**3GPP TSG-RAN WG1 #102-e R1-200xxxx**

**e-Meeting, August 17th – 28th, 2020**

**Source: Moderator (Apple Inc.)**

**Title: Feature lead summary #2 on reduced PDCCH monitoring**

**Agenda item:** **8.6.2**

**Document for:** **Discussion and Decision**

# 1 Introduction

This document summarizes the contributions made under the “reduced PDCCH monitoring” agenda item of the Rel-17 study item on “Study on support of reduced capability NR devices”.

The revised RedCap SID [1] contains the following objective related to this agenda item:

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| --- |
| Study UE power saving and battery lifetime enhancement for reduced capability UEs in applicable use cases (e.g. delay tolerant) [RAN2, RAN1]:   * Reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits [RAN1]. * Extended DRX for RRC Inactive and/or Idle [RAN2] * RRM relaxation for stationary devices [RAN2] |

In RAN1 #101 e-meeting, the following agreements on this topic was reached:

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| *Agreements:*   * Study the impact of BD and CCE limits reduction on power saving and PDCCH blocking probability (quantitatively) and impacts on latency and scheduling flexibility (at least qualitatively). * Reuse the power consumption models and scaling factors for FR1 and FR2 provided in TR 38.840 (sections 8.1.1, 8.1.2, 8.1.3) as appropriate. * For evaluation of UE power saving, for wearables, use the traffic models FTP model 3 and VoIP from TR 38.840 to characterize the wearables service types including IM, VoIP, heartbeat, etc. with proper modification of at least packet size and mean inter-arrival time. Values are FFS. * For evaluation of UE power saving, for industrial wireless sensor use cases, use a traffic model based on the service performance requirements for the process monitoring use case in TS 22.104 Table 5.2-2. At least 64 bytes UL message (plus headers, e.g. MAC, RLC, etc.) transmitted periodically with a periodicity 100 ms should be considered (other values are encouraged). |

Proposals for email approval is as follows:

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Proposal 1: For power consumption evaluation, use FTP-3 model with 100 Bytes packet size and 60s mean inter-arrival time as baseline for ‘heartbeat’ traffic.**  **Proposal 4: The scaling factor ‘0.7’ ~~defined in TR 38.840 for FR2~~ is used For 2 Rx to 1Rx power scaling.**  **Proposal 5: For evaluation, the power scaling for PDCCH candidate reduction defined in TR 38.840 is reused for Redcap UEs.**   * **~~FFS whether, if yes, how to define new scaling factor (e.g. 1.3) to model the 3-symbols CORESET configuration and the non-overlapped CCEs numbers impact on power consumption.~~**   **Proposal 7: For power consumption evaluation, the DRX configurations of Instant message and VoIP in TR 38.840 are reused.**  **Proposal 8: For power consumption evaluation, reuse the following DRX configuration defined in TS 38.840 for ‘heartbeat’ traffic model:**   * **C-DRX cycle 320msec, inactivity timer {200, 80} msec** * **FR1 On duration: 10 msec** * **FR2 On duration: 5 msec**   **Proposal 9: For the PDCCH blocking rate evaluation, the following was assumed as baseline:**   |  |  | | --- | --- | | Parameters | Assumptions | | Number of candidates for each AL | Each company to report. | | SCS/BW | FR1: 15KHz or 30KHz/20MHz  FR2: 120KHz/[100]MHz | | CORESET duration | [2 or 3] symbols | | Delay toleration (Slot) | [1] | | ~~Aggregation level Distribution~~ | ~~Atl.1: [0.4, 0.3, 0.2, 0.05 , 0.05] or Alt.4~~  ~~Other values are not precluded.~~ |   **Proposal 11: The baseline for RedCap power saving evaluation is NR Rel-16 including support for DRX with DCI format 2\_6 and cross-slot scheduling.**   * **Note that: This does not mean DCI format 2-6 and cross-slot scheduling is mandatorily supported for Redcap.**   **Proposal 15: Discussion on reduced maximum number of configurable CORESET technique for power saving is deprioritized ~~under Redcap~~ SI in Redcap power saving sub-agenda.** |

