3GPP TSG RAN WG1 Meeting #104-e R1-20XXXXX

e-Meeting, 25th January – 5th February 2021

Source: Moderator (vivo)

Title: FL summary#1 of power saving for Active Time

Agenda Item: 8.7.2

Document for: Discussion and Decision

# Introduction

This contribution is a summary of the AI 8.7.2 - Potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime. The contribution is structured as follows,

Section 2 is a summary of each topics from the contributions companies submitted and relevant online/offline discussion during the meeting. And each sub-topic is arranged a sub-section. Section 3 is a summary of the potential proposals from section 2 as suggested by moderator. Section 4 is a summary of previous agreements. Section 5 is a table of summary of proposals from contributions submitted. Section 6 is the work plan. Section 7 is the decription of WI. Section 8 is reference. Section 9 is the history of this document.

# Summary of the contributions/discussions

## Issue 1: SSSG switching and PDCCH skipping

In RAN1#103-E, it is agreed that

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**

In the following table 1, companies view on supporting SSSG (Seach space set group) switching and PDCCH skipping is captured.

Table 1: Companies’ views for SSSG switching and PDCCH skipping

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| **Company** | **Views from Tdocs** |
| 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:*** |
| Huawei, HiSilicon | ***Observation 1: PDCCH skipping can achieve the power saving effect of search space set group switching.***  ***Observation 2: PDCCH skipping can achieve more flexible skipping than search space set group switching.***  ***Observation 3: The power saving of search space set group switching may be reduced in case of multiple search space sets in an active BWP. The power saving is also reduced in case of CA, especially intra-band CA.***  ***Observation 4: Dynamic PDCCH skipping provides more power saving gains than search space set group switching for intensive eMBB traffic, meanwhile with similar or even better the latency performance.***  ***Observation 5: Dynamic PDCCH skipping provides more power saving gains than search space set group switching for VoIP. The latency of dynamic PDCCH skipping and search space set group switching are similar.***  ***Proposal 1: Specify DCI based PDCCH skipping.*** |
| CATT | ***Observation 1: SSSG switching has non-negligible drawbacks for PDCCH monitoring reduction including group common indication, new system design, less flexibility for monitoring reduction, redundant search space set configuration, additional specification changes etc.***  ***Proposal 1: Compared to SSSG switching, the PDCCH monitoring adaptation can dynamically indicate UE to reduce the PDCCH monitoring, e.g. the PCell dormancy, the PDCCH BD reduction, the PDCCH monitoring occasion granularity change, etc., without any changes of SearchSpace configuration.*** |
| vivo | **Observation 1: The similar power saving effect can be achieved by either PDCCH skipping or SS switching scheme.**  **Observation 2: Up to 31.6% power saving gain can be achieved PDCCH skipping to the next DRX cycle. Up to 12ms packet latency will be additionally increased meanwhile.**  **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.** |
| GDCNI | ***Proposal 1: DCI-based PDCCH monitoring should be considered. DCI format 2\_6 can be extended to support PDCCH skipping until the next DRX on duration.***  ***Proposal 2: Treat PDCCH skipping as part of the self-adaptation PDCCH monitoring. Skip only a certain duration and switch with DCI format 2-6.*** |
| ZTE , Sanechips | **Observation 1: Both PDCCH skipping and search space set group switching can reduce more power consumption than DRX command MAC CE.**  **Observation 2: In the case that the PDCCH skipping period is configured to be equal to the number of PDCCH monitoring occasions reduced by search space set group switching scheme, PDCCH skipping provides larger power saving gain than search space set group switching.**  **Observation 3: Latency for DRX command MAC CE, PDCCH skipping and search space set group switching are almost the same as the baseline.**  **Observation 4: For search space set group switching scheme, the sleep period is dispersed by the search space set group 1 with sparser PDCCH monitoring occasions, which results in a lower power saving gain from search space set group switching compared with PDCCH skipping.**  **Proposal 1: According to the power saving gain, latency and specification workload, PDCCH skipping should be adopted as the Rel-17 dynamic PDCCH adaptation during DRX active time.** |
| MediaTek Inc. | **Observation 1: Timer-based mechanism in Rel-16 SSSG switching can be utilized to create PDCCH skipping behaviour. Based on existing Rel-16 specification, both Rel-17 candidate schemes can be implemented by SSSG switching. Therefore, SSSG switching can be selected for Rel-17 extension.**  **Figure 2: SSSG switching can be utilized to create PDCCH skipping behaviour**  **Observation 2: 2nd PDCCH skip duration provides limited additional power saving gain. The power saving gain can even reduce because of extra delay to data scheduling. It suffices to consider PDCCH skipping with one skip duration for Rel-17.**  **Figure 3. Power consumption and latency increment in FR2 FTP traffic**  **Figure 4. Power consumption and latency increment in FR1 FTP traffic**  **Proposal 1: For Rel-17 DCI-based power saving enhancement, prioritize extension to Rel-16 search space group switching with UE-specific DCI format.** |
| Intel Corporation | **Observation 1: In terms of specification impact, both SS Set switching and PDCCH skipping can be similar. In one simple approach, a 1-bit field can be considered in scheduling DCI format to provide trigger for either SS Set switching or PDCCH skipping.**  **Observation 2: PDCCH skipping solution with dynamic indication of skipping/sparse monitoring duration can provide additional flexibility and can be more effective in adapting to changes in traffic characteristics, compared to SS Set Switching between two SS set groups.**  **Observation 5: Both PDCCH skipping and SS Set switching indication by DCI may result in similar power saving gain.**  **Proposal 1: Support PDCCH skipping indication via a DCI format in Rel-17.**   * **FFS: DCI formats.** |
| Spreadtrum Communications | ***Proposal 1: Consider to specify PDCCH skipping in Rel.17.***  ***Proposal 2: The triggering method of PDCCH skipping should be further studied.***  ***Proposal 3：Consider to specify search space set group switching for eMBB in Rel.17.*** |
| LG Electronics | ***Observation 2: Skipping monitoring all SS sets may impact the latency performance for a connected-mode UE.***  ***Proposal 3: Support SS set group switching for DCI-based PDCCH monitoring adaptation.*** |
| Asia Pacific Telecom, FGI | **Observation 1: DCI-based PDCCH skipping scheme can achieve a tradeoff between low latency for data transmission and UE power saving.**  **Observation 2: NR-U search space set group switching mechanism can be the baseline for Rel-17 power saving.**  **Observation 3: NR-U search space set group switching mechanism can only be indicated by group common DCI.**  **Observation 4: UE-specific DCI should be considered for the switching indication if enhanced power saving search space set group switching mechanism is supported.**  **Observation 5: PDCCH skipping scheme is suitable for one-shot PDCCH monitoring adaptation, whereas search space set group switching scheme is suitable for long-term PDCCH monitoring adaptation.**  **Observation 6: Although PDCCH skipping and search space set group switching could both achieve power saving gain, neither of them can tackle all kinds of traffic patterns effectively.**  **Observation 7: It’s beneficial to give the NW flexibility for selecting either one or both schemes to adapt to different traffic patterns.**  **Proposal : Both PDCCH skipping and search space set group switching schemes should be supported in Rel-17 power saving.** |
| Lenovo, Motorola Mobility | * **Proposal 1: Support adaptation of a search space configuration in every DRX cycle via enhanced power saving DCI.** * **Proposal 2: Support scheduling-DCI based dynamic PDCCH skipping during Active Time for UE power saving.** |
| CMCC | **Proposal 1. Both search space set group switching and PDCCH skipping can be supported.** |
| Samsung | **Proposal 1: Specify search space set group switching only for DCI-based dynamic PDCCH adaptation in Rel-17.** |
| Fraunhofer HHI, Fraunhofer IIS | [**Proposal 1: Adopt dynamic search space switching using implicit signaling to trigger a switch, e.g., minimum scheduling offset.**](#_Toc61869177)  [**Proposal 2: Deprioritize PDCCH skipping indication.**](#_Toc61869178) |
| Panasonic | **Proposal 2: Dynamic search space set group switching should be supported by DCI format 1\_1, 0\_1, 1\_2, 0\_2, 2\_6. Further enhancement to DCI format 2\_0 can also be considered.**  **Proposal 3: Implicit dynamic search space set group switching in conjunction with multi-slot PDSCH/PUSCH should be studied.**  **Proposal 4: PDCCH skipping for a certain duration / DRX cycle should be supported by DCI format 2\_6.** |
| Apple | ***Observation: One-time PDCCH skipping allow large skipping value to be set, which maximize UE power saving gain.***  ***Proposal 1: Support of dynamic PDCCH monitoring skipping method in Rel-17 active mode UE power enhancement.***  ***Proposal 3: Unified design to enable both skipping and switching can be studied*** |
| Qualcomm Incorporated | Observation 1: For the unified design of DCI-based power saving, search space group switching can be the baseline. To emulate PDCCH skipping with search space group switching, a dormant search space set group can be introduced.   * To enable HARQ retransmission during the dormant search space set group, discontinuous PDCCH monitoring according to RTT and Retransmission timers can be allowed. * The UE can transition back to a non-dormant search space set group by a dormancy timer or after transmitting a scheduling request.   Proposal 4: A unified design for search space set group switching and PDCCH skipping should be pursued in Rel-17. |
| InterDigital, Inc. | ***Observation 1: Search space set switching provides higher gain than PDCCH skipping.***  ***Observation 2: Existing MAC CE based mechanism can be used to skip PDCCH monitoring to the next DRX cycle.***  ***Observation 3***: **Search space set switching can be supported with minimal specification effort by extending the existing mechanism in NR-U.**  ***Proposal 1***: ***If supported, PDCCH skipping should be applicable per search space set.***  ***Proposal 2: Search space set switching is supported for connected mode UEs in Re-17.*** |
| Ericsson | [Proposal 1 For Rel-17 UE power savings, specify extension/modification of search space set group switching.](#_Toc61891276) |
| ASUSTeK |  |
| NTT DOCOMO, INC. | **Proposal 1: Enhanced Rel-16 search space set group switching should be applied to licensed bands.**  **Proposal 6: Support of both enhanced search space set group switching and PDCCH skipping for the duration of the applicable minimum scheduling offset.** |
| Nokia, Nokia Shanghai Bell | **Observation:** *With more intense traffic profiles the attainable gains from different power saving schemes are reduced.*  **Observation:** *SS switching and PDCCH skipping provide comparable gains in all evaluated scenarios.*  **Observation:** *SS switching has lower signalling overhead than PDCCH skipping for most of the evaluated traffic scenarios.*  **Proposal:** *Spesify enhacements to SS group switching in R17 to support better power saving functionality for active time power saving.* |

