3GPP TSG RAN WG1 Meeting #102-e R1-200XXXX

e-Meeting, August 17th – 28th, 2020

Source: Moderator (vivo)

Title: FL summary of potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime

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 table of summary of proposals from contributions submitted. Section 5 is a summary of previous agreements. 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.

Considering vast number of proposals, we need to identify high priority topics for discussion according to Chairman’s guidance. Therefore, the followings are proposed,

Section 2 basically contains two aspects, evaluation methodologies and high concepts according to the Chairman note’s guidance.

* For section 2.1 (evaluation methodologies), since not so many issues we need to address and I simply add a table for each subsection to collect companies’ opinions in question from Q1 – Q6.
* For section 2.2(high-level concepts),
	+ For power saving schemes and triggering schemes (Q7 and Q8),
		- As you may see, there is a vast number of proposals there (>8 power saving schemes, and couple of triggering schemes). It is grouped into several topics in section 2.2.1.9. Q7 and Q8 is asked to companies to provide comments to whether the schemes listed is clear or if there is something missing.
		- And since couple of triggering schemes (described in section 2.2.2)are mentioned in the contribution, please if possible indicate any feasible triggering schemes for each topic in Q8. This will help understanding the triggering design once for next step.
	+ For prioritization, Q9 in section 2.2.3 is asked
		- Please provide (at least) an early input on topic 1 described in Section 2.2.1.9 with more than 5 contributions (if you are OK to regard them as high priority)
		- In addition, if possible indicate prioritization for the other topics 2 – 7 in Section 2.2.1.9 (discussed in less than 5 contributions) of your companies position if they are to be regarded as high / medium / low priority

# Summary of the contributions/discussions

## Potential evaluation methodology updates

### Performance metrics

Performance metrics

One company discussed performance metrics including UE power saving gain, Latency of packet/user perceived throughput for evaluation [HW], which is also part of TR38.840 section 8.2.

One company proposes that UE power savings vs. system performance/latency/overhead impact should be considered as part of evaluation of potential enhancements for power savings during active time [E///], which is also part of the Rel-16 TR38.840.

**Question 1: Is it fine that the performance metris decribed in TR38.840 section 8.2 is reused for power saving evaluation of Rel-17 DCI-based power saving adaptation during ActiveTime?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Apple  | Yes |  |
| Ericsson | Yes, but also baseline should be clarified. | Baseline for comparison of performance gains should be existing Rel-15/16 UE power saving techniques/CA activation/dormancy. |
| OPPO | Yes | It can be mostly reused for the principle of evaluation metrics in 38.840 |
| MediaTek | Yes | We also support Ericsson’s comment on clarifying/updating the baseline setting. This is also required in the WID scope as quoted below:

|  |
| --- |
| 2-a) 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.
 |

For an efficient way to include the effect of all power saving schemes, Section 2.2 of R1-2007032 can be referred. |
| Xiaomi | Yes | The performance metrics in the current TR have been able to meet the evaluation requirement. Also, there is no any new performance metric being proposed from other companys. Therefore the performance metrics should be reused for power saving evaluation of Rel-17. |
| Samsung | Yes |  |
| Vivo | Yes | The power saving techniques can be applicable to both normal UEs and Redcap UEs. For example, for RedCap UE, it may not be CA-capable. And SCell dormancy and CA activation may not be applicable. The baseline can be clarified from the proponents. |
| CMCC | Yes |  |

### Power model

Power model

 [Huawei] proposes additional power model for DCI format 2\_6. Two values of minimum time gap in terms of slots per SCS are specified and the UE reports one of the minimum time gap. Hence, the monitoring time gap and the power consumption value of monitoring the DCI format 2\_6 need to be modeled in the evaluation, e.g., 100 for minimum time gap = 1slot and 50 for minimum time gap = 6 slots.

[Nokia] also proposes to define assumptions on WUS monitoring power consumption and ps-Offset.

Moderator proposes to have more discusses and inputs on power model for DCI format 2\_6 and reusing TR38.840 Power model as starting point.

**Question 2: Reusing TR38.840 Power model as starting point for evaluation of DCI-based power saving schemes. FFS additional power model.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Apple  | Yes |  |
| Ericsson | Yes |  |
| OPPO | Yes | Considering the WUS consumption power is relatively small, we may not include it in the modeling. The WUS power saving gain can be model for comparison. |
| MediaTek | Yes | We are fine to reuse it.  |
| Xiaomi | Yes | We can reuse TR38.840 power model as starting point. Moreover, some details of power model can be adjusted. |
| Samsung | Yes |  |
| Vivo | Yes |  |
| CMCC | Yes |  |

### Additional traffic model

Additional Traffic model

For additional traffic model, [HW][MTK][OPPO][SS][vivo][sony][Nokia] proposed to introduces “intensive eMBB traffic”. Based on FTP Model 3., some parameters need to be updated based on TR38.840. The parameters includes mean inter-arrival time, packet size (as well as data rates), and corresponding DRX settings. [vivo][Nokia] also propose another model not based on FTP Model 3 for gaming and video conferencing. While [QC] has an observation that additionalsettings other than those recommended in TR 38.840 is not evident.

A table summarizes the input on additional traffic model is as follows,

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Additional model | HW | MTK | OPPO | Samsung | Vivo | Sony | Nokia | Qualcomm |
| Model | Intensive eMBB traffic based on FTP Model 3 | Real-Time Video based on FTP model 3 | Gaming and Short Video IM based on FTP model 3 | data-intensive traffic model based on FTP model 3 | Gaming model based on FTP Model 3 | high data intensity traffic model based on FTP Model 3 | video call/conference traffic model e.g. based on [R1-070674] | TR38.840 |
| Mean inter-arrival time | 15 ms | 30 ms | 15 ms | 50 ms | 50ms | 16.67ms |  | 200ms |
| Packet size | 0.05Mbytes | 0.08 Mbytes | 0.05Mbytes / 0.01Mbytes | 1 Mbytes | 200Bytes | 0.05Mbytes |  |  |

In order to merge the input of traffic model as much as possible which minimizes evaluation burden, by considering differnet input on Mean inter-arrival time and Packet size, the following traffic models in additional to TR38.840 is proposed,

* For UE power saving scheme evaluation, besides traffic model defined in TR38.840, the following ‘additional traffic model’ can be used,
	+ FTP Model 3 with 0.15MB packet size and 50ms mean inter-arrival time

Note 0.15MB packet size and 50ms mean inter-arrival time results in 24Mbps mean data rate which matches most companies’ proposals for intensive eMBB traffic.