# 2. Evaluation methodology for power saving techniques

## 2.1 Traffic model

**Summary**

Companies preferences can be summarized as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Position/View | Description | | Companies | Num. |
| 1 | Yes. | Opt.2 (64 bytes, 100ms) | Vivo, OPPO | 2 |
| 2 | 100 bytes, 60s | SONY, Ericsson (also fine with 300s), Intel, Huawei, Interdigital, Nokia, Futurewei (some packet size value in middle between Opt.1 and Opt.2), ZTE | 8 |
| 3 | Opt.1 (100 bytes, 300s) | Yes: Huawei, Ericsson (2nd preference)  Concerned: Intel | 2 |
| 4 | No |  | MTK (no objection, but not prefer), Qualcomm (using IM traffic model or background sync in 38.840), Samsung (leave each company to decide), CATT | 4 |

Based on the inputs above, clearly modified Opt.1 i.e. FTP model 3 with pack size 100 bytes and mean arrival rate as 60s is preferred by majority of companies. Considering the fact that aligned evaluation assumption, if possible, is always beneficial to form a common ground to draw conclusion on candidate techniques, the following therefore was proposed:

**Proposal 1: For power consumption evaluation, use FTP-3 model with 100 Bytes packet size and 60s mean inter-arrival time as baseline for ‘heartbeat’ traffic.**

## 2.2. Power consumption model

Regarding Q2, almost all responses agree that the power consumption model in TR 38.840 needs to be modified to address the identified issue 1-3 listed in Table. On issue 4, 3 companies shared views, in which two suggest addressing it and one slightly prefers to deprioritize this modification.

The Table below was partially discussed in Rel-17 power saving WI email thread and copied below for continuous discussions in RedCap:

**Table: Power consumption model for RedCap**

|  |  |  |
| --- | --- | --- |
| Power State | Relative Power  (TR 84.840 with reference bandwidth of 100 MHz) | Relative Power  (REDCAP UEs with reception bandwidth of 20 MHz) |
| Deep Sleep (PDS) | 1 | [0.5] |
| Light Sleep (PLS) | 20 | [10] |
| Micro sleep (PMS) | 45 | [25] |
| PDCCH-only (PPDCCH) | 100 | [40] for same-slot scheduling;  (max {100\*0.4, [25]Note2})  [28] for cross-slot scheduling (max {100\*0.4\*0.7Note3, [25]}) |
| PDCCH + PDSCH (PPDCCH+PDSCH) | 300 | [120] |
| PDSCH-only (PPDSCH) | 280 | [112] |
| SSB/CSI-RS proc. (PSSB) | 100 (synchronization or serving cell measurement) | [40] (max {100\*0.4, [25]Note2}) |
| Intra-frequency RRM measurement (Pintra) | ·        150 (synchronous case, N=8, measurement only)  ·        200 (combined measurement and search) | ·        60Note4 (synchronous case, N=8, measurement only)  ·        80Note4 (combined measurement and search) |
| Inter-frequency RRM measurement (Pinter) | ·        150 (neighbor cell search power per freq. layer)  ·        150 (measurement only per freq. layer)  ·        Micro sleep power assumed for switch in/out a freq. layer | ·        60Note4 (neighbor cell search power per freq. layer)  ·        60Note4 (measurement only per freq. layer)  ·        Micro sleep power assumed for switch in/out a freq. layer |