## Issue 1-1: trigerring of PDCCH skipping

Skipping: Qualcomm, OPPO, vivo, Huawei, HiSi,CATT, ZTE, Apple, Panasonic, CMCC, DOCOMO, GDCNI, Intel, Samsung, Spreadtrum (15)

* Explicit indication of PDCCH adaptation
  + Scheduling DCI Supporetd by Qualcomm, Lenovo/Motorola Mobility
    - Format 1\_1
      * Supported by OPPO, vivo, Huawei, HiSi,CATT, ZTE, Apple, Spreadtrum
    - Format 0\_1
      * Supported by OPPO(optionally), vivo, Huawei, HiSi, CATT, ZTE, CMCC, Apple, Spreadtrum
    - Format 0\_2/1\_2
      * Supported by vivo, CMCC, Apple
  + Non-scheduling DCI
    - Format 2\_6 in active time
      * Supported by Huawei, HiSi, GDCNI, Intel, Panasonic, Spreadtrum
    - Format 2\_0
      * Supported by Panasonic
    - Format 1\_1 (SCell dormancy case 2)
      * Supported by CATT, Spreadtrum, Intel
  + additional indication mechanism
    - By reusing Rel-16 SCell dormancy indication when CA is configured, FFS details
      * Supported by CATT (SCell dormancy indication bits in case 1 or case 2), Intel, Spreadtrum
    - By reusing Rel-16 cross-slot scheduling indication when R16 cross-slot scheduling is configured, FFS detailds
      * Supported by Lenovo, MotM (joint indication of minimum applicable scheduling offset K0/K2 and PDCCH skipping), DOCOMO, Spreadtrum
* DCI dynamically indicates a period for skipping
  + FFS: hot to indicate the period, e.g., number of slots or skipping current DRX
    - Supported by OPPO, CATT, vivo, ZTE, Intel, CMCC, Spreadtrum
* A semi-static priod of skipping
  + PDCCH skipping for a duration indicated by minimum scheduling offset
    - Supported by Samsung
* FFS: when the UE applies the skipping commend

Please kindly provide your views for the email discussion on these options. Comments on the potential observations are also encouraged.

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| **Company name** | **Views** | **Comment(s) (including suggestions on the observations)** |
| CATT | We support semi-statically configured number of skipping interval indicated by scheduling and non-scheduling DCI. | Since DCI design for SCell dormancy has sufficient number of bits for scheduled DCI (case 1) and non-scheduled DCI (case 2), we could use the framework for PDCCH adaptation in PCell |
| Samsung | Duplicated functions from SSSG should be avoided. | PDCCH skipping for a period other than minimum K0 is not needed. Because, it can be achieved by SSSG switching. PDCCH skipping supports PDCCH monitoring adaptation on time domain adaptation only, while SSSG provide flexibility for adapation on many dimensions, including time, frequency, TRPs, etc. So, we think PCCH skipping with dynamic sleep duration should be deprioritized in general. |
| Huawei, HiSilicon | Specify PDCCH skipping | We support to specify the PDCCH skipping because PDCCH skipping is more flexible and can achieve the same effect of SS group switching. We support the reuse of dormancy framework to achieve the PDCCH skipping. |
| OPPO | PDCCH Skipping is preferred as the power saving solution. Scheduling DCI should be use to avoid extra power consumption. | The switching of SSSG would not out perform the PDCCH skipping. For this WI, we should focus on the power saving purpose. |
| Lenovo, Motorola Mobility | The above categorization can be further improved, as shown below.  1 ) Dynamic indication of skipping   * Scheduling DCI based indication * Non-scheduling DCI based indication * FFS: DCI formats, DCI field, explicit or implicit indication   2) Semi-static configuration of skipping | In the scheduling DCI based skipping indication, a set of PDCCH monitoring occasions to skip can be determined based on a scheduling offset value (i.e. K0/K2) and the minimum scheduling offset values (i.e. K0\_min/K2\_min). For example, the set of consecutive PDCCH monitoring occasions to skip starts from a PDCCH monitoring occasion right after a PDCCH monitoring occasion, where the UE has detected the DCI scheduling a PDSCH or PUSCH, and ends at the latest DCI monitoring occasion, where DCI scheduling the PDSCH or PUSCH can potentially be transmitted according to the minimum scheduling offset restriction. |
| Nokia | It is preferred to extend the SSSG functionality and not specify duplicate functionalities in terms of power saving. | As discussed in our paper, SSSG switching and PDCCH skipping provide similar power saving gain, while SSSG switching has lower overhead and with timer based mechanism this can be achieved without additional reliance to NW indication, similarly as with C-DRX. |
| ZTE, Sanechips | Support PDCCH skipping | According to our evaluation results, PDCCH skipping triggered by scheduling DCI can provide more power saving gain than SSSG switching as PDCCH skipping triggered by scheduling DCI can provide a continuous sleep period for the UE. So scheduling DCI is preferred to trigger PDCCH skipping. |
| Qualcomm | We support the PDCCH skipping functionality. | We believe the PDCCH skipping functionality, i.e., dynamic indication of a skip duration by DCI, is beneficial, especially for some traffic types. We support scheduling DCI for the triggering mechanism, but non-scheduling DCI (i.e., similar to Case 2 SCell dormancy triggering) can also be considered. We are open to discuss whether it should be supported as a separate function or as a unified function with SSSG switching. |
| Apple | PDCCH skipping should be specified as it provides the highest power saving gain. | Potential PDCCH skipping intervals can RRC configured, and dynamically indicated by scheduling and non-scheduling DCI. |
| Intel | Specify PDCCH skipping. Duration can be dynamically indicated from a set of configured values | As other companies mentioned, PDCCH skipping is more flexible and indication of duration in a dynamic manner provides useful tool for network for adaptation based on traffic characteristics. We are open to consider use of DCI format 2\_6, or scheduling/non-scheduling DCI for the indication. If included in format 1-1, we agree that SCell dormancy signaling framework can be extended for this purpose. Updated our position in the list above. |
| Ericsson | Prefer to specify extension/modification of search space set group switching. | According to our evaluations, search space set group switching provides better UPT-loss vs power-saving trade-off compared to PDCCH-skipping, and SSSG can, with suitable settings mimic the skipping functionality. |
| DOCOMO | PDCCH skipping for duration of the applicable minimum scheduling offset | PDCCH skipping along with cross-slot scheduling should be considered so that the benefit of cross-slot scheduling can be maximized. Although general PDCCH monitoring adaptation can be achieved by SSSG switching, it can satisfy other space of power saving to have PDCCH skipping for duration of the applicable minimum scheduling offset along with cross-slot scheduling. There is very low/no additional signalling overhead for indication of PDCCH skipping for the duration of the applicable minimum scheduling offset since the duration of PDCCH skipping does not need to be indicated. |
| CMCC | Support PDCCH skipping, shcdueling DCI can be used to indicate the skipping time values. | PDCCH skipping is more flexible, RRC can pre-configure some skpping time values and scheduling DCI canbe used to indicate which skpping time value to be used without introuduce additional signalling overhead. |

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## Issue 1-2: trigerring of SSSG switching

Switching: Qualcomm, MTK, CMCC, Samsung, Nokia, OPPO, vivo, LGE, Panasonic, Ericsson, DOCOMO, Spreadtrum, Fraunhofer (13)

* Explicit indication of PDCCH adaptation
  + Scheduling DCI Supporetd by Qualcomm, MTK, CMCC, Samsung, Nokia, Lenovo/Motorola Mobility
    - Format 1\_1
      * Supported by OPPO, vivo, LGE, Panasonic, Ericsson, DOCOMO
    - Format 0\_1,
      * Supported by OPPO(optionally), vivo, LGE, Panasonic, Ericsson(FFS), DOCOMO
    - Format 0\_2/1\_2
      * Supported by vivo, LGE, Panasonic
    - Format 1\_0
      * Supported by vivo(only for switch back to default)
  + Non-scheduling DCI supported by vivo, Samsung
    - Format 2\_6 in active time
      * Supported by LGE, Samsung, Qualcomm, Lenovo/Motorola Mobility (before active time)
    - Format 2\_0
      * Supported by Panasonic
    - Format 1\_0
      * Supported by vivo
  + additional indication mechanism
    - By reusing Rel-16 SCell dormancy indication when CA is configured, FFS details
      * Supported by
    - By reusing Rel-16 cross-slot scheduling indication when R16 cross-slot scheduling is configured, FFS detailds
      * Supported by DOCOMO(duration of the applicable minimum scheduling offset)
* DCI dynamically indicates a period, UE switch SSSG after timer expried
  + Supported by vivo
* RRC configured a timer, UE switch back after timer expired.
  + Supported by OPPO, vivo, MTK, Nokia, Spreadtrum
* SSSG activation/deactivation
  + DOCOMO
* Implicit SSSG switching
  + SSSG switching triggered by SR
    - Supported by Qualcomm, Nokia
  + SSSG switching triggered by RACH
    - supported by Nokia
* [FFS how to support SSSG switching for multiple groups of cell(s).](#_Toc61891280) 
  + Supported by Ericsson

Please kindly provide your views for the email discussion on these options. Comments on the potential observations are also encouraged.

