSG switching can potentially provide higher flexibility than other schemes in the joint adaptation of PDCCH monitoring periodicity, aggregation levels, number of candidates, DCI formats, etc.

Proposal 1: For the unified design of DCI-based power saving, search space group switching is considered as the baseline. To emulate PDCCH skipping with search space group switching, a dormant search space set group is introduced.

* To enable HARQ retransmission 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 by a dormancy timer or after transmitting a scheduling request.

Proposal 2: For explicit indication of PDCCH monitoring adaptation, the following candidates are considered:

* Scheduling DCI: DCI formats 0\_1/1\_1/0\_2/1\_2
* Non-scheduling DCI: DCI format 1\_1 (similar to Case 2 SCell dormancy indication), DCI format 2\_0, DCI format 2\_6 (outside active time)

Proposal 3: For implicit indication of PDCCH monitoring adaptation, the following candidates are considered:

* **Configured timer (per-non-default SSSG, if more than two SSSGs are supported)**

Proposal 4: For the unified design of PDCCH monitoring adaptation based on SSSG switching, the maximum number of configured SSSGs larger than two is considered.

Proposal 5: In the CA scenario, for the joint adaptation across CCs, carrier-group-based PDCCH monitoring adaptation is considered.

## OPPO

1. R1-2104790 DCI-based power saving adaptation solutions OPPO

***Proposal 1: Triggering PDCCH monitoring adaptation by DCI format 1\_1.***

***DCI format 0\_1 can optionally triggering PDCCH monitoring adaptation.***

***Proposal 2: 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.***

## Intel Corporation

1. R1-2104918 Discussion on DCI-based UE Power Saving Schemes during active time Intel Corporation

**Proposal 1: Support Enhancement of DCI(s) utilized for Rel-16 power saving adaptation for supporting both skipping PDCCH monitoring for a duration and SSSG switching. Consider following options/framework to provide the signaling:**

* **DCI format 2\_6 during active time**
* **Extend scheduling or non-Scheduling DCI providing SCell dormancy**

**Proposal 2: DCI indicates a duration for the switched SSSG; UE switches back to previous/default SSSG after duration ends.**

**Proposal 3: Postpone discussion on impact to data scheduling due to PDCCH skipping after deciding whether a scheduling and/or non-scheduling DCI are supported for power saving adaptation.**

**Proposal 4: Application delay is specified based on the Pswitch of SSSG switching in NR-U.**

* **Application delay for PDCCH skipping for a duration can be based on the SPS PDSCH release processing time (Capability 2 in Table 10.4-1 in TS 38.213).**
* **Application delay for SSSG switching for power saving purpose is determined according to the same rule as for the definition of Pswitch in Rel-16 NR-U design.**

## Apple

1. R1-2105118 Enhanced DCI-based power saving adaptation Apple

***Proposal 1: Different SSSG configurations and skipping steps can be configured by RRC, and jointly triggered by DCI. The skipping step is defined as SSSG periodicity.***

***Proposal 2: Additional triggering bits in scheduling DCI format 0-1, 0-2, 1-1 and 1-2 can be 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, reuse DCI format 1-1 with additional triggering bits per cell group.***

***Proposal 4: Application timeline can be specified based on the triggering methods and whether skipping or switching is triggered.***

***Proposal 5: Different reference point can be used for different triggering method.***

* ***When triggered by non-scheduling DCI: the last symbol of DCI transmission can be used as reference point.***
* ***When triggered by DL DCI: The last symbol of ACK transmission can be used as reference point.***
* ***When triggered by UL DCI: The last symbol of PUSCH transmission can be used as reference point when drx-RetransmissionTimerUL is not configured or longer than a threshold. If drx-RetransmissionTimerUL is configured and less than a threshold, the drx-RetransmissionTimerUL expire can be used as reference point***

***Proposal 6: Processing time can be defined based on the different reference point and whether skipping or switching is triggered.***

## Fraunhofer HHI, Fraunhofer IIS

1. R1-2105263 DCI-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: Specify a scheduling DCI format with a trigger indicating an SSG switch.

Proposal 3: Adopt SSG switching using the minimum offset signaling to trigger a switch.

Proposal 4: Support PDCCH skipping by enabling empty or non-empty SSGs which stay active for a configured time duration.

Proposal 5: The PDSCH processing time shall be adaptable based on certain parameters, e.g., the minimum scheduling offset or the currently active SS group.