**Question 3: For power evaluation of Redcap, can we use the values by removing bracket in Table above (Power consumption model for RedCap)? If not, what modification is needed, and why?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | We think the cross-slot power [28] may be needs some further discussion. Compared to the eMBB UEs, the benefit by cross-slot scheduling could be smaller for RedCap as the there are less reduction of PDSCH buffering. Suggest to change [28] to 32 for cross-slot. |
| Samsung | We think the relative power for RedCap UEs should consider all UE complexity reduction features, including both reduction on BW and RX antennas.  We suggest to first clarify the configuration of baseline case, for example RX BW of 20MHz, UE antennas of 2, thus no need to apply any scaling rule for baseline later.  For the Micro-sleep state, we suggest 23 to keep the ratio between micro-sleep and deep sleep to be similar as that in TR 38.840;  To determine the relative power of active state for baseline, reduction on RX BW, RX antennas, and cross-slot scheduling jointly impact the actual power consumption level in practice, so it’s not fair to apply the scaling rule in 38.840 sequentially on top of each other directly. We suggest to consider a joint scaling factor to be the middle of the maximum and minimum possible values. For example, the joint scaling factor for 0.4 (reduction on BW) and 0.7 (reduction on RX antennas) can be (0.4 + 0.4\*0.7)/2 = 0.34, the joint scaling factor for 0.4 (reduction on BW), 0.7 (reduction on RX antennas) and 0.7 (cross-slot scheduling) can be (0.4 + 0.4\*0.7\*0.7)/2 = 0.3  Therefore, we suggest the following changes:   |  |  |  | | --- | --- | --- | | Power State | Relative Power  (TR 84.840 ~~with reference bandwidth of 100 MHz~~) | Relative Power  for REDCAP UEs Note1~~with reception bandwidth of 20 MHz)~~ | | Deep Sleep (PDS) | 1 | [0.5] | | Light Sleep (PLS) | 20 | [10] | | Micro sleep (PMS) | 45 | ~~[25~~] [23] | | PDCCH-only (PPDCCH) | 100 | ~~[40]~~ [34] for same-slot scheduling Note2;  ~~(max {100\*0.4, [25]~~~~Note2~~~~})~~  ~~[28]~~ [30] for cross-slot scheduling Note3 ~~(max {100\*0.4\*0.7~~~~Note3~~~~, [25]})~~ | | PDCCH + PDSCH (PPDCCH+PDSCH) | 300 | ~~[120]~~ [102] Note4 | | PDSCH-only (PPDSCH) | 280 | ~~[112]~~ [95] Note4 | | SSB/CSI-RS proc. (PSSB) | 100 (synchronization or serving cell measurement) | ~~[40]~~ [34] Note4 ~~(max {100\*0.4, [25]~~~~Note2~~~~})~~ | | Intra-frequency RRM measurement (Pintra) | ·        150 (synchronous case, N=8, measurement only)  ·        200 (combined measurement and search) | ·      [51] ~~60~~Note4 (synchronous case, N=8, measurement only)  ·      [68] ~~80~~Note4 (combined measurement and search) | | Inter-frequency RRM measurement (Pinter) | ·        150 (neighbor cell search power per freq. layer)  ·        150 (measurement only per freq. layer)  ·        Micro sleep power assumed for switch in/out a freq. layer | [51] ~~60~~Note4 (neighbor cell search power per freq. layer)  ·       [68] ~~60~~Note4 (measurement only per freq. layer)  ·        Micro sleep power assumed for switch in/out a freq. layer |   Note1: REDCAP UEs with RX BW of 20MHz and RX antennas of [2].  Note2: scaling factor of 0.34 for same cross-slot scheduling with reduction on UE BW and RX antennas  Note3: scaling factor of 0.3 for cross-slot scheduling with reduction on UE BW and RX antennas  Note4: scaling factor of 0.34 for reduction on UE BW and RX antennas |
| Ericsson | Yes. The relative powers (e.g., during deep sleep) that are considered for the eMBB UEs and the RedCap UEs, both with 20 MHz bandwidth, seems to be different. Therefore, it would be good to clarify what other complexity reduction technique(s) (e.g., reduced Rx) than bandwidth reduction has been considered to determine the relative power values for RedCap. |
| Intel | Power scaling for sleep states needs some clarification. For example, 0.5 power scaling for deep sleep is significant reduction. We understand some reduction maybe possible, but 0.5 seems to be an over estimate, unless some more justification is provided. Some value in the range of 0.8 to 1 seem more reasonable. |
| Qualcomm | We should use idle mode power defined in Rel-17 power saving enhancements as starting point.  There is no need to make RedCap power model values lower relative to eMBB model because we do not do a cross-comparison between eMBB and RedCap based on the model itself. As long as the relative power levels within RedCap are reasonable, the evaluation of relative gain for individual proposals should be sound.  RedCap can further discuss whether to change some values based on this starting point. It is not justified yet why sleep/PDCCH power is reduced but not other powers. If so, presumably the sleep transition time/overhead also need to be updated. In the end, everything just approximately scales down by a similar factor, then there is no need in doing the scaling selectively from the beginning because only the relative difference among operations within RedCap matters. |
| Huawei, HiSilicon | 1. We prefer Alt.2. The RedCap UE is a different chipset from the normal NR eMBB chipset, which is with lower complexity and smaller chip size. So it is reasonable to assume a lower power consumption value for sleep modes. Note that 0.5 is optionally supported in TR 38.840 in Rel-16, we think it is a suitable value for RedCap UEs. If other smaller values are used, the light sleep and micro sleep should be adjusted proportionally to keep the same ratio. For the proposal of 0.8 from Intel, we think it would be too high, we are open for the compromised value between 0.5 and 0.8. 2. The reference configuration of the power model is 20MHz with two Rx antennas. 3. We are open to discussion further refinement on the scaling, e.g. from VIVO. |
| OPPO | The consideration of Power Reduction will be special for RedCap UE and the value can be shrink as we discussed in Power Saving AI.  We are general OK with certain scaling factors. For us, one reasonable factor for reduced RX should be around 0.7 and 0.6. The reason for this is obvious, the number of RX chain will be more proportional to power saving. For smaller bandwidth, the power consumption does not reduced that way. We can accept the current 0.4 for BW, but a larger value would be also OK to us.  Your proposed value is ok, and further update should consider both BW and RX. |