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| **Company name** | **Views** | **Comment(s) (including suggestions on the observations)** |
| CATT | Rel-16 SSSG is supported | The SSSG supported by Rel-16 NR-U should be the starting point for SSSG. Dedicated DCI, e.g., DCI format 1\_1, could be used for search space switching indication if the substantial power saving gain is shown comparing to skipping and no complicated miss-detection of SSS triggering DCI handling |
| Samsung | Support explicit and UE-specific indication | Compared with Rel-16 NR-U, the enahcnement can be UE-specific indication/field, which can be provided either based on scheduling DCI or GC-PDCCH.  Explicit indication can be considered first as majority support it. Implicit indication methods can be FFS. |
| Spreadtrum | Explicit indication |  |
| Panasonic | To clarify our position in above | We also support DCI format 2\_6 before active time.  Regarding DCI format 2\_0, we are open to discuss and consider for SSSG switching before drawing conclusions, considering whether group-common or UE-specific indication is intended. |
| LG | Support explicit SS set group switching by DCI indication | Switching only by detecting any DCI formats like NR-U may cause unneccesary monitoring adaptation of connected-mode UEs, which can be unnecessary power consumption.  SSSG switching by explicit DCI indication should be the first consideration and other implicit indication, e.g. timer-based, could be FFS. |
| OPPO | SSSG swithing would be beneficial for using together with the cross-slot indication. | In out contribution, we suggest to triggering together SSSG with the cross-slot scheduling. The triggering scheme can reuse the cross-slot triggering bits in Rel-16.  We agree with DoCoMo that it can configured with cross-slot switching. |
| Lenovo, Motorola Mobility | We support scheduling DCI based switching and DCI format 2\_6 based switching. | Regarding explicit switching indication via group-common PDCCH, if UE is configured with DCI format 2\_6 for adaptive DRX operation specified in Rel-16, DCI format 2\_6 based search space switching indication may be better than DCI format 2\_0 based indication, since it can reduce the number of DCI formats to monitor. |
| Nokia | Support SSSG switching with scheduling DCI, and also timer based switching. Discuss further the needed implicit mechanisms. | Similar as discussed in context of minimum scheduling slot offset restriction, certain procedures could result implicit switching of the SSSG e.g. to enable more frequent scheduling.  For DCI format 2\_6 use inside Active Time, we would think that further discussion would be needed e.g. in relation to DCI format 2\_0. To clarify that in our assumption DCI format 2\_0 is also supported. Correspondingly the use case for outside Active Time for power saving purpose should be further discussed. |

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| Fraunhofer | Explicit indication | The SSSG mechanism should be supported using explicit indication in order to avoid any ambiguity issues between the gNB and the UEs. |
| ZTE, Sanechips |  | Power saving gain is the most important factor to evaluate a power saving scheme. According to our simulation results, PDCCH skipping triggered by scheduling DCI can provide more power saving gain than SSSG switching. |
| Apple |  | Agree with ZTE comment. Power saving gain should be the criterion used to down selection. |
| Intel | Rel-16 NR-U design needs to be revised for UE specific adaptation | Although in principle both SSS and skipping may result in similar power saving gain, we think the feature of dynamic indication of duration is more useful, more efficient than timer based solution. If at all needed, SSS scheme can be combined with the feature of duration indication. |
| Ericsson | Support extension SSSG switching including explicit indication via scheduling DCI format. | Given there are multiple DCI formats inside Active (DCI 2\_0, scheduling DCI formats) that can potentially carry SSSG switching, enabling monitoring of DCI format 2\_6 inside Active time needs further discussion.  We are OK to study further other enhancementsm including for timer-based switching, implicit SSSG switching mechanisms, etc. |
| DOCOMO | Enhanced Rel-16 SSSG switching and skipping for duration of the applicable minimum scheduling offset | Enhanced Rel-16 SSSG switching should be supported, i.e., extention of supported DCI format, e.g., DCI format 0\_1 and 1\_1, and timer-based approach.  In addition, as mentioned above, PDCCH skipping for duration of the applicable minimum scheduling offset should be also considered, since there is very low/no additional signalling overhead. |
| CMCC | Support shcueduling DCI based SSSG swiching | SSSG switching and PDCCK skipping can be considerd using the same scheudling DCI format. |

## Summary of issue 1-1 and 1-2

1. **By reviewing the simulation results for PDCCH skipping and SSSG switching as follows,**

The results is updated from last meeting as follows.



**Table1. eMBB Traffic**

**Table2. Intensive eMBB Traffic**

**Table3.VoIP Traffic**

1. **By reviewing the supporting companies for PDCCH skipping and SSSG switching as follows,**

* SSSG Switching: Qualcomm, MTK, CMCC, Samsung, Nokia, OPPO, vivo, LGE, Panasonic, Ericsson, DOCOMO, Spreadtrum, Fraunhofer (13)
* PDCCH Skipping: Qualcomm, OPPO, vivo, Huawei, HiSi,CATT, ZTE, Apple, Panasonic, CMCC, DOCOMO, GDCNI, Intel, Samsung, Spreadtrum (15)

Most companies supporting SSSG switching can also support PDCCH skipping and vice verse. Therefore the following 3 options are provided and FL suggest companies to consider support the PDCCH switching and skipping functionalities in a unfied design.

**Initial Proposal:**

The following Rel-17 PDCCH adaptation in active time can be considered,

**Option 1: (switching)**

* Modification of the Rel-16 SSSG switching, e.g., UE-specific DCI / format 2\_6 / timer based indication of SSSG switching, details FFS.

**Option 2**: **(skipping)**

* Dynamic PDCCH skipping for a certain duration / DRX cycle indicated by e.g., scheduling DCI

**Option 3: (unified design)**

* allow a unified design for SSSG switching and PDCCH skipping based on enhancement to Rel-16 SSSG switching
  + e.g., a dormant search space set group to emulate PDCCH skipping with search space set group switching
  + modification of the Rel-16 SSSG switching, e.g., UE-specific DCI / format 2\_6/ timer based indication of SSSG switching, details FFS.

Please kindly provide your views for on Option 1, 2 and 3. Comments on the suggestions are also encouraged.

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| **Company name** | **Views** | **Comment(s) (including suggestions on the observations)** |
| CATT | Option 2 | PDCCH skipping with both scheduling and non-scheduling DCI. SSSG framework has the transition delay during the switch, which is additional UE power consumption |
| Samsung | Option 1 | We support option 1 over option 2. Because the benefit of option 2 can be achieved by option 1 based on NW implementation. For example, NW can configure a SSS group with periodicity of N slots, which is equalvanent to skip PDCCH duration of N-1 slots. But option 2 can’t achieve all the benefits from option 1. For example, option 1 offers adapation on other PDCCH montoring aspects, e.g. BD numbers, monitored CORESETs/CCE ALs, etc. |
| Huawei, HiSilicon | Option 2 | Search Space Set group switching can be fully realized by PDCCH skipping indication. Furthermore, if periodical skipped duration is supported as discussed in our contribution, the signaling overhead can be also minimized. PDCCH skipping is more flexible and can provide more power saving gains.  Regarding the option 3, it is wiered to introduce a new search space set group but actually there is not any search space set configured for the search space set group. Furthermore, the miss-detection and false detection of DCI indicating the SS group switching would cause misalignment regarding the monitored search space sets between gNB and UE. Even there is timer to fall back to group 1 and group 0, the UE performance shall be significantly impacted.  BTW. There is some corrections on our results in the excel sheet which has been uploaded. Our results in the figure of Table2 is not for intensive eMBB but for VoIP case. This should be also corrected. |
| Panasnoic | Option 1 and 2 | Regarding option 3, it is not so clear on how to realize the PDCCH skipping for a certain duration. Based on timer? Combining the skipped duration with a certain SSSG looks not so efficient configuration. Separate design is okay. |
| LG | Option 1 | As can be seen from the contributions, option 2 can be implemented by option 1. Also, we concern how option 2 can cope with unexpected traffic. Moreover, for power saving, option 1 is easier to be introduced than option 2 because it can be based on and enhanced from that already specified in NR-U. |
| OPPO | Option 2 | PDCCH skipping is faster than SSSG switching as the SS sets have numbers of different parameter to adapat. There is a ambiguity issues for the SSSG switching which requires more effort for both NB and UE side to recover. |
| Lenovo, Motorola Mobility | We support option 1 and option 2 | Scheduling DCI based PDCCH skipping can optimize UE’s PDCCH monitoring behavior for mixed traffics/applications.  Search space set switching is suitable to adapt to high-activity/low-activity time of a particular traffic/application. |
| Nokia | Option 1 | As discussed in our paper, SSSG switching and PDCCH skipping provide similar power saving gain, when assuming that only SS monitoring period is adapted. SSSG adaptation allows also other monitoring parameters to be adjusted, as noted by Samsung. SSSG switching can provide the power saving it with lower system overhead and with timer based mechanism this can be achieved without additional reliance to NW indication, similarly as with C-DRX. We think it is bit strange to consider UE autonomous ‘periodic’ PDCCH skipping to emulate SSSG behaviour.  Regarding option 3, it should be under network control how it configures the SS monitoring periodicity (and other parameters) for each SS set groups. |

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| Fraunhofer | Option 1 | SSSG switching and PDCCH skipping achieve a comparable result if configured appropriately. However, SSSG switching works with less signaling overhead. For example, if a UE is to stay with a sparse PDCCH monitoring density for a longer period, PDCCH skipping indication would need to indicate to the UE on a periodic basis that it has to skip monitoring occasions. In contrast, the SSSG mechanism would indicate once and stay in the sparser configuration in a semi-persistent manner. |
| ZTE, Sanechips | Option 2 | According to our evaluation results, DCI-based PDCCH skipping can provide more power saving gain than SSSG switching as PDCCH skipping can provide a continuous sleep duration for the UE.  Besides, PDCCH skipping has following benefits:   1. The monitoring pattern of PDCCH skipping is more flexible than SSSG switching; 2. For the triggering method, both PDCCH skipping and SSSG switching needs to be triggered by DCI. But PDCCH skipping does not need a timer, while it seems to be necessary for SSSG switching to consider a timer triggered mechanism to make sure UE will fallback to a default behavior in case of miss detection; 3. The application delay for PDCCH skipping is obviously less than that for SSSG switching, and a short application delay is more beneficial to UE power saving.   Hence, we think PDCCH skipping should be specified. |
| Apple |  | Agree with ZTE comment. Power saving gain should be the criterion used to down selection. |
| Intel | Option 2 | We agree with the issue with Option 3 raised by Panasonic. However, we can also be supportive of unified design where SSS can benefit from dynamic duration indication. If at all needed, following unified design under Option 3 can be considered as compromise   * Include duration indication along with SS Set Set group index in DCI |
| Ericsson | Option 1 | According to our evaluations, search space set group switching provides better UPT-loss vs power-saving trade-off compared to PDCCH-skipping. The incremental gains by specifying both SSSG switching and PDCCH skipping as opposed to specifying just one of them would be negligible. |
| DOCOMO | Option 1 and 2 | Regarding Option 3, it not clear what is “unified design”. The detailed design should be discussed based on what functionalities are supported. From our perspective, the functionalities of SSSG switching and PDCCH skipping for duration of the applicable minimum scheduling offset should be supported. |
| CMCC | Option 1 and 2 | PDCCH skipping in option 2 can be used to inidacte different skipping time flexibility, but option 3 seems cannot rezlize this function. |