**Question 3:**

* **Is it OK to have an additional traffic model for UE power saving scheme evaluation besides traffic model defined in TR38.840?**
* **Is it OK to use FTP Model 3 for the additional traffic model?**
* **What is the modification of the additional traffic model compared to traffic model defined in TR38.840 if used? e.g, mean inter-arrival time and/or packet size and/or data rate?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Apple  | Yes. | Agree to add one additional traffic model. Suggest packet size of 0.05Mbytes with 15ms inter-arrival time.  |
| Ericsson | No | The model in 38.840 should be used for the evaluations. Note new traffic models for real-time video/gaming may be considered for XR SI - so duplicate effort in this work item should be avoided. |
| OPPO | Yes | The 38.840 did not capture fully the use traffic. And this is the time for updating the traffic model in connected mode case. The parameter of Short Video would be one of the important one in the current smartphones. We consider 15 ms mean arrival time-interval and 0.05Mbytes~0.01Mbytes Packet size. To simplify the evaluation, a signle merged value from contributions can be considered.Note, the short video like IM is quite different case with other SI. |
| MediaTek | Yes | * To conclude whether enhancement is needed for connected mode power saving, we should consider covering all type of data characteristics, particularly in packet size and inter-packet arrival time. For short inter-packet arrival time, RAN1 only consider VoIP with very small packet size. While fixing small BWP bandwidth or number of MIMO layers can optimize VoIP power consumption, the same scheme will degrade the data efficiency for the traffic with large packet size. In this regard, additional model with short inter-packet arrival time, e.g., 30 ms, and large packet size, e.g. 10k bytes to 100 kbytes, will be necessary for the evaluation of Rel-17 power saving enhancements.
* “Video conference” becomes common due to COVID-19, but we are not able to tell what is the power saving performance with NR power saving schemes. It is suggeseted RAN1 can include “Video conference” traffic to cover such common real-world traffic.
	+ XR traffic is rare in real world and still under definition in SA4. It is more reasonable UE power saving group can cover this existing real-world traffic instead of waiting for XR SI that should target to enable a “future” traffic.
* For modeling “Video conference”, **FTP model 3** can be utilized since it has been widely utilized in NR, including “R15 enabled use case” in TR 38.824 and “FTP” and “IM” in TR 38.840. The following settings can also be considered:
	+ Reuse VoIP DRX setting for similar latency requirement
	+ Mean inter-packet arrival time of 1/30 second
	+ Fixed packet size w.r.t. data rate for HD or full-HD streaming
	+ CA setting e.g., FR2 4 x 100 Mhz CCs
 |
| Xiaomi | - | We are open to discuss the additional traffic model and would rather to reuse the FTP Model 3. The detailed parameters can be discussed further. |
| Samsung | Yes | We suggest to consider additional traffic model for data-intensive traffic based on FTP model 3. |
| Vivo | Yes | We propose to have gaming model based on FTP Model 3 and 50ms mean inter-arrival. The packet size can be determined by data rate. And we are open to discuss. |
| CMCC | Yes | We are open to introduce additional traffic model. |

### DRX settings

DRX Settings

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| DRX settings | HW | MTK | Vivo | Sony | Nokia | Qualcomm |
| DRX setting(Period, On duration timer , Inactivity timer) | (20, 5, 10)ms | (20, 5, 10 )ms | 40ms | (20, 5, 10)ms, short DRX can be considered | (20,4,5) short DRX cycle of 10 ms with 10 cycles(40,4,5) short DRX cycle of 20 ms with 5 cycles(80,8,5) short DRX cycle of 40 ms with 3 cycles | TR38.840,No short DRX |

Most companies prefers 20ms or 40ms long DRX period. And the value of DRX cycle for evaluation is reasonable to consider traffic model aforementioned. Therefore it is considered the Reference DRX configurations decribed in TR38.840 section 8.2 is reused for DRX settings for ‘additional traffic model’. Note that 40ms period DRX configuration has already been included in TR38.840. And whether (20, 5, 10)ms DRX setting can be FFS if necessary.

**Question 4: Is it OK to reuse reference DRX configurations decribed in TR38.840 section 8.2 as DRX settings for evaluation?**

|  |  |  |
| --- | --- | --- |
|  **Company** | **Yes/No** | **Comments** |
| Apple  | FFS | Related to the parameter setting in Question 3.  |
| Ericsson | No  | In addition to the C-DRX configurations in 38.840 section 8.2, short DRX configurations should be added, including following examples:* (long DRX cycle, IAT, short DRX cycle, number of short DRX cycles, on duration)
	+ 160 ms, 20 ms, 20ms, 4 cycles, FR1 On duration= 8ms
	+ 160 ms, 20 ms, 20ms, 4 cycles, FR2 On duration = 4ms

It may be also good to clarify that the question is about C-DRX settings.  |
| OPPO | Yes | A common assumption for DRX setting could be helpful. Both 40 ms and 20ms is ok. We should pick one. |
| MediaTek | Yes | * + We support reusing reference DRX configurations in TR38.840.
	+ Short cycle is an optional feature that can be used to reduce the power consumption due to long DRX inactivity timer. Alternatively, DCI based power saving scheme can achieve the same purpose if network indicates UE to enter power saving after completing the last data transmission. If both schemes can provide the same functionality, we suggest to focus one setting and avoid duplicated evaluation efforts.
	+ Since the scope is to investigate “extension(s) to Rel-16 DCI-based power saving adaptation during DRX Active Time for an active BWP”, we suggest to consider the baseline configuration with DRX long cycle and **all** Rel-15 and Rel-16 DCI based power saving schemes.

Note that it is not precluded that companies can simulate both DRX short cycle and all Rel-15 and Rel-16 DCI-based power saving schemes. But, from our observation, the additional benefit with short cycle is restricted to 1.5% - 4% while much complicating UE behaviors for power consumption analysis. Please refer slide 31 of R1-2003667 for more detail information. |
| Xiaomi | - |  We are open to discuss the additional traffic model with updated DRX configurations.On the other hand, noted that short DRX configuration is not provided in TR. We suggest that it should be added. |
| Samsung | Yes | The same DRX configurations can be reused for traffic models defineded in TR28.840. For additional traffic models, it’s OK to consider different DRX configuration as needed. |
| vivo | Yes | We support reusing reference DRX configurations in TR38.840.  |
| CMCC | Yes | OK to reuse reference DRX configurations decribed in TR38.840 |

### SSB measurement for RLM/BFD

[Nokia][MTK][vivo] mentions that UE is also required to perform radio link monitoring ( also other purposes, e.g., BFD) but it is modelled in the evaluation. It is proposed to define SSB and /or CSI-RS configurations for evaluation of objective 2a. [MTK][vivo] propose to consider SSB measurement per DRX cycle for RLM/BFD.

* Include the assumption in Table XX for modelling SSB measurement power consumption per DRX cycle for RLM/BFD.
* Modelling of SSB measurement overlapped with other channels/signals should follow TR38.840

Table XX: Assumed number of measured/total beams for RLM/BFD per DRX cycle

|  |  |  |
| --- | --- | --- |
|  | FR1 | FR2 |
| # measured beams / # total beams | 2 (1 slot) / 8 (4 slots)  | 8 (4 slot) / 64 (32 slots)  |