**Summary**

Candidates proposed by companies is summarized in Table below.

|  |  |  |  |
| --- | --- | --- | --- |
| Power State | Alt1 | Alt.2 | Alt.3 (Reuse the (Idle/inactive-mode operation with reception bandwidth 20 MHz) |
| Deep Sleep (PDS) | [0.5] or [0.8] | [0.5] or [0.8] | 1 |
| Light Sleep (PLS) | [10] | [10] | 20 |
| Micro sleep (PMS) | [25] | [23] | 45 |
| PDCCH-only (PPDCCH) | [40] for same-slot scheduling;  (max {100\*0.4, [25]Note2})  [32] for cross-slot scheduling (max {100\*0.4\*0.7Note3, [25]}) | [34] for same-slot scheduling Note2;  [30] for cross-slot scheduling Note3 | 50 |
| PDCCH + PDSCH (PPDCCH+PDSCH) | [120] | [102] Note4 | 120 |
| PDSCH-only (PPDSCH) | [112] | [95] Note4 | 112 |
| SSB/CSI-RS proc. (PSSB) | [40] (max {100\*0.4, [25]Note2}) | [34] Note4 | 50 |
| Intra-frequency RRM measurement (Pintra) | ·        60Note4 (synchronous case, N=8, measurement only)  ·        80Note4 (combined measurement and search) | [51] Note4 (synchronous case, N=8, measurement only)  [68] Note4 (combined measurement and search) | ·        [60]Note4 (synchronous case, N=8, measurement only)  ·        [80]Note4 (combined measurement and search) |
| Inter-frequency RRM measurement (Pinter) | ·        60Note4 (neighbor cell search power per freq. layer)  ·        60Note4 (measurement only per freq. layer)  ·        Micro sleep power assumed for switch in/out a freq. layer | [51] Note4 (neighbor cell search power per freq. layer)  ·       [68]  Note4 (measurement only per freq. layer)   Micro sleep power assumed for switch in/out a freq. layer | ·        [60]Note4 (neighbor cell search power per freq. layer)  ·       [150] Note4 (measurement only per freq. layer)  ·        Micro sleep power assumed for switch in/out a freq. layer |