## 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]

* More search space set groups can be considered to provide adaptation in multiple dimensions other than time domain, i.e. PDCCH skipping. [samsung][vivo]
* 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. [Ericsson]
* to extend the number of possible SS set groups from 2 to e.g. 3. This could facilitate further adaptation to the traffic for example by enabling gradual relaxation of the PDCCH monitoring. [Nokia]
* more SS set groups are supported e.g. 3, that whether common ‘inactivty’ timer is used for the adaptation or whether it can be separately configured for groups *N*, *N*>0.[Nokia]
* To emulate PDCCH skipping with search space group switching, a dormant search space set group can be introduced, e.g., as group 2. [Qualcomm]

One example from [Qualcomm] is as follows,



Figure 3: Unified design of DCI-based power saving: switching among SS set groups.

Some companies thinks it is not needed, [Supported by MTK]

Observation 2: 2nd PDCCH skip duration provides limited additional power saving gain. The power saving gain can even reduce because of extra delay to data scheduling. It suffices to consider PDCCH skipping with one skip duration for Rel-17. [MediaTek]

Considering vast support of both PDCCH skipping and SSSG switching, a unified design can be considered,

**Initial Proposal (issue 4)**

* **Rel-17 supports 2 SSSGs with PDCCH monitoring for an active BWP,**
* **A ‘Skipping’ SSSG is supported for Rel-17 search spacing set group switching and when it is configured on an active BWP, 3 SSSGs is supported for the active BWP**
  + **UE does not monitoring PDCCH on ‘Skipping’ SSSG,**
    - **FFS details, e.g., skipping others**
  + **FFS: how to configure/indicate ‘Skipping’ SSSG**

Please kindly provide your views. Comments on the potential observations are also encouraged.

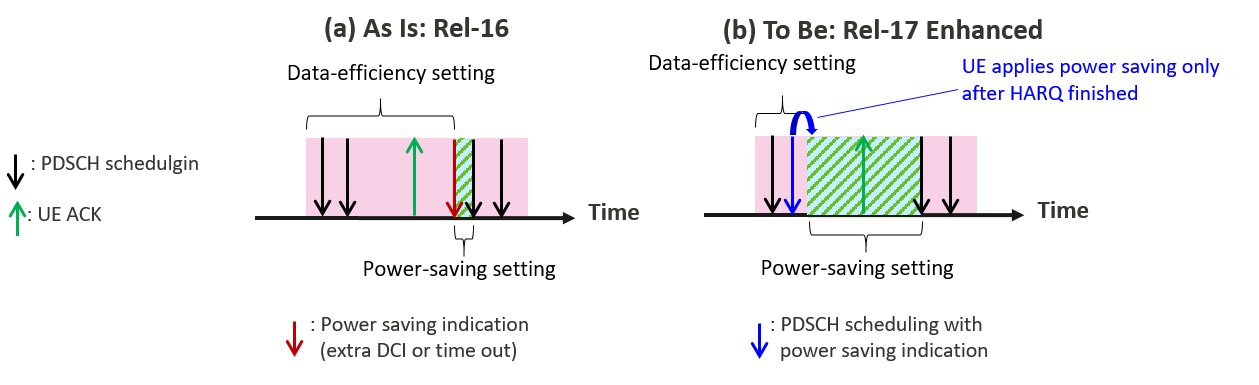
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| **Company name** | **Views** | **Comment(s) (including suggestions on the observations)** |
| CATT | Not support | DCI is decoded from blind decoding of the PDCCH candidates indicated by the search space indication. The DCI indication for SSSG and skipping is the chicken-and-egg problem, which might cause the concatenated effects of error detection. |
| Samsung | More than 2 SSSGs can be supported to provide more flexibility adapation on PDCCH monitoring. | How to configure/indicate SSSGs should be discussed for all SSSGs. |
| Spreadtrum |  | More than 2 SSSGs can be considered, but it is unnecessary to define or restrict the function of those SSSG, since this depend on the gNB implementation. For example, 3 SSSGs with different PDCCH monitoring periodicity can be configured. Of course, One of the three SSSGs can be configured as a ‘Skipping’ SSSG, if necessary.  Therefore, we only need to discuss the necessity of 3 or more SSSGs, and the triggering method between them. |
| Huawei, HiSilicon | Not support | Agree with CATT that the miss-detection or false detection of DCI may cause misalignment regarding the monitored search space sets between gNB and UE. Even there is timer to fall back to group 1 and group 0, the UE performance shall be significantly impacted. |
| LG | If supported, it should be considered carefully | We think that SSSG switching between two groups link NR-U could advantageous over PDCCH skipping from DCI field perspective because it can be triggered by only one bit. However, if more than 2 SSSGs are supported, more than 1 bit DCI field is needed and it may become signalling overhead.  On the other hand, the difference between configuring ‘skipping’ SSSG and unified design (option 3) from summary of issue 1-1 and 1-2 is somewhat ambiguous. |
| OPPO |  | We wonder if the dormant SSSG is really needed.  We can define as switching state without PDCCH monitoring for a time, which we may call it “timer”  We would like to go to the details after we conclude for the higher layer concept. |
| Lenovo, Motorola Mobility | Not support the proposal | ‘Skipping’ means not monitoring PDCCH. Therefore, no need to additionally signal/configure a search space set group that is not going to be monitored. 3 SSSG may lead to an increased DCI bit field size for switching indication. |
| Nokia | Support considering more than 2 SS set groups for additional flexibility. | Like noted in issue 1-1 and 1-2 summary, it should be under network control how the SS set groups are configured.  We don’t share the concerns related to DCI detection performance. DCI is used to control other functionality, such as BWP change, thus it should be robust enough from system perspective. |

|  |  |  |
| --- | --- | --- |
| Fraunhofer | More than 2 SSSGs can be supported | We agree that 3 SSSGs can provide more flexibility and hence, enable sophisticated use cases. The issue of misalignment has to be at least discussed. However, in our opinion an appropriate configuration by the NW can avoid severe misalignments. |
| ZTE, Sanechips |  | This issue depends on the outcome of the issue 1. It is too early to discussion issue 2. |
| Qualcomm | Support | Besides the enhanced flexibility, we think one of the the main purposes of more than 2 SSSGs to support different skipping duration, when SSSG switching is used to emulate PDCCH skipping. Thus, the maximum number of SSSGs needs further discussion, not limited to 3. |
| Apple | Do not support this proposal | Depends on discussion of issue 2. |
| Intel | Do not support | Agree with Apple that it depends on the outcome of previous proposal. Moreover, the connection between unified design as Option 3 in previous proposal and this proposal on dormant SSSG is not clear. |
| Ericsson | Baseline should be with Rel-16 SSSG switching with two SSSGs. | SSSG configuration should be flexible, just like in Rel-16. So, 2nd bullet in the proposal is not essential, but we are OK to consider more than 2 SSSGs.  The false detection rate for DCI is extremely small ( < 1e-6) and hence it should be be a non-issue. DCI mis-detection is also not an issue as it is used for other functions such as cross-slot adaptation, SCell dormancy indication, BWP switching, DCI format 2\_0-based SSSGS, etc. |
| DOCOMO |  | More than 2 SSSGs can be considered for more flexibility. For skipping SSSG, the functionality for PDCCH skipping should be discussed first. |
| CMCC |  | Can be discussed further. |

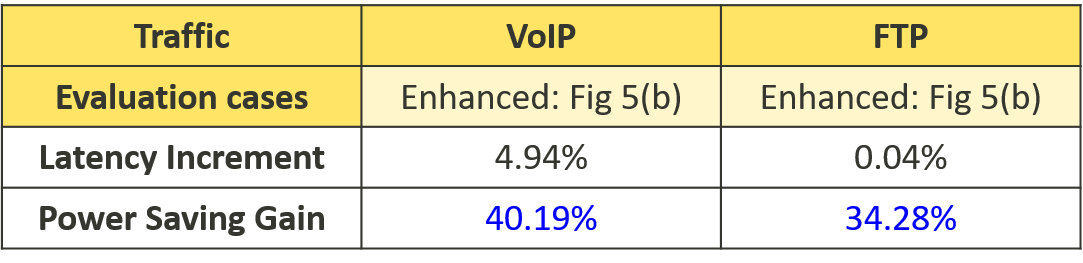
## Issue 3: interaction with HARQ/retransmission

Some companies pointed out that the 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]

MediaTek states that as shown in Figure 5(b), the retransmission-aware adaptation, i.e., applying adaptation only after HARQ ACK is fulfilled, allows UE save more power because network is able to send the adaptation triggering before receiving the HARQ-ACK information from UE.

**Figure 5: Illustration of power saving adaptive (a) Rel-16 (b) Rel-17 enhanced**

Observation 5: The retransmission-aware adaptation can reduce UE power consumption significantly. Compared to legacy behaviour, it can provide 40.2% and 34.3% of power saving gain for VoIP and FTP, respectively.

**Table 3 Performance comparison for (a) Rel-16 and (b) Rel-17 enhanced**

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

Apple proposed that

*Scheduling grant can be used to trigger PDCCH monitor skipping. Additional trigger bits in scheduling DCI 0-1, 0-2, 1-1, 1-2.*

* *When triggered by DL DCI: Skipping commend applies after ACK/NACK transmission.*
* *When triggered by UL DCI: skipping commend applies after PUSCH transmission*
* *Further discuss whether group based non-scheduling DCI should be used for monitoring adaptation.*
* *Timer based method can be defined.*

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.