**Question 5: Does SSB measurement for RLM/BFD need to be modelled in evalution and how to model?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Apple  | No | RLM/BFD relaxation will be discussed in rel-17 RAN4. We recommend separate discussion from 8.7.2.  |
| Ericsson | OK, but as optionally modeled in evaluation. | This may depend on the scenario. |
| OPPO | No | Considering the measurement power consumption may not contribute differently to different DCI-based power saving scheme. We nee further dicuss to understand the motivation of introducing it.The measurement may be considered in the RLM relaxation, which is different agenda item. |
| MediaTek  | Yes | For identifying the candidate relaxation schemes for RLM/BFD, power saving benefit should be justified. In this regard, RAN1 should provide a updated model that captures per-DRX SSB measurement power consumption required by RLM/BFD. |
| Xiaomi | OK | SSB measurement for RLM/BFD can be considered here. Beause UE still needs to perform SSB measurement while WUS indicates that DRX OnDurationTimer doesn’t need to strart. But whether SSB measurement makes a impact on power saving assessments needs further discussion. |
| Samsung | No | We think it’s OK to ignore the power consumption fro RLM/BFD in connected mode, especially when the SINR is not bad.  |
| Vivo | Yes | In the power saving evaluation, RLM/BFD is part of the dominat part. We see more than 30% power consumption by RLM based on our contribution ([R1-2005392](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005392.zip)). Model RLM/BFD it is nessasry.In Rel-16 UE power saving, 1 SSB burst set with 2SSB is assumed for evaluation for loop convergence, with periodicity of max (160ms, DRX cycle). When the DRX cycle is short (e.g., 40ms), the RLM periodidity is 40ms which is much less than 160ms. Therfore we think the max (160ms, DRX cycle) periodic measurement assumption we used in Rel-16 is not enough.Therefore we propose to consider SSB measurement every DRX Cycle into consideration for CONNECTED mode UE for RLM/BFD. |
| CMCC | Yes | Open to this issue. |

### Others

Instead of existing BW and CC configuration in TR38.840, one company proposes to consider **4 CCs of total 400 MHz for FR2.**

One company proposes to model UL activity or UL traffic and to model UCI related activity as DL triggerd (HARQ FB) and periodic CSI reporting.

**Question 6: Is there any others related to evaluation methodologies for power saving evaluation and what is it? Provide motivation if any.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Ericsson | Whether interruption is needed or not during transitions should be explicitly clarified for each scheme during the evaluations. The impact of presence/absence of interruptions on power savings and system impact should be included in the evaluation. This is high priority from our perspective given the significant NW impact.  |
| MediaTek | For DCI-based power saving schemes, network DCI indication overhead and UE power saving gain are important trade-off. For any Rel-17 enhancement scheme, justification on DCI indication overhead is therefore necessary. |
|  |  |
|  |  |
|  |  |

## High-level concepts

### DCI-based power saving schemes for active time

#### Adaptation of PDCCH monitoring behaviours

Most of the proposals mentions DCI indication to change PDCCH monitoring behaviour, which is beneficial from UE power saving perspective. Two main stream of machensim includes search space set group switching which is similar to Rel-16 NR-U SS set group switching which is triggered by DCI 2\_0 or timer or detection of any PDCCH.

Note in RedCap SI, one of the objective is to reduce PDCCH monitoring in order to save power as well as UE cost reduction, which is also relevant to this WI. For the design of DCI-based power saving schmes for active time in power saving WI, it is also better to also take RedCap UE into account.

##### SS set group switching

Enhancement of search space set group switching

Many companies [HW, E///, ZTE, OPPO, SS, Spreadtrum, apple, IDC, Docomo, vivo, Nokia, QC] mention Rel-16 search space set group switching which is defined in Rel-16 NR-U WI. By this scheme, the UE only monitors one of the search space set groups, and it is switched to another by timer or the indication in DCI format 2\_0 or by detection of some DCI formats. As the PDCCH monitoring periodicity is configured per search space set, the periodicity of PDCCH monitoring is changed along with the search space set group switching. Other parameters defined in a search space set can also be switched, e.g., aggregation level, number of blind decoding and etc. Similar scheme can be considered to be extended in Rel-17 power saving.

Instead of Search space switching, some companies also think CORESET-level adaption is useful [LG]. And if the SS is switched, the corresponding CORESET might also be changed.

Triggering of space set group switching is investigated from many companies’ proposals,

The following parameters related to SS set group switching can be considered

* + PDCCH monitoring periodicity and duration,
	+ aggregation level,
	+ number of blind decoding

##### PDCCH skipping

Enhancement of PDCCH skipping

Many companies [HW, ZTE, OPPO, intel, Lenovo, CMCC, Spreadtrum, apple, IDC, vivo, QC] mention DCI based signaling indicating UE to skip PDCCH monitoring for a certain duration in active time.

Some companies [Nokia][HW][…] also mentioned DCI based signaling to go to DRX, which is similar to use a DRX Command MAC CE[Nokia]. While another source [HW] thinks that compared with DRX command MAC-CE, the packets may be delayed for short duration but can be scheduled at once after the short duration if DCI-based PDCCH skipping is used . gNB can control the total sleep time of UE more flexibly to achieve a tradeoff between low traffic latency and UE power saving gain.

Triggering of PDCCH switching are investigated from many companies’ proposals,

* The following schemes for PDCCH skipping can be considered,
	+ Indication to change PDCCH monitoring behaviour, e.g.,
		- o to monitor PDCCH or to skip monitoring PDCCH,
		- to skipped PDCCH monitoring for a certain duration,
		- to adapt to different PDCCH parameters

#### MIMO layer adapation

Some companies [Samsung][vivo][HW] propose to dynamic adaptation to the maximum number of MIMO layers within the active BWP. For example, if there is no data transmission, gNB can indicates the UE to use the default configuration with smaller maximum number of MIMO layers for UE power saving. When the traffic data arrives, gNB indicates the UE to switch to larger maximum number of MIMO layers. Or it would be beneficial to support antenna adaptation method which does not require BWP switching for further power saving.

#### Relaxing PDSCH processing time

One company [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.

#### Downlink and uplink DCI decoupling

In Rel-15 and Rel-16 specification, the non-fallback DCI for DL and UL scheduling are always configured in same search space for non-fallback. This will lead to unnecessary blind decoding for some DCI format (e.g., UL or DL grant) especially if their DCI size is different.

The straightforward way is to decouple non-fallback DCI for DL and UL scheduling, i.e., configure different SS [vivo].

#### frequency domain domain

One company [Nokia] proposes the concept of resource block sets can be adapted for licensed band operation to control PDCCH monitoring behaviour in the frequency domain.

#### Dynamic change DRX parameters

One company [Sony] proposes L1 dynamic signaling mechanism where the configuration of the inactivity timer and DRX cycles in connected mode can be easily and quickly adapted based on the traffic for the UE or network conditions.

#### multi-PDSCH/multi-PUSCH scheduling

Two company [Panasonic][Lenovo] proposes multi-PDSCH/multi-PUSCH scheduling. In this case, even if PDCCH monitoring occasions are reduced for a UE like once per 2 slots or once per 4 slots, the throughput is not impacted. Multiple TB scheduling was supported by eMTC and NR-U and was also discussed in URLLC. For Rel.17 power saving enhancement, it can also be discussed and studied due to the power saving technical merit.

#### Others

*void*

#### Summary

In a summary, the following schemes are proposed in contributions from a high-level concepts. And there is a vast number of proposals there.