**Question 3a: For Redcap power consumption analysis, which alternative above is suggested and why? If not, what modification is needed?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| OPPO | Alt 2, which take full consideration of reduced capabilities. |
| Qualcomm | Alt 3. To address vivo’s concern we can reduce micro sleep power (35) and cross-slot PDCCH power (40) but leave deep sleep power and light sleep power unchanged.  For inter-frequency measurement only per freq. layer, set [150] to 80.   |  | | --- | | Alt.3 (Reuse the (Idle/inactive-mode operation with reception bandwidth 20 MHz) | | 1 | | 20 | | ~~45~~ 35 | | 50 for same-slot scheduling, 40 for cross-slot scheduling | | 120 | | 112 | | 50 | | ·        [60]Note4 (synchronous case, N=8, measurement only)  ·        [80]Note4 (combined measurement and search) | | ·        [60]Note4 (neighbor cell search power per freq. layer)  ·       [~~150~~80] Note4 (measurement only per freq. layer)  ·        Micro sleep power assumed for switch in/out a freq. layer | |
| vivo | We are fine with either Alt 1 or Alt 2 |
| CATT | Alt 3: UE power model for IDLE mode UE based on BWP scaling defined in TR38.840 should be able to reuse for REDCAP UE power model.  We can’t agree with the proposed REDCAP UE power model in either Alt 1 or Alt 2. UE would turn off all components to get the utmost power saving for both eMBB and REDCAP. We need justification in the REDCAP system design to provide extra power saving if the power consumption is different in the sleeping mode (deep sleep, light sleep, and micro sleep) between eMBB and REDCAP UEs. |
| Ericsson | Alt 1 or Alt 2. We also agree with CATT that clarification needs to be provided for the extra power saving for a RedCap UE compared to an eMBB UE (for the same reception bandwidth) in different sleep states. It is also required to note the number of UE Rx antennas in both Alt 1 and Alt 2. |
| Intel | Alt 3 |
| Samsung | Alt 2.  Alt1 and Alt3 only consider power scaling from Rel-16 power model due to reduction on BWP, but the Rel-16 power model assumes 4 antennas. We think both number of RX chain and UE operating BW should be taken into account for determining the baseline power model. It doesn’t make sense to only consider one and ignore the other.  Also, it’s likely that Rel-17 power saving WI would consider potential enhancement applicable for both eMBB UEs and RedCap UEs. It’s worthwhile to consider more accurate power model for RedCap UEs. |

There are a few additional issues needs to be addressed as follows:

* Issue 3: The scaling factor for 2 Rx to 1Rx need is missed.
* Whether the power scaling for PDCCH candidate reduction is still applicable for the modified power consumption model for 20MHz bandwidth?

On Issue 3, vivo proposed to consider ‘0.7’ for scaling factor, which is used for FR2 in TR 38.840, i.e. 1Rx power is 0.7 of 2Rx power. Six companies expressed support for this proposal.

**Question 4:** **For evaluation, can we reuse the scaling factor ‘0.7’ for 2 Rx to 1 Rx power scaling, same as defined for FR2 in TR 38.840? If not, which value is suggested?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Yes |
| MediaTek | No. It is not necessary as power saving adaptation via reducing #RX antenna is not within the scope. |
| SONY | Yes. The scope if about “Study UE power saving and battery lifetime enhancement for reduced capability UEs”. While reducing the number of antennas to save power is not within the scope, studying power saving schemes for 1RX UE (a type of Redcap UE) is within the scope. |
| Futurewei | Yes |
| Ericsson | Yes |
| Intel | Yes. Regarding MTK’s comments, proper scaling for RedCap specific parameters such as BW, antennas should be considered since the corresponding UE need to be properly modeled for any meaningful observations. |
| Qualcomm | Yes |
| Samsung | No. The scaling factor in TR38.840 is proposed for eMBB UE with different baseline configuration. It’s applicable to UE with much larger BW. Since the chipset and baseline configuration all changed, we think modification is needed.  Instead of the scaling factor, we think the configuration of RX antennas for baseline is more important and relevant. Similar as Rel-16 PS WI, only one baseline setting is enough. No need to provide relative power for all possible settings with different RX antennas, as our goal is not to evaluate power saving for reduction on RX antennas. We think proposal 2 can be considered together with Q3, which is the relative power for RedCap baseline considering all UE complexity reduction features. |
| Fraunhofer | Yes |
| Huawei, HiSilicon | We should put the value of 0.7 in square brackets. |
| InterDigital | Yes. |
| Nokia | Yes |
| LG | Yes. |
| Lenovo, Motorola Mobility | Yes |
| ZTE,Sanechips | Yes. |
| OPPO | Yes. |
| CATT | Yes. |
| SONY2 | In proposal 2, the text about FR2 means that it is unclear that the proposal is about FR1. This could be resolved by removing the text about “defined in TR 38.840 for FR2” in the proposal:  **Proposal 4: The scaling factor ‘0.7’ ~~defined in TR 38.840 for FR2~~ is used for 2 Rx to 1Rx power scaling.**  The text “For FR1” could also be added to that start of this sentence. |