**Initial Proposal :**

* **Further study SSSG switching /skipping by considering minimizing the impact to data scheduling for new transmissions and retransmissions, e.g.,**
  + **Sswitching /skipping after HARQ-ACK condition is satisfied**
    - **SSSG switching to default SSSG if HARQ ACK condition is satisfied**
    - **When triggered by DL DCI: Skipping commend applies after ACK/NACK transmission**
  + **When triggered by UL DCI: skipping commend applies after PUSCH transmission**
  + **UE monitor PDCCH for retransmission data, but it does not monitor PDCCH for an initial-transmission data during the PDCCH skipping period**

Please kindly provide your views. Comments on the potential observations are also encouraged.

|  |  |  |
| --- | --- | --- |
| **Company name** | **Views** | **Comment(s) (including suggestions on the observations)** |
| CATT | Not support | This is the gNB implementation once the PDCCH skipping or SSSG is supported. |
| Samsung | Can be discussed if needed after determining the indication method. | This proposal seems to be needed only for scheduling DCI based triggering.  The impact to new transmissions and retransmissions won’t exist if scheduling DCI without PDSCH/PUSCH scheduled or GC-PDCCH with UE-specific fields are considered. |
| Spreadtrum |  | According to 38.321, if a *drx-HARQ-RTT-TimerDL* expires and if the data of the corresponding HARQ process was not successfully decoded, start the *drx-RetransmissionTimerDL* for the corresponding HARQ process in the first symbol after the expiry of *drx-HARQ-RTT-TimerDL*. When the *drx-RetransmissionTimerDL* is running, UE should perform PDCCH monitoring. We think this UE behavior should not be changed even a UE is in a skipping duration. |
| Huawei, HiSilicon |  | In general OK to discuss this issue as the second level detail. |
| LG | Could be discussed | UE behavior regarding HARQ process in DRX active time is based on DRX timers. Thus, if the timer about HARQ is running, the UE could switch to ‘HARQ’ SSSG which contains SS sets where HARQ resposes are expected (only if more than 2 SSSG are supported).  We need to discuss further. |
| OPPO | It should be supported. | The issue is how the UE side act (intervally) during the skipping duration.  It can also help for Search Space set group switching scheme. |
| Lenovo, Motorola Mobility | Agree with the intention of the proposal. | After receiving skipping indication, UE can stop monitoring DL DCI format(s) upon expiration of *drx-RetransmissionTimerDL* if *drx-HARQ-RTT-TimerDL* or *drx-RetransmissionTimerDL* is running, and  UE can stop monitoring UL DCI format(s) upon expiration of *drx-RetransmissionTimerUL* if *drx-HARQ-RTT-TimerUL* or *drx-RetransmissionTimerUL* is running, |
| Nokia |  | Can be discussed as a part of second level details, noting also that with SSSG switching the scheduling delay impact can be accounted in SS set group configuration(s). |
| ZTE, Sanechips |  | We agree that the PDCCH adaptation scheme may increase the latency of re-transmissiom, which should be addressed. However, we think this issue can be discussed after issue 1 is settled down. |
| Qualcomm |  | If conventional SSSG switching is used, handling HARQ retransmission by a proper SSSG configuration would be up to gNB implementation. However, either PDCCH skipping or skipping/dormant SSSG (unified design) is used, HARQ retransmission should be supported during the skip duration. We think this can be achieved by existing DRX functionality. This may also depend on how we define the “skip duration”; if we assume that the drx-onDurationTimer or drx-InactivityTimer is suspended/invalidated during the skip duration, halding HARQ retransmission is naturally supported by existing RTT and ReTx timers. |
| Apple | Support on high level. | Can be 2nd level of details on skipping interaction with different HARQ timers. |
| Intel | Postpone discussion until progress is made on skipping or SSS solution | This consideration may not work if non-scheduling DCI is used to trigger. |
| Ericsson | Support to study mechanisms to minimize impact to data scheduling | Adverse latency impact due to pre-mature switching (e.g. to sparse monitoring) via scheduling DCI should be avoided. |
| DOCOMO | Can be discussed later | This issue should be discussed after the basic design is determined. |
| CMCC | Fine to support | Can be discussed further. |

## Issue 4: minimum application dealy

Before the UE starts to skip PDCCH/ switch SSSG, UE needs time to decode DCI carried the signaling. There were several 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 .
* New parameter

**Initial Proposal:**

* Further study the application delay for PDCCH adaptation indication

Please kindly provide your views. Comments on the potential observations are also encouraged.

|  |  |  |
| --- | --- | --- |
| **Company name** | **Views** | **Comment(s) (including suggestions on the observations)** |
| CATT | No additional Application delay | The only latency of PDCCH skipping is the PDCCH decoding delay of scheduling or non-scheduling DCI. Once DCI is successfully decoded, the PDCCH skipping indication field is the additional information field along with search space for indicating next PDCCH monitoring occasion. There is no additional application delay. |
| Samsung | Support | Application delay should to be specified in order to achieve fast adapation.  The exisiting method from NR-U can be baseline. |
| Huawei, HiSilicon | Support | The application delay should be discussed. |
| LG | Support | The delay could be based on from NR-U. |
| OPPO | Could be considered further | It depends on the schemes selected. |
| Lenovo, Motorola Mobility | Fine with the proposal. |  |
| Nokia | Support, 2nd level of details | The application delay can be agreed as a second level of details. The NR-U method can be considered as a baseline. |
| Fraunhofer | Support |  |
| ZTE, Sanechips | Support | The application delay, and factors that impact the application delay should be discussed. |
| Qualcomm | Support |  |
| Apple | FFS | Depends on scheme selected. The only latency of PDCCH skipping is the PDCCH decoding delay of scheduling or non-scheduling DCI. |
| Intel | Postpone discussion until progress is made on skipping or SSS solution |  |
| Ericsson | Support | Can use Rel-16 as baseline |
| DOCOMO | Support | Application delay should be discussed after the basic design is determined. |
| CMCC | support |  |

## Issue 5: Other related aspects to SSSG switching and PDCCH skipping

**UAI**

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

**SSSG switching when ON duration**

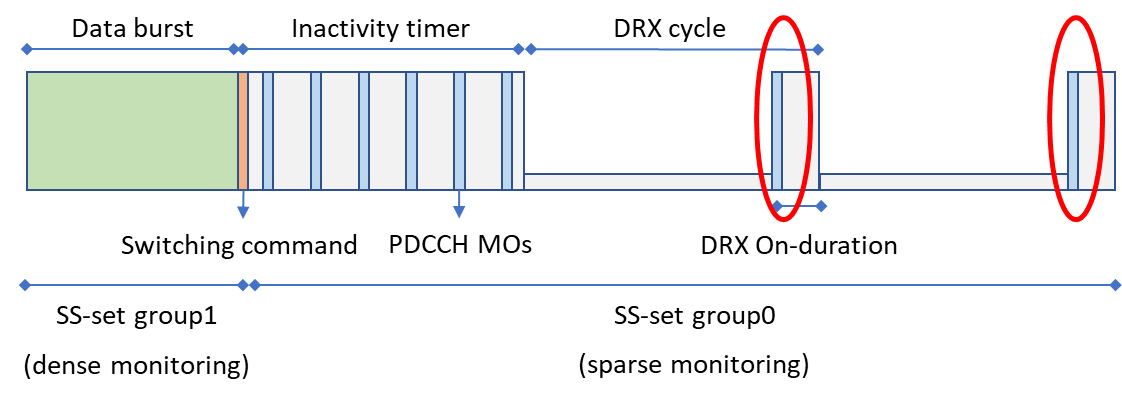


Figure 7. The UE might need to use sparse monitoring during DRX on-duration.

[*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.*](#_Toc61891282) *[Ericsson]*

**Uplink activities**

*Adaptation of uplink activity including CSI reporting and SRS transmission may be based on search space set group switching and DCI-based PDCCH monitoring skipping command. [Nokia]*

Please kindly provide your views for the email discussion on these options. Comments on the potential observations are also encouraged.

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| **Company name** | **Views** | **Comment(s) (including suggestions on the observations)** |
| CATT | No | This is an implementation issue. |
| Samsung | UAI and and default SSSG can be discussed further. | For SSSG switching when ON duration, a default SSSG can be considered. The default SSSG can be used for many other cases, e.g. when no indicaiton is received or after timer expires.  We are not clear about the benefit of adaptation of uplink activity including CSI reporting and SRS transmission. |
| Huawei, HiSilicon | Low priority |  |
| LG | Could be discussed further | SSSG that a UE monitors when DRX on-duration starts can be indicated by DCI format 2\_6 outside DRX Active Time with wake-up signal.  The default SSSG, as Samsung stated, can be used for DCI miss-detection case, fallback after timer expires. Or, it could be always monitored by a UE to prepare for some error cases.  It is appropriate to discuss further and more detail of UE behaviors and definitions are needed. |
| OPPO | No | We did not see the need for the configuration with DRX ON. |
| Lenovo, Motorola Mobility |  | DCI format 2\_6 (outside Active time) based search space set group switching can dynamically indicate which search space set group UE has to monitor when coming out of DRX for each DRX cycle. |
| Nokia |  | We are OK to down prioritize these. |
| ZTE, Sanechips |  | OK to down prioritize these. |
| Qualcomm |  | OK with low priority. Similar UL activity restriction associated with a dormant SCell can be considered. |
| Apple | Low priority |  |
| Intel | Low priority |  |
| Ericsson | Support default SSSG for DRX ON duration | SSSSG switching interacation with DRX functionality should be taken into account.  DRX function allows UE to wake-up for a small On duration, and if PDCCH monitoring in that On duration is further reduced (because UE is in sparse SSSG), this can lead to much smaller number of opportunities for addressing the UE in the On duration. Such situations should be avoided. |
| DOCOMO | Low priority | Can be discussed at later stage. |
| CMCC | Low priority |  |

## Issue 6: Additional traffic model

[vivo] A modified traffic model inter-arrival time can be considered in for power saving evaluation.