**For Rel-17 DCI-based power saving schemes in active time, the followings are considered,**

* **Topic 1:** Adaptation of PDCCH monitoring behaviours
	+ **Topic 1-1:** Search space set group switching with the change of
		- PDCCH monitoring periodicity and duration,
		- aggregation level,
		- number of blind decoding
	+ **Topic 1-2:** PDCCH skipping which indicate to change PDCCH monitoring behaviour, e.g.,
		- to monitor PDCCH or to skip monitoring PDCCH,
		- to skipp PDCCH monitoring for a certain duration,
		- to adapt to different PDCCH parameters
	+ **Topic 1-3:** CORESET switching
* **Topic 2:** Dynamic adaptation to the maximum number of MIMO layers within the active BWP
* **Topic 3:**Relaxing PDSCH processing time
* **Topic 4:**Decoupling non-fallback DCI for DL and UL scheduling, i.e., configure different SS for each
* **Topic 5:**RB sets adapatation for PDCCH monitoring in frequency domain
* **Topic 6:**L1 dynamic signaling mechanism where the configuration of the inactivity timer and DRX cycles in connected mode can be changed
* **Topic 7:**Multi-PDSCH/multi-PUSCH scheduling

**Question 7:**

* **Is there any other topic which has not been listed for DCI-based power saving schemes in active time?**
* **Or is there any topic which is not well captured?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
|
| Company A | Comments |
| Ericsson | WUS for short DRX can also be considered. |
| MediaTek | To agree the list, justification on whether an item is in the WI scope is needed. We suggest to remove the item(s) that cannot regarded as an extension to existing Rel-16 DCI-based power saving adaptation during DRX Active Time for an active BWP. For example, Topics 5, 6 and 7 may need further clarification.

|  |
| --- |
| 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] |

Another consideration is whether we can evaluate the power saving performance. For example, we seem not able to evaluate Topic 3 as no power scaling is defined w.r.t. a relaxed PDSCH processing time. Overall, we suggest to keep only the items with good justification on scope compliance and evaluation feasible. |
| Xiaomi | As we can see from the simulation, WUS applying to DRX short cycle can provide significant power saving. So we think PHY layer enhancement to support WUS applying to DRX short cycle should be considered. And considerring the limited time, we do not need to include other more topics. |
| Samsung  | For Topic 1-2, it’s not clear whether PDCCH skipping duration can be associated with minimum scheduling offset. In our view, we prefer the PDCCH skipping jointly adapted with cross-slot scheduling.  |
| vivo  | For topic 1-3, we think it can be achieved by SS switching since SS is linked to CORESET. Hence it can be merged to 1-1. |

### Triggering of DCI-based power saving adaptation during DRX ActiveTime

Scheduling DCI triggering

Triggering power saving adaptation by scheduling DCI are mentioned by many companies.

For SS set group switching, the Rel-16 NR-U adopts DCI format 2\_0 using field *SearchSpaceSwitchTrigger-r16 to* trigger the UE to switch between search space set group 0 and 1. For licensed band, it is naturally to optimize that to include search-space group switching bit(s) in a UE specific scheduling DCI or by detection of absence/presence of scheduling DCI instead of group-common PDCCH 2\_0. And it is proposed by many companies [vivo, ZTE, MTK,CATT, SS, CMCC, Spreadtrum,LG,Panasonic, apple, E///, Qualcomm, Nokia, 13 companies].

For PDCCH skipping, many companies mention that using DCIfor skipping [HW, vivo, zte, intel,OPPO, CMCC, Spreadtrum, Apple, IDC, 9 companies].

One company [HW] mentions for the active BWP, the maximum number of MIMO layers can be dynamically switched by L1 signaling with short switch delay.

Also, for the topic multi-PDSCH/multi-PUSCH scheduling,, companies mentiuons it can be triggered by scheduling DCI. [Lenovo][Panasonic]

Detecting scheduling grant

3 companies [OPPO][vivo][Spreadtrum] proposes to change PDCCH monitoring behaviours based on detection of scheduling grant.

Timer triggering

Timer based adaptation is also mentioned by some companies[vivo][Spreadtrum]. For example, a timer, which is similar to the timer *searchSpaceSwitchingTimer-r16*, can trigger the UE to switch between search space set group 0 and 1.

Interact with HARQ

Some companies propose to optimize the PDCCH monitoring when interacts with potential HARQ retransmission [MTK][QC].

[QC] proposes similar to the existing UE behavior for handling HARQ retransmission during the DRX operation, a set of timers (e.g., RTT timer and retransmission timer) may be configured per HARQ process to control the UE’s discontinuous PDCCH monitoring behavior.

[MTK] proposes pre-indication adaptation. For example, network sends the adaptation triggering in the scheduling DCI for the last TB of a packet. If PDSCH is received successfully, UE switches to power saving duration. Otherwise, UE stays in data-efficient duration. The results show the pre-indication adaptation can achieve 9% and 38% of power saving gains for VoIP in 1CC/FR1 and Real-Time video in 4CC/FR2 when compared to convention adaptation, respectively.

The following for DCI-based power saving adaptation during DRX ActiveTime can be considered when interact with HARQ retransmission, e.g.,

* timers (e.g., RTT timer and retransmission timer) may be configured per HARQ process to control the UE’s discontinuous PDCCH monitoring behaviour.
* When a UE receives the pre-indication for power saving, the UE is permitted to apply the adaptation if the configured condition(s) fulfils and network configures the condition(s).

One example of, the condition can be that when PDSCH is received successfully, UE adapation based on pre-indication if the configured condition(s) fulfils can also be used to other cases.

Joint indication vs independent indication

Besides independent indication of the Rel-17 DCI based power saving schemes in active time, some companies propose to joint indication of the PDCCH monitoring adaptation with

* cross-slot scheduling defined in Rel-16 [DoCoMo][OPPO] [MTK]
* Scell dormancy [MTK][CATT][Panasonic]

DCI dormat 2\_6 triggering

4 companies [LG][vivo][Lenovo][Qualcomm] propose to use DCI format 2\_6 to indicate adaptation of the PDCCH monitoring during next DRX cycle in the active time.

Others

One company [vivo] propose to switch SS set groupby detecting some UL transmission, e.g., SR / CG.

One company [OPPO] propose to further consider the mechanism based on the group common DCI. UE have to receive that special DCI format to do the switching, which is in parallel with scheduling DCIs. Similar to that, one compay [IDC] propose that go-to-sleep indication may be transmitted in the scheduling DCI or in a group-common PDCC.

In Rel-16, DCI format 2\_6 is monitored out side active time, one company [LG] suggests to use DCI format 2\_6 in active time to adapt the PDCCH monitoring.

**In summary, the following can be considered to dynamic trigger DCI-based power saving adaptation during DRX ActiveTime,**

* **Scheduling DCI**
	+ **The indication of PDCCH monitoring behaviour adaptation can be**
		- **Explicit/implicit indicated by scheduling DCI**
		- **Joint indication of the PDCCH monitoring adaptation with**
			* **cross-slot scheduling defined in Rel-16**
			* **Scell dormancy**
	+ **The scheduling DCI for indicating PDCCH monitoring behaviour adaptation can be DCI format x\_1/x\_2**
		- **DCI format x\_1**
		- **DCI format x\_2**
* **Timer based adaptation,**
	+ **A timer e.g., similar toTimer *searchSpaceSwitchingTimer-r16,* can trigger the UE to switch between search space set group 0 and 1**
	+ **A set of timers (e.g., RTT timer and retransmission timer) configured per HARQ process to control the UE’s discontinuous PDCCH monitoring behavior.**
* **UE is permitted to apply the adaptation after receiving pre-indication for power saving and if the configured condition(s) fulfils. Network configures the condition(s)**
* **DCI format 2\_6 to indicate adaptation of the PDCCH monitoring during next DRX cycle in the active time**
* **UL transmission, e.g., SR / CG**
* **Group common DCI**