**Summary**

|  |  |  |  |
| --- | --- | --- | --- |
| Position | Description | Companies | Num. |
| 1 | Reuse the scaling factor ‘0.7’ for 2 Rx to 1 Rx power scaling | Vivo, SONY, Futurewei, Ericsson, Intel, Qualcomm, Fraunhofer, InterDigital, Nokia, LGe, Lenovo, ZTE, OPPO, CATT | 14 |
| 2 | No | MediaTek (it not within the scope), Samsung (new value is needed due to differences between normal NR devices and Redcap devices) | 2 |
| 3 | FFS | Huawei | 1 |

In light of the feedback, the following was proposed for progress:

**Proposal 4: The scaling factor ‘0.7’ ~~defined in TR 38.840 for FR2~~ is used for 2 Rx to 1Rx power scaling.**

**Question 5: For evaluation, can the power scaling for PDCCH candidate reduction in TR 38.840 be reused? If not, what modification is needed?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Yes |
| MediaTek | Yes |
| SONY | Yes |
| Futurewei | Yes |
| Ericsson | Yes |
| Intel | As the UE is already BW limited, 3OS CORESET is a useful configuration to realize larger number of CCEs to reduce blocking and also for coverage enhancements. So it will be good to list a scaling factor if CORESET duration is increased. We suggest 1.3 scaling factor compared to the value used in reference configuration. Also, as described above in our comments, a given number of candidates may use a wide range of number of CCEs, leading to different power consumption. So it needs to be reflected as well. |
| Qualcomm | Yes |
| Samsung | Yes. |
| Fraunhofer | Yes |
| Huawei, HiSilicon | Yes, the scaling method for BD reduction in TR 38.840 can be used, but the ‘maximum operation’ agreed in Rel-17 power saving should be used. |
| InterDigital | Yes. |
| Nokia | Yes |
| LG | Yes. |
| Lenovo, Motorola Mobility | Yes |
| ZTE,Sanechips | Yes. Additionally, we agree with Intel that scaling factor for CORESET duration can be considered. |
| OPPO | Yes |
| CATT | Yes |

**Proposal 5: For evaluation, the power scaling for PDCCH candidate reduction defined in TR 38.840 is reused for Redcap UEs.**

Two companies proposed to define scaling factor to model the 3-symbols CORESET configuration. The reason is that 3-symbols CORESET is a useful configuration to realize larger number of CCEs to reduce blocking and also for coverage enhancements. It seems beneficial to evaluate power consumption of this configuration to have a full picture of performance, e.g. power consumption vs. reduced blocking rate. One company additionally to reflect the non-overlapped CCEs numbers impact when defining new power consumption model