* reusing FTP Model 3 with modified mean inter-arrival time(e.g., online gaming)

|  |  |
| --- | --- |
|  | Modified FTP traffic 3 |
| Model | FTP model 3 |
| Packet size | 0.1 Mbytes |
| Mean inter-arrival time | 50 ms |
| DRX setting | Period = 40 ms |

[Samsung] It is desirable that Rel-17 targets heavier data traffic such as video streaming or gamming that would be the main use-scenarios of NR. To this end, we assume a data-intensive traffic model for the evaluation purpose. For simplicity, we re-use the FTP Model 3 with larger packet size and shorter inter-arrival time, e.g., 1MB packet size with relatively smaller inter-arrival time, e.g., from 50 ms to 100 ms.

Meanwhile, some companies use an intensive packet arrival time in order to study the power saving gain. Such as,

* For Huawei results, FTP 3 traffic model: 30ms mean inter-arrival, 0.1Mbytes packet, with DRX configuration = (20, 10, 5)ms
* For vivo, FTP 3 traffic model: 30ms mean inter-arrival, 0.15Mbytes packet, with DRX configuration = (40ms, 10ms, 8ms)
* For Nokia results,for data intensive traffic, DL packet is arrived 30ms, with DRX configuration = (20ms, 4ms, 8ms)
* For Samsung results, FTP 3 traffic model, 1MB packet size with relatively smaller inter-arrival time, e.g., from 50 ms to 100 ms
* For ZTE results, data-intensive traffic is modelled as FTP model 3 with 50ms mean arrival time and 0.1Mbyte packet size.

**Initial proposal:**

The following ‘intensive eMBB traffic’ model is considered for Rel-17 Power saving evaluation,

* + Based on FTP Model 3
  + packet size: [0.1MB]
  + mean inter-arrival time: [30ms]
  + DRX configuration: (C-DRX cycle, InactivityTimer, onDurationTimer) = [(20ms,10ms,5ms)]

Note: This does not preclude to use other traffic models and companies report which traffic model(s) is used

Please kindly provide your views. Comments on the potential observations are also encouraged.

|  |  |  |
| --- | --- | --- |
| **Company name** | **Views** | **Comment(s) (including suggestions on the observations)** |
| CATT | No | The power saving gain of any power saving technique should be oberserved at all different traffic models. Additional traffic model of intensive eMBB would not provide any information for the design of PDCCH skipping or SSSG. |
| Samsung | Yes |  |
| OPPO | Yes |  |
| Nokia |  | While we are in principle fine to consider additional traffic model, it may not be best use of discussion time at this stage. |
| Apple |  | Fine with additional traffic model. |
| Ericsson | No | We prefer to focus on specification aspects at this stage. |

## Issue 7: Other power saving schemes

**PDSCH processing relaxation**

[Samsung] proposes that in order to achieve power saving from relaxed processing, it’s essential to consider relaxation on both PDCCH processing timeline and PDSCH reception and ACK/NACK feedback timeline, so that UE can lower the clock rate for all DL processing modules.

In RAN1#103-E, discussion on how to power model for relaxing PDSCH processing is discussed in the email discussion.

**Initial proposal for power model for relaxing PDSCH processing**

* Support power model of processing time relaxation over *X* slots, such that P(X) = Ps\*X + (Pt - Ps)/X, where Pt is the power without relaxation, and Ps is the power for micro-sleep.

Please kindly provide your views. Comments on the potential observations are also encouraged.

|  |  |  |
| --- | --- | --- |
| **Company name** | **Views** | **Comment(s) (including suggestions on the observations)** |
| CATT | No | We don’t see any justification of power saving gain with relax PDSCH processing (not in Rel-16 UE power saving study). We consider the relax PDSCH processing would increase UE power consumption in principle since the duration of PDSCH process is longer than normal PDSCH processing. |
| Samsung | Yes | The model indicates that power consumption of signal processing (excluding micro-sleep cost) is scaled over processing time, X, due to lower clock rate. |
| OPPO | Yes | We can consider the modification of power model. |
| Lenovo, Motorola Mobility | Not support the proposal | Power saving from relaxed PDSCH processing time has not been thoroughly studied/justified. Further, spec impacts of new PDSCH processing time may be significant. |
| Nokia | No | We think that we should focus to the power saving mechanisms when there is no data activity. Linkage to processing rates of different functionalities is an UE implementation issue. |

|  |  |  |
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| Fraunhofer | Yes | Agree with Samsung. |
| ZTE, Sanechips |  | Not within the WID scope. |
| Qualcomm | No | Processing timeline is highly dependent on the implementation, and it would be very hard to find a commonly agreeable model. For some implementation, finishing PDCCH/PDSCH processing as early as possible and getting into sleep earlier may be more power efficient. |
| Apple | No |  |

## Issue 8: AOB

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| --- | --- | --- |
| **Company name** | **Views** | **Comment(s) (including suggestions on the observations)** |
|  |  |  |