**Question 8:**

* **Considering specific triggering schemes maybe only applicable for specific power saving schemes (described in section 2.2.1.9), provide your view on it if any of these triggering schemes has such restriction of usage. And provide feasible triggering schemes (described in section 2.2.2) for each topics.**
* **Is there any other triggering schemes for Rel-17 DCI-based power saving schemes in active time?**
* **Is there any triggering schemes not well captured from above?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
|
| Company A | Comments |
| Apple  | Scheduling DCI, timer based, and group common DCI can be used for topic 1 of 2.2.1.9, “Adaptation of PDCCH monitoring behaviours” |
| Ericsson | This is good starting point for this discussion. |
| OPPO | Our contributions does not means the Rel-17 enhancement should be Group Common DCI. Instead, it means the orginal Rel-16 SS switching adopt group common, which should be not good for power saving enhancement.  |
| MediaTek | We think the first level items can be consolidated a bit. One possibility is to merge pre-indication scheme under scheduling DCI since the proposal is actually to improve restransmission handling for a power saving indication based on scheduling DCI. Also the proposal with RTT timer concept can be categorized together. In this regard, the following update to the list is suggested:* **Scheduling DCI**
	+ **The indication of PDCCH monitoring behaviour adaptation can be**
		- **Explicit/implicit indicated by scheduling DCI**
		- **Joint indication of the PDCCH monitoring adaptation with**
			* **cross-slot scheduling defined in Rel-16**
			* **Scell dormancy**
	+ **The scheduling DCI for indicating PDCCH monitoring behaviour adaptation can be DCI format x\_1/x\_2**
		- **DCI format x\_1**
		- **DCI format x\_2**
	+ **Enhancement for retransmission handling**
		- **Apply adaptation only after HARQ ACK condition is fulfilled**
		- **Apply adaptation right after DCI indication but start timer(s) to handle retransmission if required**
* **Timer based adaptation,**
	+ **A timer e.g., similar toTimer *searchSpaceSwitchingTimer-r16,* can trigger the UE to switch between search space set group 0 and 1**
	+ **~~A set of timers (e.g., RTT timer and retransmission timer) configured per HARQ process to control the UE’s discontinuous PDCCH monitoring behavior.~~**
* **~~UE is permitted to apply the adaptation after receiving pre-indication for power saving and if the configured condition(s) fulfils. Network configures the condition(s)~~**

Also we suggest to consider justification on scope compliance and evaluation feasible before deciding the final list. For example, DCI format 2\_6 that is monitored outside DRX Active Time, is not in the WI scope. |
| Xiaomi | It is too early to be deep into the triggering details. We would like to later consider it after we have the consensus on introducing the specific power saving schemes. |
| Samsung  | Besides scheduling DCI, DCI format 2\_6 with modification can also be considered for triggering adapation of PDCCH monitoring behaviours within DRX cycle.  |
| Vivo | The group common DCI should be removed. |

### Summary

In section 2.2.1, there are vast number of schemes proposed. This section ask for input from companies on the priority for each schems described in section 2.2.1. Note per chairman’s guidance, the priority actually means the priority for discussion purpose only.

**Question 9: priority for each topic described in section 2.2.1.9 and relevant reasons**

|  |  |
| --- | --- |
| **Company** | **High/low priority for each topic and relevant reasons** |
|
| Company A | Comments |
| Apple  | Topic 1 of 2.2.1.9 is the high priority. Topic 1 can potentially provide the biggest power saving gain.  |
| Ericsson | We prefer to prioritise schemes indicated in our contribution, but more generally, the following criteria should be used to prioritize. * Clear gain and distinction in functionality from schemes already specified in Rel-15/16.
* Avoid overlap with schemes being discussed in other WI.
 |
| OPPO | Topic 1 should be prioritized. Others need more input and discussion. |
| MediaTek  | For the list in Section 2.2.1.9, we suggest to prioritize Topics 1-1 and 1-2. For the list in Section 2.2.2, prioritization on Scheduling DCI topic, with retransmission handling enhancement included, is also suggested. |
| Xiaomi | Topic 1,2,3 captured in 2.2.1.9 should be the first priority.  |
| Samsung | We prefer to discuss Topic 1, 2, 3 with high priority. We’ve learnt PDCCH monitoring overhead is the main issue for power saving in connected mode from Rel-16. So we think Topic 1 regarding adaptation of PDCCH monitoring behaviors within active time should be set with high priority. For Topic 2 and 3, they are simple and effective extension from Rel16 PS schemes.  |
| Vivo | We prefer topic 1(especifally topic 1-1 and 1-2) and topic 4 as high priority.For topic 1-1, triggering method including explicit/implicit indicated by scheduling DCI, timer based method and UL transmission, e.g., SR / CG is prioritized.For topic 1-2, explicit DCI triggering method is prioritized. |
| CMCC | Topic 1 and Topic 7 can be with high priority. |

# Summary of the potential proposals

Offline proposal:

# Proposals from companies’ submitted contributions

|  |
| --- |
| [R1-2005264](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005264.zip) Extension(s) to Rel-16 DCI-based power saving adaptation for an active BWP Huawei, HiSilicon |
| **Proposal 1: The traffic model for the UE power saving scheme evaluation at least include FTP traffic, instant messaging, VoIP and intensive eMBB traffic.****Proposal 2: To evaluate the extension(s) of time domain adaptation for power saving, PDCCH based power saving signalling (wake-up indication) and cross slot scheduling based power saving are taken as the baseline for evaluation.** **Proposal 3: The following metrics are considered in the evaluation of power saving mechanisms in the study:*** **UE power saving gain**
* **Latency of packet/user perceived throughput**

**Proposal 4: Reuse the existing power consumption models in TR 38.840 and add the power consumption model in Table 2 in Rel-17.****Proposal 5: Reuse link level simulation assumptions and system level simulation assumptions in TR 38.840 listed in Table 3.****Observation 1: Existing DRX mechanism (including MAC-CE based termination of inactivity timer), WUS indication and dormancy adaptation cannot skip PDCCH monitoring in certain short durations.****Proposal 6: Study DCI based PDCCH skipping in short duration in Rel-17 to trade-off between latency impact and power saving gain, including DCI based PDCCH skipping in indicated duration and adaptation to PDCCH monitoring periodicity.** **Proposal 7: Study the enhancement of dynamic adaptation to the maximum number of MIMO layers for shorter application delay.** |
| [R1-2005391](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005391.zip) Discussion on DCI-based power saving adaptation vivo |
| **Observation 1:** **In Rel-15/16, the non-fallback DCI for DL and UL scheduling are always configured simultaneously, which means UE need to blind decode both DCI formats in the same monitoring occasions. However, it is inefficient for UE power consumption if the DL and UL traffic are not symmetric.****Observation 2:** **It is necessary to support search space group switching without BWP framework for both RedCap UE and non-RedCap UEs, due to the following restrictions of BWP framework.*** **In Rel-15 and Rel-16, the maximum number of configured BWPs for DL/UL per cell is 4 and the BWPs may already be used for adapting different bandwidth and different maximum DL MIMO layers, the remaining BWPs to indicate different SS configuration is limited.**
* **For RedCap UEs, dynamic BWP switching is not likely to be supported for RedCap UE with 20MHz bandwidth.**
* **Long BWP switching delay**