## Samsung

1. R1-2105324 Discussion on DCI-based power saving techniques Samsung

**Proposal 1: Support search space set group (SSSG) switching with search space set group associated with a CORESET group for PDCCH monitoring adaptation across TRPs.**

**Proposal 2: Support search space set group (SSSG) switching among more than two search space set groups, including empty SSSS group for PDCCH skipping.**

**Proposal 3: Support triggering methods for SS set group switching, including**

* **Opt-1: the scheduling DCI format with PDSCH/PUSCH**
* **Opt-2: group-common DCI format, e.g., DCI format 2-6**

**Propose 4: Support UE assistance information of preferred search space set group.**

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

**Proposal 6: Support PDSCH processing time relaxation based on minimum scheduling offset.**

## MediaTek Inc.

1. R1-2105388 On enhancements to DCI-based UE power saving during DRX active time MediaTek Inc.

**Observation 1: It is necessary to resolve the impact to data scheduling caused by PDCCH skipping adaptation**

**Observation 2: If UE switches to power-saving setting ONLY when the outcome of HARQ processing is valid, PDCCH adaptation can still achieve significant power saving gain while causing less impact to data scheduling.**

**Observation 3: If the HARQ processing outcome is invalid or unknown, a configured delay switch duration can accommodate possible data retransmission or retransmission request.**

**Proposal 1: Adaptation of UE PDCCH monitoring can depend on HARQ processing outcome after receiving the scheduling DCI that indicate the adaptation.**

* **If HARQ processing outcome is valid, UE switches to power-saving setting.**
* **If HARQ processing outcome is invalid or unknown, UE waits for a configured time duration for ReTXs.**
* **Whether UE switches to power-saving setting in RTT time left for UE implementation.**



Figure 2: Illustration of UE power saving adaptive depends on HARQ processing.

**Observation 4: Application delay should depend on UE processing time.**

**Proposal 2: Different application delay can be specified for Rel-17 enhancement as an extension for Rel-16 SSSG switching and analogous to cross-slot scheduling.**



Figure 4: Based on the setting UE stays and switches to, the application delay should be different

**Observation 5: Alt 1 can reuse R16 SSSG switching specification and achieve the same power saving gain as Alt 2a over FTP traffic.**



**Figure 5: Both alternatives achieve lots of power saving gain in frequent-less traffic**

**Observation 6: Alt 1 can achieve better power saving than Alt 2a for XR traffic with frequent UL.**



**Figure 6: Alt 2a can support XR traffic well by setting appropriate SSSG.**

**Proposal 3: Alt 1 (based on SSSG switching) is recommend.**

**Observation 7: “scheduling DCI based” triggering scheme has been widely used in Rel-15/16 power saving techniques including BWP switch, SCell dormancy and cross-slot scheduling. In addition, compared to “non-scheduling DCI based” solution, its signalling overhead is small. Therefore, for the triggering scheme of Rel-17 power saving enhancement, “scheduling DCI based” solution can be prioritized.**

**Proposal 4: Support the scheduling DCI format for DCI for Rel-17 SSSG switching enhancement, including**

* + **Format 1\_1,**
  + **Format 0\_1,**
  + **Format 0\_2/1\_2**

**Proposal 5: Specify the UE behaviour when receiving power saving indications from both UL grant and DL grant.**

## LG Electronics

1. R1-2105436 Discussion on DCI-based power saving adaptation during DRX ActiveTime LG Electronics

***Observation 1: SS set group switching by detecting a DCI may cause unnecessary power consumption for a connected-mode UE.***

***Observation 2: Skipping monitoring all SS sets may impact the latency performance for a connected-mode UE.***

***Proposal 1: 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 2: For triggering PDCCH monitoring adaptation during DRX Active Time, the following DCI formats are considered:***

* + - ***scheduling DCI (DCI format x\_1, DCI format x\_2)***
    - ***DCI format 2\_6***
      * ***Discuss whether and how to define the monitoring window for DCI format 2\_6 inside DRX Active Time.***

***Proposal 3: Consider supporting DCP outside DRX Active Time indicates PDCCH monitoring adaptation inside DRX Active Time.***

***Proposal 4: For PDCCH monitoring adaptation, the following SS set (group) configurations should be considered for handling error cases or sudden data transmission:***

* + - ***default SS set(s) which a UE returns to monitor after a certain period of time***
    - ***always-on SS set(s) which a UE always monitors***

***Proposal 5: 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.***

## Panasonic

1. R1-2105476 Potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime Panasonic

Proposal 1: 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 (including no search space) with/without timer back to the first list of the search spaces. DCI indicates which index in the list the UE should follow.