# Summary of the potential proposals

# 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**

# Proposals from companies’ submitted contributions

|  |  |  |
| --- | --- | --- |
| [**R1-2100170**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100170.zip) | 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: Indicating PDCCH search space groups is supported as PDCCH monitoring adaptation:***  ***1-bit DCI field indicating 1 of 2 configured Search Space groups.***  ***Autonomous PDCCH monitoring adaptation is triggered by timer.***  ***Proposal 6: Cross-slot scheduling indication bit in the DCI can also trigger the search space group switching.***  ***The application delay can be also applicable to the search space group switching.*** | | |
| [**R1-2100218**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100218.zip) | Extension(s) to Rel-16 DCI-based power saving adaptation for an active BWP | Huawei, HiSilicon |
| ***Observation 1: PDCCH skipping can achieve the power saving effect of search space set group switching.***  ***Observation 2: PDCCH skipping can achieve more flexible skipping than search space set group switching.***  ***Observation 3: The power saving of search space set group switching may be reduced in case of multiple search space sets in an active BWP. The power saving is also reduced in case of CA, especially intra-band CA.***  ***Observation 4: Dynamic PDCCH skipping provides more power saving gains than search space set group switching for intensive eMBB traffic, meanwhile with similar or even better the latency performance.***  ***Observation 5: Dynamic PDCCH skipping provides more power saving gains than search space set group switching for VoIP. The latency of dynamic PDCCH skipping and search space set group switching are similar.***  ***Observation 6: For dynamic PDCCH skipping, the detailed design of PDCCH skipping signaling and the application delay should be further studied.***  ***Observation 7: The design of explicit signaling and implicit switching rule should be further studied to support search space set group switching for licensed band.***  ***Observation 8: The issue of DCI missed detection needs to be resolved to support search space set group switching.***  ***Observation 9: Search space set group switching in NR-U cannot be directly applied to licensed band. The specification impacts of search space set group switching and dynamic PDCCH skipping is similar.***  Based on the observations, it is proposed that  ***Proposal 1: Specify DCI based PDCCH skipping.*** | | |
| [**R1-2100395**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100395.zip) | PDCCH monitoring adaptation | CATT |
| ***Observation 1: SSSG switching has non-negligible drawbacks for PDCCH monitoring reduction including group common indication, new system design, less flexibility for monitoring reduction, redundant search space set configuration, additional specification changes etc.***  ***Proposal 1: Compared to SSSG switching, the PDCCH monitoring adaptation can dynamically indicate UE to reduce the PDCCH monitoring, e.g. the PCell dormancy, the PDCCH BD reduction, the PDCCH monitoring occasion granularity change, etc., without any changes of SearchSpace configuration.***  ***Proposal 2: The existing DCI formats 0\_1 and 1\_1 in Rel-16 are reused without introducing additional information field, in which the bits in SCell dormancy indication field could be repurposed for mapping or grouping indication*** ***of the PDCCH monitoring adaptation for PCell and/or SCell dormancy indication.*** | | |
| [**R1-2100455**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100455.zip) | Discussion on DCI-based power saving adaptation in connected mode | vivo |
| **Observation 1: The similar power saving effect can be achieved by either PDCCH skipping or SS switching scheme.**  **Observation 2: Up to 31.6% power saving gain can be achieved PDCCH skipping to the next DRX cycle. Up to 12ms packet latency will be additionally increased meanwhile.**  **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: Scheding 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 search space sets with group index 0 and stop group index 1**     - **‘1’ : starts monitoring PDCCH according to search space sets with group index 1 and stop group index 0**     - **FFS: more bits for extending more than 2 SS set groups** * **Scheme 2: A duration indicated by scheduling DCI**   + **UE switch back SSSG after a last symbol of a remaining duration indicated by scheduling DCI** * **Scheme 3: RRC configured timer for switching** * **Scheme 4: Non-scheduling DCI triggered SSSG switching** * **FFS whether and how the schemes are applied for a switching between two SSSG(s).**   **Proposal 5: A modified traffic model inter-arrival time can be considered in for power saving evaluation.**   * **reusing FTP Model 3 with modified mean inter-arrival time(e.g., online gaming)**  |  |  | | --- | --- | |  | **Modified FTP traffic 3** | | Model | FTP model 3 | | Packet size | 0.1 Mbytes | | Mean inter-arrival time | 50 ms | | DRX setting | Period = 40 ms | | | |
| [**R1-2100498**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100498.zip) | Extension to Rel-16 DCI-based power sabing adaptation during DRX Active Time | GDCNI |
| ***Proposal 1: DCI-based PDCCH monitoring should be considered. DCI format 2\_6 can be extended to support PDCCH skipping until the next DRX on duration.***  ***Proposal 2: Treat PDCCH skipping as part of the self-adaptation PDCCH monitoring. Skip only a certain duration and switch with DCI format 2-6.*** | | |
| [**R1-2100526**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100526.zip) | Extension to Rel-16 DCI-based power saving adaptation during DRX Active Time | ZTE , Sanechips |
| **Observation 1: Both PDCCH skipping and search space set group switching can reduce more power consumption than DRX command MAC CE.**  **Observation 2: In the case that the PDCCH skipping period is configured to be equal to the number of PDCCH monitoring occasions reduced by search space set group switching scheme, PDCCH skipping provides larger power saving gain than search space set group switching.**  **Observation 3: Latency for DRX command MAC CE, PDCCH skipping and search space set group switching are almost the same as the baseline.**  **Observation 4: For search space set group switching scheme, the sleep period is dispersed by the search space set group 1 with sparser PDCCH monitoring occasions, which results in a lower power saving gain from search space set group switching compared with PDCCH skipping.**  **Proposal 1: According to the power saving gain, latency and specification workload, PDCCH skipping should be adopted as the Rel-17 dynamic PDCCH adaptation during DRX active time.**  **Proposal 2: DCI format 0\_1 and DCI format 1\_1 are preferred to be used to indicate PDCCH skipping.**  **Proposal 3: 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 4: A list of PDCCH skipping periods is configured by RRC, DCI is further used to indicate one PDCCH skipping period.** | | |
| [**R1-2100593**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100593.zip) | On enhancements to DCI-based UE power saving during DRX active time | MediaTek Inc. |
| **Observation 1: Timer-based mechanism in Rel-16 SSSG switching can be utilized to create PDCCH skipping behaviour. Based on existing Rel-16 specification, both Rel-17 candidate schemes can be implemented by SSSG switching. Therefore, SSSG switching can be selected for Rel-17 extension.**  **Figure 2: SSSG switching can be utilized to create PDCCH skipping behaviour**  **Observation 2: 2nd PDCCH skip duration provides limited additional power saving gain. The power saving gain can even reduce because of extra delay to data scheduling. It suffices to consider PDCCH skipping with one skip duration for Rel-17.**  **Figure 3. Power consumption and latency increment in FR2 FTP traffic**  **Figure 4. Power consumption and latency increment in FR1 FTP traffic**  **Proposal 1: For Rel-17 DCI-based power saving enhancement, prioritize extension to Rel-16 search space group switching with UE-specific DCI format.**  **Observation 3: “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.**  **Observation 4: As shown in Figure 5(b), the retransmission-aware adaptation, i.e., applying adaptation only after HARQ ACK is fulfilled, allows UE save more power because network is able to send the adaptation triggering before receiving the HARQ-ACK information from UE**.  **Figure 5: Illustration of power saving adaptive (a) Rel-16 (b) Rel-17 enhanced**  **Observation 5: The retransmission-aware adaptation can reduce UE power consumption significantly. Compared to legacy behaviour, it can provide 40.2% and 34.3% of power saving gain for VoIP and FTP, respectively.**  **Table 3 Performance comparison for (a) Rel-16 and (b) Rel-17 enhanced**  **Observation 6: The retransmission-aware adaptation is compatible to all DCI-based adaptation, e.g., SCell dormancy indication and cross-slot scheduling adaptation in Rel-16. In addition, it can also be used for retransmission handling for both Rel-17 PDCCH monitoring reduction candidate schemes.**  **Proposal 2: Support retransmission-aware adaptation for scheduling DCI based power saving indication.**   * **Apply adaptation only after HARQ ACK condition is fulfilled** * **FFS other conditions.** | | |
| [**R1-2100664**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100664.zip) | Discussion on PDCCH monitoring reduction techniques during active time | Intel Corporation |
| **Observation 1: In terms of specification impact, both SS Set switching and PDCCH skipping can be similar. In one simple approach, a 1-bit field can be considered in scheduling DCI format to provide trigger for either SS Set switching or PDCCH skipping.**  **Observation 2: PDCCH skipping solution with dynamic indication of skipping/sparse monitoring duration can provide additional flexibility and can be more effective in adapting to changes in traffic characteristics, compared to SS Set Switching between two SS set groups.**  **Observation 3: Configuration of a timer may not be needed for PDCCH skipping if skipping duration can be dynamically indicated.**  **Observation 4: SCell dormancy indication field in DCI format 1\_1 or DCI format 2\_6 if monitored in active time can be leveraged to include PDCCH skipping signal.**  **Observation 5: Both PDCCH skipping and SS Set switching indication by DCI may result in similar power saving gain.**  **Proposal 1: Support PDCCH skipping indication via a DCI format in Rel-17.**   * **FFS: DCI formats.** | | |
| [**R1-2100815**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100815.zip) | Discussion on power saving techniques for connected-mode UEs | Spreadtrum Communications |
| ***Observation 1: PDCCH skipping brings significant power saving gain on the top of WUS and cross-slot scheduling.***  ***Observation 2: Search space set group switching brings significant power saving gain on the top of WUS and cross-slot scheduling.***  ***Proposal 1: Consider to specify PDCCH skipping in Rel.17.***  ***Proposal 2: The triggering method of PDCCH skipping should be further studied.***  ***Proposal 3：Consider to specify search space set group switching for eMBB in Rel.17.***  ***Proposal 4：The triggering method of search space set group switching should be further studied.*** | | |
| [**R1-2100905**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100905.zip) | Discussion on DCI-based power saving adaptation during DRX ActiveTime | LG Electronics |
| ***Proposal 1: Discuss whether and how the DCI format 2\_6 outside DRX Active Time indicates PDCCH monitoring adaptation inside DRX Active Time.***  ***Proposal 2: Consider supporting search space set level activation/deactivation for DCI-based PDCCH monitoring adaptation.***  ***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 3: Support SS set group switching for DCI-based PDCCH monitoring adaptation.***  ***Proposal 4: For triggering PDCCH monitoring adaptation during DRX Active Time, the following DCI formats are considered for further discussion:***   * + - ***Scheduling DCI (DCI format x\_1, DCI format x\_2)***     - ***DCI format 2\_6***       * ***FFS: Discuss whether and how to define the monitoring window for DCI format 2\_6 inside DRX Active Time.***   ***Proposal 5: If the search space set group switching and/or PDCCH monitoring skipping is supported, the default SS set(s) which a UE always monitors or returns to monitor after a certain period of time for PDCCH monitoring adaptation should be considered for handling error cases or sudden data transmission.***  ***Proposal 6: UE can be configured to apply different PDCCH monitoring adaptations for different cases.*** | | |
| [**R1-2100980**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2100980.zip) | Discussion on extension(s) to Rel-16 DCI-based power saving adaptation | Asia Pacific Telecom, FGI |
| **Observation 1: DCI-based PDCCH skipping scheme can achieve a tradeoff between low latency for data transmission and UE power saving.**  **Observation 2: NR-U search space set group switching mechanism can be the baseline for Rel-17 power saving.**  **Observation 3: NR-U search space set group switching mechanism can only be indicated by group common DCI.**  **Observation 4: UE-specific DCI should be considered for the switching indication if enhanced power saving search space set group switching mechanism is supported.**  **Observation 5: PDCCH skipping scheme is suitable for one-shot PDCCH monitoring adaptation, whereas search space set group switching scheme is suitable for long-term PDCCH monitoring adaptation.**  **Observation 6: Although PDCCH skipping and search space set group switching could both achieve power saving gain, neither of them can tackle all kinds of traffic patterns effectively.**  **Observation 7: It’s beneficial to give the NW flexibility for selecting either one or both schemes to adapt to different traffic patterns.**  **Proposal : Both PDCCH skipping and search space set group switching schemes should be supported in Rel-17 power saving.** | | |
| [**R1-2101000**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101000.zip) | Enhanced DCI based power saving adaptation | Lenovo, Motorola Mobility |
| * **Proposal 1: Support adaptation of a search space configuration in every DRX cycle via enhanced power saving DCI.** * **Proposal 2: Support scheduling-DCI based dynamic PDCCH skipping during Active Time for UE power saving.** * **Proposal 3: 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 4: Consider joint indication of minimum applicable scheduling offset K0/K2 and PDCCH skipping.** | | |
| [**R1-2101054**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101054.zip) | Discussion on PDCCH monitoring reduction during DRX active time | CMCC |
| **Proposal 1. Both search space set group switching and PDCCH skipping can be supported.**  **Proposal 2. Both skipping for a duration and all the PDCCH monitoring occasions in current DRX cycle can be supported in PDCCH skipping schemes.**  **Proposal 3. DCI format 0\_1/0\_2/1\_2 is used to indicate PDCCH skipping in the following cases,**   * **FDRA field is all '0's (when type 0 RA is used for UE);** * **FDRA field is all '1's (when type 1 RA is used for UE);** * **FDRA field is all '0's or all '1's (when both type 0 and type 1 RA is used for UE).**   **Proposal 4. RRC signalling can configure multiple PDCCK skipping candidate durations, and DCI format 0\_1/0\_2/1\_2 is used to indicate UE which PDCCH skipping candidate duration is used or skipping all PDCCH monitoring occasions in current DRX cycle after detecting it.**  **Proposal 5. Scheduling DCI with additional bit(s) or repurposing scheduling DCI is prefered for search space set group switching indication.** | | |
| [**R1-2101220**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101220.zip) | Discussion on DCI-based power saving techniques | Samsung |
| **Proposal 1: Specify search space set group switching only for DCI-based dynamic PDCCH adaptation in Rel-17.**  **Proposal 2: Support at least one of triggering methods for SS set group switching, including**   * **Opt-1: the scheduling DCI format with PDSCH/PUSCH** * **Opt-2: the scheduling DCI format without PDSCH/PUSCH** * **Opt-3: group-common DCI format, e.g., DCI format 2-6**   **Proposal 3: Support more than two search space set groups, where some search space set groups can be configured per BWP and associated with a CORESET group.**  **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.**  **Proposal 7: Support power model of processing time relaxation over X slots, such that P(X) = Ps\*X + (Pt - Ps)/X, where Pt is the power without relaxation, and Ps is the power for micro-sleep.** | | |
| [**R1-2101285**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101285.zip) | DCI-based Power Saving Enhancements | Fraunhofer HHI, Fraunhofer IIS |
| [**Proposal 1: Adopt dynamic search space switching using implicit signaling to trigger a switch, e.g., minimum scheduling offset.**](#_Toc61869177)  [**Proposal 2: Deprioritize PDCCH skipping indication.**](#_Toc61869178)  [**Proposal 3: The PDSCH processing time shall be adaptable based on certain parameters, e.g., the minimum scheduling offset or the currently active SS group.**](#_Toc61869179) | | |
| [**R1-2101302**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101302.zip) | Potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime | Panasonic |
| **Proposal 1: Multiple TB scheduling should be studied for Rel.17 power saving enhancement due to the power saving merit provided by sparse PDCCH monitoring.**  **Proposal 2: Dynamic search space set group switching should be supported by DCI format 1\_1, 0\_1, 1\_2, 0\_2, 2\_6. Further enhancement to DCI format 2\_0 can also be considered.**  **Proposal 3: Implicit dynamic search space set group switching in conjunction with multi-slot PDSCH/PUSCH should be studied.**  **Proposal 4: PDCCH skipping for a certain duration / DRX cycle should be supported by DCI format 2\_6.**  **Proposal 5: During DRX active time, PDCCH skipping supported by a common PDCCH, e.g. DCI format 2\_0, could be studied if the use case can be justified.** | | |
| [**R1-2101394**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101394.zip) | Enhanced DCI-based power saving adaptation | Apple |
| ***Observation: One-time PDCCH skipping allow large skipping value to be set, which maximize UE power saving gain.***  ***Proposal 1: Support of dynamic PDCCH monitoring skipping method in Rel-17 active mode UE power enhancement.***  ***Proposal 2: Scheduling grant can be used to trigger PDCCH monitor skipping. Additional trigger bits in scheduling DCI 0-1, 0-2, 1-1, 1-2.***   * ***When triggered by DL DCI: Skipping commend applies after ACK/NACK transmission.*** * ***When triggered by UL DCI: skipping commend applies after PUSCH transmission*** * ***Further discuss whether group based non-scheduling DCI should be used for monitoring adaptation.*** * ***Timer based method can be defined.***   ***Proposal 3: Unified design to enable both skipping and switching can be studied*** | | |
| [**R1-2101476**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101476.zip) | DCI-based power saving adaptation during DRX ActiveTime | Qualcomm Incorporated |
| Observation 1: For the unified design of DCI-based power saving, search space group switching can be the baseline. To emulate PDCCH skipping with search space group switching, a dormant search space set group can be introduced.   * To enable HARQ retransmission during the dormant search space set group, discontinuous PDCCH monitoring according to RTT and Retransmission timers can be allowed. * The UE can transition back to a non-dormant search space set group by a dormancy timer or after transmitting a scheduling request.   Proposal 1: A search space set switching mechanism by a scheduling DCI and/or DCI format 2\_6 is considered as a Rel-17 connected-mode power saving scheme.  Proposal 2: For search space set group switching for Rel-17 power saving, the maximum number of search space set groups larger than two is considered.  Proposal 3: Scheduling DCI-based PDCCH skip indication is considered as a Rel-17 connected-mode power saving scheme. During the indicated skip duration, the UE can still monitor PDCCH in a discontinuous manner to handle potential HARQ retransmissions.  Proposal 4: A unified design for search space set group switching and PDCCH skipping should be pursued in Rel-17. | | |
| [**R1-2101505**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101505.zip) | PDCCH monitoring reduction in Active Time | InterDigital, Inc. |
| ***Observation 1: Search space set switching provides higher gain than PDCCH skipping.***  ***Observation 2: Existing MAC CE based mechanism can be used to skip PDCCH monitoring to the next DRX cycle.***  ***Observation 3***: **Search space set switching can be supported with minimal specification effort by extending the existing mechanism in NR-U.**  ***Proposal 1***: ***If supported, PDCCH skipping should be applicable per search space set.***  ***Proposal 2: Search space set switching is supported for connected mode UEs in Re-17.*** | | |
| [**R1-2101558**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101558.zip) | Design of active time power savings mechanisms | Ericsson |
| [Proposal 1 For Rel-17 UE power savings, specify extension/modification of search space set group switching.](#_Toc61891276)  [Proposal 2 Support explicit indication of search space set group switching via scheduling DCI format 1\_1. FFS : DCI format 0\_1.](#_Toc61891277)  [Proposal 3 For self-scheduling, PCell’s scheduling DCI format 1\_1 can indicate SSSG switching for the primary cell. Details of the indication FFS.](#_Toc61891278)  [Proposal 4 For self-scheduling, an SCell’s scheduling DCI format 1\_1 can indicate SSSG switching for the SCell. Details of the indication FFS.](#_Toc61891279)  [Proposal 5 Study further how to support SSSG switching for multiple groups of cell(s). Details including number of groups FFS.](#_Toc61891280)  [Proposal 6 HARQ retransmissions should not be delayed due to SSSG switching and mechanisms to avoid this should be supported e.g. a configurable timer-based application delay or HARQ feedback-based application of the SSSG switching command.](#_Toc61891281)  [Proposal 7 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.](#_Toc61891282)    Figure 7. The UE might need to use sparse monitoring during DRX on-duration. | | |
| [**R1-2101567**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101567.zip) | Power saving adaptation during Active Time | ASUSTeK |
| **Proposal 1: For comparing different PDCCH monitoring adaptation candidate, a power model with finer granularity could be developed for Rel-17.**  **Proposal 2: RAN1 further consider/compare PDCCH monitoring adaptation schemes studied in Rel-16, at least from the following two domain:**   * **time domain** * **CCE domain** | | |
| [**R1-2101624**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101624.zip) | Discussion on extension to DCI-based power saving adaptation | NTT DOCOMO, INC. |
| **Proposal 1: Enhanced Rel-16 search space set group switching should be applied to licensed bands.**  **Proposal 2: DCI format 0\_1 and 1\_1 can indicate search space set group switching.**  **Proposal 3: Based on search space set group switching, some mechanism providing more flexibility on adaptation of the parameters related to PDCCH monitoring should be considered.**  **Proposal 4: Search space set level activation/deactivation should be considered.**  **Observation 1: PDCCH skipping along with cross-slot scheduling can maximize the benefit of cross-slot scheduling.**  **Proposal 5: PDCCH skipping for the duration of the applicable minimum scheduling offset from PDCCH monitoring occasion should be supported.**  **Observation 2: Search space set group switching can provide general adaptation of PDCCH monitoring based on traffic amount and so on, but cannot provide skipping PDCCH monitoring immediately after the scheduling DCI due to switching delay.**  **Observation 3: There is very low signalling overhead for indication of PDCCH skipping for the duration of the applicable minimum scheduling offset since the duration of PDCCH skipping does not need to be indicated.**  **Proposal 6: Support of both enhanced search space set group switching and PDCCH skipping for the duration of the applicable minimum scheduling offset.** | | |
| [**R1-2101666**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_104-e/Docs/R1-2101666.zip) | UE power saving enhancements for Active Time | Nokia, Nokia Shanghai Bell |
| **Observation:** *Adaptation of uplink activity including CSI reporting and SRS transmission may be based on search space set group switching and DCI-based PDCCH monitoring skipping command.*  **Observation:** *From latency point of view, it is benefitial if uplink activity related to indication of data buffer activates the regular, i.e. more frequent monitoring.*  Evaluation results for the SS set group switching and PDCCH skipping were presented in Section 3, with following observations and proposals:  **Observation:** *With more intense traffic profiles the attainable gains from different power saving schemes are reduced.*  **Observation:** *SS switching and PDCCH skipping provide comparable gains in all evaluated scenarios.*  **Observation:** *SS switching has lower signalling overhead than PDCCH skipping for most of the evaluated traffic scenarios.*  **Proposal:** *Spesify enhacements to SS group switching in R17 to support better power saving functionality for active time power saving.*  In Section 4 we discussed on the possible enhancements on SS set group switching for active time power saving purposes, and made following proposals:-  **Proposal:** Introduce support for DCI based SS set group switching to scheduling DCIs.  **Proposal:** Consider the possibility to increase the number of SS set group sets from 2.  **Proposal:** Support timer based UE autonomous SS set group adaptation for active time power saving.  **Proposal:** Discuss the need of implicit SS set group change based on the reception of DCI or triggered by some other procedures. | | |