**Observation 3: In FR2, due to the restriction of analog beamforming, there is only one beam direction across the whole bandwidth at one time. There are some optimizations available to adapt the PDCCH monitoring behavior to match the time pattern for analog beam.**Proposal 1: To consider decoupling non-fallback DCI for DL and UL scheduling, i.e., configure different SS for DL and UL DCI.**Proposal 2: The power model for reducing the PDCCH candidates in TR38.840 can be used to evaluate the power saving gain for decouple non-fallback DCI for DL and UL scheduling.**Proposal 3: Following can be considered for PDCCH search space adaptation within a BWP.* Explicit SS set switching by scheduling DCI
* Implicit SS set switching by detecting scheduling grant, UL transmission (SR/CG), etc.
* Potential extension to WUS, e.g. WUS indicates SS set switching
* Timer based SS set switching

Proposal 4: To consider PDCCH skipping-like method, which is dynamic and small time-scale method to adapt the PDCCH monitoring. For evaluation methodologies, the followings are proposed,**Observation 4: The RLM/BFD measurement and its power contribution were not modelled in Rel-16 power saving study, which made the results deviated from the reality.** **Proposal 5: UE power saving evaluation shall explicitly model SSB measurement for RLM/BFD purpose every DRX cycle for CONNECTED mode UE.** **Proposal 6: A modified traffic model inter-arrival time can be considered in for power saving evaluation. The following alternatives can be considered,*** **Alt 1: adopt traffic model in Appendix in R1-2005391 for online gaming.**
* **Alt 2: reusing FTP Model 3 with reduced mean inter-arrival time and packet size (e.g., online gaming)**

|  |  |
| --- | --- |
|  | Modified FTP traffic 3 for gaming |
| Model | FTP model 3 |
| Packet size | 200 bytes |
| Mean inter-arrival time | 50 ms |
| DRX setting | Period = 40 ms |

 |
| [R1-2005523](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005523.zip) Extension to Rel-16 DCI-based power saving adaptation during DRX Active Time ZTE |
| **Observation 1: Even configured with power saving techniques specified in Release 15 and Release 16, most UE power is consumed in the PDCCH-only state in BWP2.** **Observation 2: The power saving gain by using PDCCH switching for FTP 3 and VoIP traffic model is 13.2% and 13.5% for FR1, and 30% and 39.4% for FR2.** **Observation 3: The power consumption in the PDCCH-only state in BWP2 is reduced significantly when PDCCH skipping is applied.** **Proposal 1: Power consumption in the PDCCH-only state in BWP2 should be further reduced.** **Proposal 2: Both PDCCH switching and PDCCH skipping techniques should be further studied to improve the energy efficiency in DRX Active Time.**  |
| [R1-2005617](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005617.zip) Evaluation methodology and enhancement for connected mode UE power saving MediaTek Inc. |
| **Proposal 1: For Rel-17 UE power saving enhancements for connected mode, include “Real-Time Video” traffic type exhibiting both high data rate (e.g. 20 Mbps for full-HD/1080p) and frequent data activity (e.g., 10 ms – 50 ms) for more complete traffic type coverage.****Proposal 2: The following parameters are suggested for the “Real-Time Video” traffic type:*** **FTP model 3 with mean inter-packet arrival time of 30 ms and packet size of 0.08 Mbytes**
* **DRX (long cycle, on-duration, inactivity timer) = (20 ms, 5 ms, 10 ms)**
* **1 CC of total 100 MHz for FR1 and 4 CCs of total 400 MHz for FR2**

**Proposal 3: Rel-17 power consumption analysis is based on partitioning UE processing timeline into data-efficient durations and power-saving durations. The power consumption characteristics for different types of durations are based on the corresponding settings for reception BW, number of MIMO layers, same/cross-slot scheduling, PDCCH monitoring and SCell dormancy.****Proposal 4: For data-efficient duration, include a delay of X (ms) after the last TB of a packet, comprising of at least the delays of UE ACK/NACK for the last TB, gNodeB processing for HARQ, and gNodeB indication for UE power saving. X = 8 ms is suggested, and larger X values can be reported if utilized.****Proposal 5: For data-efficient and power-saving settings, please refer Table 1 for Rel-17 power consumption baseline.****Table 1: Data-efficient and power-saving settings for Rel-17 power consumption baseline****Proposal 6: Include the assumption in Table 2 for modelling SSB measurement power consumption per DRX cycle for RLM/BFD.****Table 2: Assumed number of measured/total beams for RLM/BFD per DRX cycle****Observation 1: For less-frequent data traffic, including FTP and IM, Rel-15 and Rel-16 DCI-based power saving schemes can achieve significant power saving, leaving less margin for Rel-17 enhancements.****Observation 2: For frequent data traffic, including Real-Time Video and VoIP, Rel-15 and Rel-16 DCI-based power saving schemes achieve less power saving, and the power consumption portion of PDCCH-only monitoring is still dominant.****Proposal 7: Rel-17 UE power saving enhancements for connected-mode can focus on frequent data traffic, including Real-Time Video and VoIP, in FR2.****Observation 3: Rel-16 supports cross-slot scheduling adaptation and search space set switching to reduce UE power by time-domain adaptation, but the adaptation triggering is through different DCI formats. To achieve more efficient adaptation and minimize signaling overhead, the joint adaptation of two features can be considered.****Proposal 8: Support joint adaptation of cross-slot scheduling and search space set switching by reusing the bit field of “minimum applicable scheduling offset indicator” in DCI format 0\_1/1\_1 to minimize the signaling overhead.****Observation 4: As shown in Figure 6(b), pre-indication adaptation allows UE to go to power saving earlier because network is able to send the adaptation triggering before receiving the HARQ-ACK information from UE. And UE applies the adaptation only if the network configured condition fulfils.****Observation 5: The pre-indication adaptation is compatible to all DCI-based adaptation, e.g., SCell dormancy indication and cross-slot scheduling adaptation in Rel-16.****Observation 6: The pre-indication adaptation with fulfilled condition(s) can reduce UE power consumption significantly. Compared to conventional adaptation, it can provide 9% and 38% of power savings for VoIP in 1CC/FR1 and Real-Time video in 4CC/FR2, respectively.****Proposal 9: Support pre-indication adaptation to achieve fast and efficient adaptation.*** **Network configures the condition(s) for UE power saving. When a UE receives the pre-indication for power saving, the UE is permitted to apply the adaptation if the configured condition(s) fulfils.**

**FFS the condition.** |
| [R1-2005721](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005721.zip) PDCCH monitoring adaptation CATT |
| **Proposal 1: The PDCCH monitoring adaptation can be applied to 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 search space configuration.****Proposal 2: The existing DCI format 0\_1 and 1\_1 in Rel-16 are reused without introducing additional information field, in which the SCell dormancy indication field could be repurposed as the joint indication** **including the PDCCH monitoring adaptation for PCell and/or SCell dormancy indication.** |
| [R1-2005886](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005886.zip) On PDCCH monitoring reduction techniques during active time Intel Corporation |
| **Observation 1: GTS provides significant additional power saving gain with respect to cross-slot scheduling with BWP adaptation enabled*** **For cell center UE, i.e., 50% UE, GTS with up to 10ms sleep duration provides up to 30% additional power saving gain on top of power saving provided by Rel-16 schemes with less than 13% UPT loss.**