Proposal 2: DCI formats capable of UE specific indication should be considered with higher priority than group common DCI.

**Proposal 3: To support DCI based PDCCH monitoring adaptation in active time, enhancement based on DCI format 1\_1, 1\_2, and 0\_2 should be prioritized.**

## Nokia, Nokia Shanghai Bell

1. R1-2105505 UE power saving enhancements for Active Time Nokia, Nokia Shanghai Bell

Based on the last meeting discussion, the debate seems not be anymore as which functionalities to support, but how to support them. Some companies, as illustrated in Alt1 would like to use common frame work, building upon Rel-16 functionalities to enable the discussed power saving methods, while other companies would prefer to separate these to different features. As discussed earlier our preference is to build upon existing frame work, based on Alt 1. This would enable, through timer based SSSG switching similar power saving mechanisms in Active time as are currently possible through C-DRX. As this would be autonomous (through the timers), this circumvents the UE-NW interaction, while retaining both synchronised on the PDCCH monitoring occasions.

**Proposal:** Adopt Alt1 from last meetings agreement for further work.

In section 2 we summarised the earlier evaluations and made following observations and proposal:

**Observation:** *With more intense traffic profiles the attainable gains from different power saving schemes are reduced.*

**Observation:** *SSSG switching and PDCCH skipping provide comparable gains in all evaluated scenarios.*

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

In section 3 we discussed the possible extensions to SSSG framework to enhance achievable power saving via reduced PDCCH monitoring and made following:-

**Proposal:** Introduce support for DCI based SS set group switching to scheduling DCIs, format x\_1 and x\_2.

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

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

**Observation:** Consider whether implicit SSSG switching needs to be triggered based on detection of non-scheduling DCI.

**Proposal:** Procedures such as SR transmission or beam failure recovery should result UE to change SS set group to monitor PDCCH more frequently.

**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 default SS set group that is applied during On Duration, at least when DCP is configured.

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

**Proposal:** PDCCH monitoring relaxation should not be applied to CSS.

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

## NTT DOCOMO, INC.

1. R1-2105710 Discussion on extension to DCI-based power saving adaptation NTT DOCOMO, INC.

**Observation 1: The benefit of SSSG switching is that UE can perform PDCCH skipping multiple times without additional DCI indication, and can stop PDCCH skipping based on the timer or data arrival. It can provide power saving gain for a long term with small DCI overhead.**

**Observation 2: The benefit of PDCCH skipping for a duration is that the skipping duration can be flexibly indicated along with DCI indication. gNB can flexibly determine the skipping duration based on scheduling condition and so on.**

**Proposal 1: Following options should be considered for the common design for both SSSG switching and PDCCH skipping for a duration.**

* **Option 1: DCI indicating SSSG switching can indicate PDCCH monitoring periodicity for the target SSSG, i.e., PDCCH skipping duration.**
* **Option 2: DCI indicating PDCCH skipping for a duration can indicate the number of PDCCH skipping.**
  + **UE performs PDCCH monitoring between PDCCH skipping durations**

**Proposal 2: SSSG switching enhanced for the licensed bands should be supported.**

* **DCI indicating SSSG switching can indicate PDCCH monitoring periodicity for the target SSSG, i.e., PDCCH skipping duration.**

**Proposal 3: DCI format 0\_1 and 1\_1 can indicate SSSG switching.**

**Observation 3: PDCCH skipping along with cross-slot scheduling can maximize the benefit of cross-slot scheduling.**

**Proposal 4: PDCCH skipping for the duration of the applicable minimum scheduling offset from PDCCH monitoring occasion should be supported.**

## InterDigital, INC.

1. R1-2105744 PDCCH monitoring reduction in Active Time InterDigital, Inc.

**Proposal 1: Scheduling DCI is used for explicit indication of PDCCH monitoring reduction in Active Time.**

**Proposal 2: To support a common design, down-select one of the following unified schemes:**

* **Unified scheme 1: DCI indicates a next state with null SSSG definition.**
* **Unified scheme 2: DCI indicates either a next state or PDCCH skipping duration based on current state without null SSSG definition.**

**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.**

## ITRI

1. R1-2105758 Discussion on DCI-based power saving adaptation ITRI

**Observation 1:**

More SSSG may increase DCI bit for switching indication and complicate UE behavior on the error handling.

**Observation 2:**

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

**Proposal 1:**

Support the enhancement of Rel-16 SSSG switching to support PDCCH monitoring adaptation including skipping for a duration.

**Proposal 2:**

For the case of multi-cell operation, the SSSG for different (group of) serving cells should be indicated individually.