**Question 5a: Whether needs to define a new scaling factor to model the 3-symbols CORESET configuration? If yes, what values is proposed? If not, please briefly explain why?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Huawei, HiSilicon | No need. We feel that there should be no big difference to use two or three symbols CORESET for the evaluation of relative power saving gain. |
| OPPO | We are ok for 1.3 |
| Qualcomm | One way to resolve this problem without incurring discussion of new power model is to assume 3 OFDM symbol CORESET only slightly increases PDCCH power consumption. |
| vivo | For PDCCH-only case with cross-slot scheduling, there may be some difference since the Rx needs to receive one more symbol, but for baseband processing there would be no much difference between 2OS and 3OS CORESET. However, to accurately model the difference, we should split the Rx power consumption and baseband power consumption, which seems to be difficult to reach a conclusion.  For same slot case (PDCCH-only, or PDCCH+PDSCH), we expect the difference would be marginal between 2OS and 3OS, since the UE Rx has to buffer all the symbols anyway.  Overall, we see it is difficult to have an accurate model for this and the overall impact to the power evaluation would be small, so suggest we do not define a model for it. |
| CATT | No need.  The PDCCH power consumption model at 100 unit for eMBB is modeled based on the PDCCH candidate set with available CCEs within 100 MHz. When 3 symbols PDCCH is used in 20 MHz BW for REDCAP, the number of PDCCH candidates should increase in proportion to roughly 1.5 times of that with 2-symbol PDCCH. It is roughly equivalent to have 30 MHz BW with 2-symbol PDCCH. Using the scaling rule formula, X MHz = 0.4 + 0.6 \* (X - 20) / 80. Linear interpolation for intermediate bandwidths. The scaling factor is roughly [ 0.48 – 0.5 ] of 100 MHz power consumption in eMBB.  The power consumption model is as follows,  PDCCH only = [48 – 50]  PDCCH + PDSCH = 120 (same scaling factor since the addition of power consumption in PDCCH is the subtraction of power consumption in PDSCH)  PDSCH only = 112  Based on above analyses, the power saving model for eMBB IDLE mode can be totally resued. |
| Ericsson | No need. Agree with Huawei/HiSilicon. |
| Intel | Since 3OS CORESET can be a useful configuration to improve coverage, we suggest to update the model adopted in TR 38.840, assuming a suitable scaling factor and we think this can be reasonably accommodated since power consumption calculation is based on the formula only, not by simulation. Moreover, PDCCH blocking performance study includes 3OS CORESET as an option, so adapting the power consumption model for 3OS CORESET would help to arrive at more accurate overall observations. |
| Samsung | We are open to consider slightly increased PDCCH-only power for 3-symbol CORESET. |

**Question 5b: Whether needs to define a new scaling to capture the non-overlapped CCEs numbers impact? If yes, what values is proposed? If not, please briefly explain why?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Huawei, HiSilicon | No need. We don’t think reduction of non-overlapped CCEs shall provide significant power saving gain. Furthermore, the impact on the scheduling flexibility due to CCE limit restriction is not preferred. |
| OPPO | This was missed in Rel-16 study. We agree it can save power. However, it may save less power for it only have channel estimation. The value could be some one close to 1, like 0.9. |
| Qualcomm | Agree with OPPO that the power saving gain of reduced CCE is limited. This can be deprioritized. Companies can assume and report their power assumption for reduced CCE limit if it is evaluated. |
| vivo | If there is an interest to study reduced CCE, why the reduced number of CORESET is deprioritized, since it can naturally reduce the number of CCEs. |
| CATT | No need. The BWP scaling formula in TR38.840 should be reused. The number of non-overlapped CCE in 3-symbol PDCCH in 20 MHz is roughly equivalent to 2-symbol PDCCH in 30 MHz. Although the BWP scaling formula is defined with X=20, 40, 60, 80, the roughly estimate of PDCCH candidate with linear interpolation should apply in this case. |
| Ericsson | No. Non-overlapped CCEs mainly impacts the channel estimation complexity, and does not have a considerable impact on the power saving gain. Therefore, we prefer to down-prioritize this item. |
| Intel | Unless study on reduction of non-overlapped CCE is deprioritized, we do not see why this should not be addressed. As we explained before for a given number of PDCCH candidates, number of CCEs can widely vary. To this end, we are fine with suggestions from Qualcomm that companies can report their assumptions, if evaluated. |
| Samsung | No. We expect the non-overlapped CCE limit is mainly determined by UE BW, and the power saving gain from reduced CCEs is limited. |

## 2.3. DRX configuration

One Company Comment that DRX setting should be discussed and aligned for power consumption study, same as what we did in Rel-16 power saving study. More especially, the following configuration of (DRX cycle, ON duration, inActivityTimer) was proposed by one company:

* For Instant messaging:
  + (DRX cycle, ON duration, inActivityTimer) = (320ms, 10ms, 80ms).
* Heartbeat (process monitoring)
  + (DRX cycle, ON duration, inActivityTimer) = (100ms, [1]ms, [1]ms).