**Observation 2: Go-to-sleep signal has better potential for power saving gain compared to Short DRX.****Observation 3: For cell center UE, Go-to-sleep signal with 10ms sleep duration provide 29% power saving gain with 12% UPT loss compared to short DRX with 10ms.** **Proposal 1: NR supports DCI based go-to-sleep signals during active time for PDCCH monitoring reductions*** **FFS: Extension of Rel-16 DCI based solutions for triggering go-to-sleep signal.**
* **FFS: Monitoring of measurement signals during sleep duration**
 |
| [R1-2005936](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005936.zip) Potential enhancement to DCI based power saving adaptation Lenovo, Motorola Mobility |
| * **Proposal 1: Study enhancement to power saving DCI to support adaptation of a search space configuration in every DRX cycle.**
* **Proposal 2: Study necessary enhancement to support multi-PDSCH/multi-PUSCH scheduling.**
* **Proposal 3: Study scheduling based dynamic PDCCH skipping during Active Time for power saving mode UE.**
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| [R1-2006043](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006043.zip) DCI-based adaptation for PDCCH OPPO |
| ***Proposal 1: Models of power consumption and power scaling for adaptation is reused in Rel-17 with some necessary modification.******Proposal 2: The new FTP models 3 for Gaming and Short Video IM could use 0.05 Mbytes packet size and 15ms mean inter-arrival time. Smaller Packet size like 0.01Mbytes can be also considered.******Proposal 3: Power saving enhancement consider the PDCCH monitoring adaptation schemes including:******Indicating Search Space group adaptation.******Indicating skipping of PDCCH monitoring occasions.******Autonomous PDCCH monitoring adaptation.******Proposal 4: In power saving mode with cross-slot minimum k0, The UE specific PDCCH search space monitoring periodicity can be matched to the current applicable minimum K0 values.******Considering the (min(K0)+1) as the monitoring periodicity.*** |
| [R1-2006159](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006159.zip) On enhancements of power saving techniques during DRX active time Samsung |
| Proposal 1: Support power saving signal for dynamic PDCCH adaptation during DRX active time. Search space set switching specified in Rel-16 can be a starting point.Proposal 2: Support joint adaptation on minimum scheduling offset and PDCCH skipping when the UE is operated with cross-slot scheduling based power saving.Proposal 3: Support joint adaptation on minimum PDSCH processing time and minimum scheduling offset.Proposal 4: Support maximum MIMO layer adaptation without BWP switchingProposal 5: Consider data-intensive traffic model that is modelled by FTP Model 3 with 1MB packet size and 50ms inter-arrival time |
| [R1-2006223](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006223.zip) Discussion on PDCCH monitoring reduction during DRX active time CMCC |
| **Proposal 1. Three PDCCH monitoring reduction techniques can be studied in Rel-17, and Alt 1 can be the highest priority:****Alt 1. Go-to-sleep indication;****Alt 2. PDCCH monitoring periodicity adaptation;****Alt 3. Search space set grouping.****Proposal 2. The DCI indication scheme of PDCCH monitoring reduction techniques e.g., adding bits or re-purpose DCI fields can be further studied.** |
| [R1-2006271](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006271.zip) Discussion on power saving techniques for connected-mode UE Spreadtrum Communications |
| ***Proposal 1: Consider to specify PDCCH skipping.******Proposal 2：Consider to specify PDCCH monitoring periodicity switching.***  |
| [R1-2006313](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006313.zip) Discussion on DCI-based power saving adaptation during DRX ActiveTime LG Electronics |
| **Proposal 1: For power saving on PDCCH monitoring, followings could be considered in Rel-17;*** **Configurable BD/CCE limit**
* **Dynamic CORESET (and/or search space set) activation/deactivation**

**Proposal 2: The DCI format 2\_6 could be used to indicate which search space set(s) are monitored during next DRX cycle.** **Proposal 3: The DCI format 2\_6 could be monitored during Active time for indicating CORESET/search space set activation/deactivation.**  |
| [R1-2006387](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006387.zip) Potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime Panasonic |
| **Proposal 1: The support of PDCCH monitoring reduction for traffic adaptation** **time domain within active time should be studied.****Proposal 2: DCI based PDCCH monitoring adjustment on parameters in RRC parameters *SearchSpace* and *ControlResourceSet* should be studied for Rel.17 power saving enhancement.**Proposal 3: Multiple TB scheduling should be studied for Rel.17 power saving enhancement.**Proposal 4: UE behaviour on simultaneous configuration of secondary DRX group, WUS and dormancy indication should be clarified with minimum specification impact.** |
| [R1-2006529](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006529.zip) PDCCH based power saving enhancements for connected-mode Ues Apple |
| **Proposal** * Consider the support of additional power adaptation method in active time
	+ Dynamic PDCCH monitoring skipping
	+ Dynamic change of PDCCH monitoring parameters
 |
| [R1-2006548](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006548.zip) PDCCH-based power saving signal design considerations InterDigital, Inc. |
| ***Proposal 1: Search space switching/activation is considered to reduce PDCCH monitoring in Active Time.*** |
| [R1-2006668](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006668.zip) Discussion on potential enhancements for power savings during active time Ericsson |
| **Proposal 1 As a baseline, Rel-15/16 power savings mechanisms including the following should be considered for evaluating the gain of potential Rel-17 enhancements for power savings during active time.****a. Long and short DRX and associated MAC command CEs****b. BWP switching****c. WUS****d. Cross-slot scheduling****e. SCell dormancy****f. Secondary DRX****g. Search space set group switching****Proposal 2 UE power savings vs. system performance/latency/overhead impact should be considered as part of evaluation of potential enhancements for power savings during active time.****Proposal 3 It should be clarified whether a scheme evaluated for potential enhancements for power savings during active time entails an interruption or not.****a. Corresponding impact on UE power savings and system performance should be included in the evaluations.****b. If needed, RAN4 feedback should be taken at early stage of the study.** |
| [R1-2006738](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006738.zip) Discussion on extension to DCI-based power saving adaptation NTT DOCOMO, INC. |
| Proposal 1: It should be discussed first on what Rel-16 DCI-based power saving adaptation(s) the enhancements will be considered.Proposal 2: Consider following Rel-16 DCI-based power saving adaptation(s) as the candidates for enhancements to reduce PDCCH monitoring.* Rel-16 cross-slot scheduling enhancements, i.e., minimum scheduling offset of K0/K2
* Search space set group switching