**Proposal 3:**

Further study the SSSG switch impacts over PDCCH monitoring.

## Lenovo, Motorola Mobility

1. R1-2105772 Enhanced DCI based power saving adaptation Lenovo, Motorola Mobility

* **Observation 1: UE can fully utilize both Rel-16 and Rel-17 UE power saving features without increasing PDCCH monitoring capability, if a DCI format(s) supports both Rel-16 and Rel-17 power saving adaptation.**
* **Proposal 1: For DCI based PDCCH monitoring adaptation in active time, support Alt 2a, i.e. enhancement of DCI(s) utilized for Rel-16 power saving adaptation for supporting both skipping PDCCH monitoring for a duration and SSSG switching.**
* **Observation 2: Rel-16 search space set group configuration may result in an unnecessary high signalling overhead.**
* **Proposal 2: In Rel-17, support configuring more than one value for a subset of search space configuration parameters in a given search space configuration.**
* **Proposal 3: Rel-17 NR supports search space 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 adaptation within a DRX cycle based on scheduling DCI.**
* **Proposal 4: Support scheduling-DCI based dynamic PDCCH skipping during Active Time for UE power saving.**
* **Proposal 5: A set of PDCCH monitoring occasions not to be monitored can be determined based on scheduling information including a scheduling offset value (e.g. K0/K2) and the minimum scheduling offset values for PDSCH and PUSCH (K0\_min/K2\_min).**
* **Proposal 6: Support joint indication of minimum applicable scheduling offset K0/K2 and PDCCH skipping.**

## Ericsson

1. R1-2105794 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.](#_Toc71665270)

[Observation 2 UE PDCCH monitoring behavior during PDCCH monitoring adaptation application delay should be clear to avoid different understanding between NW and UE.](#_Toc71665271)

[Proposal 1 Support following as a common solution for SSSG switching and PDCCH skipping](#_Toc71665274)

[a. DCI indicates one of the following states to the UE](#_Toc71665275)

[i. switch to SSSG0](#_Toc71665276)

[ii. switch to SSSG1](#_Toc71665277)

[iii. skip PDCCH monitoring for duration X (X configured by RRC)](#_Toc71665278)

[iv. no change to PDCCH monitoring](#_Toc71665279)

[Proposal 2 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 feedback-based application of the PDCCH monitoring adaptation command.](#_Toc71665280)

[Proposal 3 PDCCH monitoring adaptation for Rel. 17 should not entail an interruption to UE transmission/reception on any serving cell.](#_Toc71665281)

[Proposal 4 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.](#_Toc71665282)

[Proposal 5 UL scheduling request can be used as a trigger to switch between SS-set groups. The SS-set group that UE monitors after transmitting an UL scheduling request is configurable by NW.](#_Toc71665283)

[Proposal 6 Support explicit indication of PDCCH monitoring adaptation via scheduling DCI format 1\_1. FFS : DCI format 0\_1.](#_Toc71665284)

[Proposal 7 For self-scheduling, PCell’s scheduling DCI format 1\_1 can indicate SSSG-switching/skipping for the primary cell.](#_Toc71665285)

[Proposal 8 For self-scheduling, an SCell’s scheduling DCI format 1\_1 can indicate SSSG-switching/skipping for the SCell.](#_Toc71665286)

[Proposal 9 Study further how to support SSSG-switching/skipping for multiple groups of cell(s). Details including number of groups FFS.](#_Toc71665287)

## Asia Pacific Telecom, FGI

1. R1-2105824 Discussion on extension(s) to Rel-16 DCI-based power saving adaptation Asia Pacific Telecom, FGI

**Observation 1: Simply reusing SSSG switching mechanism in Rel-16 without any enhancements cannot satisfy both switching and skipping functionalities since whichever the SSSG switched to, the UE still needs to monitor search space sets in that SSSG so that PDCCH skipping cannot be achieved.**

**Observation 2: By introducing an empty SSSG to be one of the SSSGs for switching, the common design for DCI based PDCCH monitoring adaptation to support both SSSG switching and PDCCH skipping for a duration can be achieved.**

**Proposal 1: Support enhancement of Rel-16 SSSG switching to support PDCCH monitoring adaptation including skipping for a duration**

**Proposal 2: Explicit indication by a DCI and timer-based SSSG switching in Rel-16 should be the baseline for Rel-17 DCI based PDCCH monitoring adaptation.**