# Work plan

# 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*

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| --- |
| 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#104-E in AI 8.7.2,**

1. [R1-2100170](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100170.zip) DCI-based power saving adaptation solutions OPPO
2. [R1-2100218](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100218.zip) Extension(s) to Rel-16 DCI-based power saving adaptation for an active BWP Huawei, HiSilicon
3. [R1-2100395](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100395.zip) PDCCH monitoring adaptation CATT
4. [R1-2100455](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100455.zip) Discussion on DCI-based power saving adaptation in connected mode vivo
5. [R1-2100498](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100498.zip) Extension to Rel-16 DCI-based power sabing adaptation during DRX Active Time GDCNI
6. [R1-2100526](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100526.zip) Extension to Rel-16 DCI-based power saving adaptation during DRX Active Time ZTE , Sanechips
7. [R1-2100593](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100593.zip) On enhancements to DCI-based UE power saving during DRX active time MediaTek Inc.
8. [R1-2100664](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100664.zip) Discussion on PDCCH monitoring reduction techniques during active time Intel Corporation
9. [R1-2100815](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100815.zip) Discussion on power saving techniques for connected-mode UEs Spreadtrum Communications
10. [R1-2100905](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100905.zip) Discussion on DCI-based power saving adaptation during DRX ActiveTime LG Electronics
11. [R1-2100980](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2100980.zip) Discussion on extension(s) to Rel-16 DCI-based power saving adaptation Asia Pacific Telecom, FGI
12. [R1-2101000](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101000.zip) Enhanced DCI based power saving adaptation Lenovo, Motorola Mobility
13. [R1-2101054](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101054.zip) Discussion on PDCCH monitoring reduction during DRX active time CMCC
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15. [R1-2101285](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101285.zip) DCI-based Power Saving Enhancements Fraunhofer HHI, Fraunhofer IIS
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17. [R1-2101394](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101394.zip) Enhanced DCI-based power saving adaptation Apple
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22. [R1-2101624](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101624.zip) Discussion on extension to DCI-based power saving adaptation NTT DOCOMO, INC.
23. [R1-2101666](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104\Docs\R1-2101666.zip) 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
2. [R1-2005614](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005614.zip) Work plan for UE power saving enhancements MediaTek Inc.
3. R1-2007419 LS on evaluation methodology for connected mode UE power saving enhancement RAN1, vivo, MediaTek

# 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)