Observation 1: It would be beneficial to consider PDCCH skipping in some slot(s) when cross-slot scheduling is applied in order to achieve further power saving gain.Observation 2: Based on the search space set group switching, it would be possible to change the PDCCH monitoring periodicity with entering/leaving CDRX state.Observation 3: Some mechanism providing more flexibility on adaptation of the parameters related to PDCCH monitoring can be considered. |
| [R1-2006755](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006755.zip) Power saving adaptation during Active Time ASUSTEK COMPUTER (SHANGHAI) |
| **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**
 |
| [R1-2006817](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006817.zip) DCI-based power saving adaptation during DRX ActiveTime Qualcomm Incorporated |
| [Observation 1: For Rel-17 connected-mode power saving evaluation, need for additional DRX cycles other than those recommended in TR 38.840 is not evident.](#_Toc47691394)[Observation 2: For Rel-17 connected-mode power saving evaluation, evaluation for Short cycle DRX is not necessary.](#_Toc47691395)[Observation 3: For Rel-17 connected-mode power saving evaluation, need for new traffic models other than those in TR 38.840 is not evident.](#_Toc47691396)[Observation 4: Rel-16 search space set switching feature can be reused for Rel-17 connected-mode power saving.](#_Toc47691397)[Proposal 1: For Rel-17 connected-mode power saving evaluation, the Rel-16 power models, traffic models, and evaluation methodology in TR 38.840 are reused.](#_Toc47691398)[Proposal 2: 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.](#_Toc47691399)[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.](#_Toc47691400) |
| [R1-2006898](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006898.zip) UE power saving enhancements for Active Time Nokia, Nokia Shanghai Bell |
| In Section 2.1 we discussed the general assumptions and made following observations and proposals:**Observation:** *Power saving concepts for objective 2a must be compared with baseline utilizing all relevant Rel-15 and Rel-16 power saving features.***Observation:** *The UE assistance information of Rel-16 result in the DRX configuration to be accurately tailored to any traffic model being studied.***Proposal: RAN1 to define assumptions on WUS monitoring power consumption and ps-Offset. The duration is 1 slot and WUS is always correctly detected.****Proposal: RAN1 to define DRX configurations, including short DRX, for selected traffic models before evaluating new power saving features for objective 2a.** **Proposal: RAN1 to define DRX configurations, including short DRX, for selected traffic models before evaluating new power saving features for objective 2a.** In Section 2.2 we discussed the traffic model related aspects:-**Proposal: Account also UL activity in the power consumption evaluation for the Active Time.****Proposal: Model UCI related UL activity as DL triggered (HARQ FB) and periodic (CSI reporting).****Proposal: For bi-directional traffic, base the UL user data activity on the corresponding traffic model.****Proposal: Approximate the UL-DL slot configuration with 5ms pattern as {DDDDDDUUUU} (6 DL, 4 UL).****Proposal: RAN1 to select/define a video call/conference traffic model e.g. based on [6].** **Proposal: RAN1 to define SSB and CSI-RS configurations for evaluation of objective 2a.**Finally in Section 2.3 we discuss the different mechanisms for power saving enhancements during active time and make following proposals and observations:**Proposal: It should be ensured that the introduced enhancements do not have unneccesary overlap, and that priority is given for enhancement of existing functionalities.****Proposal: RAN1 to clarifiy the applicability of search space set switching for UE power saving in licensed bands, and discuss potential optimizations to further reduce the PDCCH monitoring based on it.****Observation:** *To increase power saving gains from PDCCH monitoring adaptation, the search space set switching could be complemented with cross-slot scheduling.***Observation:** *The concept of resource block sets can be adapted for licensed band operation to control PDCCH monitoring behaviour in the frequency domain.* **Observation:** *Methods to reduce PDCCH monitoring during Active Time could be evaluated for power saving benefit and specification impact.* **Observation:** *Methods to reduce the UL power consumption during Active Time could be evaluated for power saving benefit.* |
| [R1-2006946](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006946.zip) Power saving enhancements for connected mode UEs Sony |
| **Proposal 1. Update TR38.840 to include a high data intensity traffic model that supports a high data rate with frequent data activity**.**Proposal 2. Evaluations should consider the UE simultaneously supporting different traffic models in order to more realistically model UE operation**.**Proposal 3: Study dynamic DRX configuration, where the configuration of the inactivity timer and DRX cycles can be signaled via DCI.** |
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# Summary of the previous agreements

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# Work plan

A suggested work plan for connected-mode enhancement is proposed to be discussed in [[R1-2005614](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005614.zip)] as follows,

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| --- | --- | --- |
| **Quarter** | **Meeting** | **Work plan** |
| Q3/2020 | RAN1#102-e | **Connected-mode enhancements:*** Evaluation methodology updates (based on TR 38.840)
* Identify candidate enhancements

**LS evaluation methodology updates to RAN2** |
| Q4/2020 | RAN1#103-e | **Connected-mode enhancements (2nd & 3rd weeks):*** Conclude beneficial enhancement(s) for DCI-based scheme(s)
 |
| Q1/2021 | RAN1#104 | **Connected-mode enhancements:*** Specify enhancement(s) for DCI-based power saving scheme(s)
 |
| Q2/2021 | RAN1#104bis | **Connected-mode enhancements:*** Specify enhancement(s) for DCI-based power saving scheme(s)

**LS Initial RRC parameters to RAN2** |
| Q2/2021 | RAN1#105 | **Connected-mode enhancements:*** Finalize enhancement(s) for DCI-based power saving scheme(s)

**LS final RRC parameters to RAN2** |

# Work Item Description

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

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

# Reference

The following contributions are submitted in RAN1#102-E in AI 8.7.2,

1. [R1-2005264](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005264.zip) Extension(s) to Rel-16 DCI-based power saving adaptation for an active BWP Huawei, HiSilicon
2. [R1-2005391](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005391.zip) Discussion on DCI-based power saving adaptation vivo
3. [R1-2005523](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005523.zip) Extension to Rel-16 DCI-based power saving adaptation during DRX Active Time ZTE
4. [R1-2007032](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Inbox/R1-2007032.zip) Evaluation methodology and enhancement for connected mode UE power saving MediaTek Inc. revised from R1-2005617
5. [R1-2005721](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005721.zip) PDCCH monitoring adaptation CATT
6. [R1-2005886](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005886.zip) On PDCCH monitoring reduction techniques during active time Intel Corporation
7. [R1-2005936](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005936.zip) Potential enhancement to DCI based power saving adaptation Lenovo, Motorola Mobility
8. [R1-2006043](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006043.zip) DCI-based adaptation for PDCCH OPPO
9. [R1-2006159](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006159.zip) On enhancements of power saving techniques during DRX active time Samsung
10. [R1-2006223](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006223.zip) Discussion on PDCCH monitoring reduction during DRX active time CMCC
11. [R1-2006271](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006271.zip) Discussion on power saving techniques for connected-mode UE Spreadtrum Communications
12. [R1-2006313](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006313.zip) Discussion on DCI-based power saving adaptation during DRX ActiveTime LG Electronics
13. [R1-2006387](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006387.zip) Potential extension(s) to Rel-16 DCI-based power saving adaptation during DRX ActiveTime Panasonic
14. [R1-2006529](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006529.zip) PDCCH based power saving enhancements for connected-mode Ues Apple
15. [R1-2006548](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006548.zip) PDCCH-based power saving signal design considerations InterDigital, Inc.
16. [R1-2006668](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006668.zip) Discussion on potential enhancements for power savings during active time Ericsson
17. [R1-2006738](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006738.zip) Discussion on extension to DCI-based power saving adaptation NTT DOCOMO, INC.
18. [R1-2006755](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006755.zip) Power saving adaptation during Active Time ASUSTEK COMPUTER (SHANGHAI)
19. [R1-2006817](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006817.zip) DCI-based power saving adaptation during DRX ActiveTime Qualcomm Incorporated
20. [R1-2006898](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006898.zip) UE power saving enhancements for Active Time Nokia, Nokia Shanghai Bell
21. [R1-2006946](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2006946.zip) Power saving enhancements for connected mode UEs Sony

Other references:

1. RP-200938, “Revised WID: UE Power Saving Enhancements for NR”, MediaTek Inc., RAN#88-e
2. [R1-2005614](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_102%5CDocs%5CR1-2005614.zip) Work plan for UE power saving enhancements MediaTek Inc.

# History

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