**Proposal 3: Introduce an empty SSSG to be one of the SSSGs for SSSG switching.**

**Observation 3: Two SSSGs with one empty SSG has less spec impact while more than two SSSGs with one empty SSG provides better flexibility on PDCCH monitoring adaptation which introduces more power saving gain.**

**Proposal 4: RAN1 down selects one of the following alternatives for SSSG switching in Rel-17.**

* **Alt (a): Total number of SSSGs remains two, with one empty SSSG and one non-empty SSSG.**
* **Alt (b): Total number of SSSGs can be larger than two, with one empty SSSG and multiple non-empty SSSGs.**

**Observation 4: For SR, the UE should monitor the PDCCH to receive the scheduling for UL grant. For RACH, the UE should monitor the PDCCH to receive the Msg2/Msg4/MsgB.**

**Observation 5: Since NW can not predict the UE will trigger SR and CBRA, the explicit SSSG switching indication by NW to switch out of the empty SSSG does not work.**

**Proposal 5: Implicit SSSG switching for SR and RACH should be considered.**

## ASUSTeK

1. R1-2105850 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**

## Nordic Semiconductor ASA

1. R1-2105888 On PDCCH monitoring adaptation Nordic Semiconductor ASA

***Observation-1:*** *Section 10.4 of TS 38.213 is applicable to licensed spectrum without need for further changes.*

***Observation-2:*** *Feature searchSpaceSetGroupSwitchingwithoutDCI-r16**does not depend on COT duration and therefore is fully applicable to licensed spectrum, and thus should be used as baseline for DCI based PDCCH monitoring adaptation in active time for an active BWP.*

***Proposal-1:*** *To achieve 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, introduce DCI format 1\_1, 1\_2, 0\_1 and 0\_2 indicating, upon reception of such DCI format*

* *Initialize timer to 0 (remain in group 0)*
* *Initialize timer to value X*
* *Initialize timer to value Y*
* *Initialize timer to value corresponding to end of C-DRX active time*
* *Note: gNB may configure SS-group 1 to be empty, upon switching to SS-group 1, UE does not monitor PDCCH until timer expiry*

***Proposal-2:*** *Reuse the existing timelines for search-space group switching form sub-clause 10.4 of TS 38.213*

# 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 |

# Reference

**The following contributions are submitted in RAN1#105-E in AI 8.7.2,**

1. R1-2104224 Extension to Rel-16 DCI-based power saving adaptation during DRX Active Time ZTE, Sanechips
2. R1-2104253 Extensions to Rel-16 DCI-based power saving adaptation for an active BWP Huawei, HiSilicon
3. R1-2104374 Discussion on DCI-based power saving adaptation in connected mode vivo
4. R1-2104434 Discussion on power saving techniques for connected-mode UEs Spreadtrum Communications
5. R1-2104535 PDCCH monitoring adaptation CATT
6. R1-2104624 Discussion on PDCCH monitoring reduction during DRX active time CMCC
7. R1-2104684 DCI-based power saving adaptation during DRX ActiveTime Qualcomm Incorporated
8. R1-2104790 DCI-based power saving adaptation solutions OPPO
9. R1-2104918 Discussion on DCI-based UE Power Saving Schemes during active time Intel Corporation
10. R1-2105118 Enhanced DCI-based power saving adaptation Apple
11. R1-2105263 DCI-based Power Saving Enhancements Fraunhofer HHI, Fraunhofer IIS
12. R1-2105324 Discussion on DCI-based power saving techniques Samsung
13. R1-2105388 On enhancements to DCI-based UE power saving during DRX active time MediaTek Inc.
14. R1-2105436 Discussion on DCI-based power saving adaptation during DRX ActiveTime LG Electronics
15. R1-2105476 Potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime Panasonic
16. R1-2105505 UE power saving enhancements for Active Time Nokia, Nokia Shanghai Bell
17. R1-2105710 Discussion on extension to DCI-based power saving adaptation NTT DOCOMO, INC.
18. R1-2105744 PDCCH monitoring reduction in Active Time InterDigital, Inc.
19. R1-2105758 Discussion on DCI-based power saving adaptation ITRI
20. R1-2105772 Enhanced DCI based power saving adaptation Lenovo, Motorola Mobility
21. R1-2105794 Design of active time power savings mechanisms Ericsson
22. R1-2105824 Discussion on extension(s) to Rel-16 DCI-based power saving adaptation Asia Pacific Telecom, FGI
23. R1-2105850 A common framework for SSSG switching and PDCCH skipping ASUSTeK
24. R1-2105888 On PDCCH monitoring adaptation Nordic Semiconductor ASA

**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)