The following DRX configurations were used in TR 38.840 for Rel-16 power saving study:

|  |  |  |
| --- | --- | --- |
|  | Instant messaging | VoIP |
| DRX setting | Period = 320 ms  On duration = 10 ms  Inactivity timer = 80 ms | Period = 40 ms  On duration = 10 ms  Inactivity timer = 10 ms |

**Question 7: For power consumption evaluation, can the DRX configurations of Instant message and VoIP in TR 38.840 be reused? If not, what modification is needed?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Yes |
| MediaTek | Yes |
| SONY | Yes |
| Futurewei | Yes |
| Ericsson | Yes |
| Intel | Yes |
| Qualcomm | Yes |
| Samsung | Yes |
| Fraunhofer | Yes |
| Huawei, HiSilicon | Yes |
| InterDigital | Yes |
| Nokia | Yes |
| LG | Yes |
| Lenovo, Motorola Mobility | Yes |
| ZTE,Sanechips | Yes |
| OPPO | Yes |
| CATT | Yes |

**Proposal 7: For power consumption evaluation, the DRX configurations of Instant message and VoIP in TR 38.840 are reused.**

**Question 8: For Heartbeat model, can the proposed DRX configuration (DRX cycle, ON duration, inActivityTimer) = (100ms, [1]ms, [1]ms) be used? If yes, can we remove the bracket? If not, what modification is needed?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | We prefer to reuse the existing DRX configuration in TR38.840. |
| MediaTek | NO. We don’t see it essential to consider the ‘heartbeat’ traffic. The scope for power saving in this SI is very limited, and the considered traffic models are sufficient for baseline evaluations. |
| SONY | The DRX setting for the heartbeat should be, in some sense, compatible with the traffic model in section 2.1 / question 1. The DRX settings here are only compatible with option 2 of section 2.1 / question 1. The existing DRX configuration in TR38.840 would be more appropriate for option 1 of section 2.1 / question 1. |
| Futurewei | In our view, the DRX configuration of 38.840 should be the baseline. If the existing configurations are not suitable, others can be considered |
| Ericsson | In our view, the On duration and inactivity timer values are low. We suggest the following values from TR 38.840 (Section 8.2):  - C-DRX cycle 160msec, inactivity timer {100, 40} msec  - FR1 On duration: 8 msec  - FR2 On duration: 4 msec  For the sake of progress, we are also fine with other DRX configuration in TR 38.840. |
| Intel | Given the mean inter arrival time, which can be quite large, considered in Q.1, we are not sure how this model is justified. We suggest to use DRX configurations listed in TR 38.840. |
| Qualcomm | We prefer to reuse existing DRX configuration for IM defined in TR 38.840. |
| Samsung | Any of existing DRX configuration in TR38.840 can be reused. Company has to freedom to select according to their assumption on the mean inter-arrival time. No need to discuss this. |
| Huawei, HiSilicon | It is not a proper assumption for the on duration length of 1ms, which would restrict the gNB scheduling in the 1ms duration. This would impact network scheduling flexibility.  Furthermore, it is difficult to discuss this DRX setting before we agreed on the exact heartbeat model. |
| InterDigital | We can reuse the eixsting models. |
| Nokia | Reuse existing models. |
| LG | Unless there is a compatibility issue, the existing DRX configuration in TR 38.840 should be reused. We can also make/adjust the Heartbeat model so that there is no compatibility issue with the existing DRX configuration. |
| Lenovo, Motorola Mobility | DRX configuration for IM defined in TR 38.840 can be reused. |
| ZTE,Sanechips | The current DRX configuration in TR38.840 can be the baseline. |
| OPPO | Reuse |
| CATT | We don’t see the need to customize the DRX configuration for any traffic, such as heartbeat model, which is not realistic in the network implementation. We need to reuse the common DRX configuration in TR38.840. |

**Summary**

On Q7, responses from companies can be categorized as follows:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Description | Companies | Num. of Companies |
| Category-1 | Reuse the existing DRX configuration in TR38.840 | Vivo, SONY, Futurewei, Ericsson (2nd preference), Intel, Qualcomm, Samsung, Interdigital, Nokia, LGe, Lenovo, Motorola, ZTE, OPPO, CATT | 15 |
| Category-2 | New configuration | Ericsson (1st preference, 100,40, 8/4) | 1 |
| Category-3 | FFS based on traffic model of ‘heartbeat’ | Huawei | 1 |

**Proposal 8: For power consumption evaluation, reuse the following DRX configuration defined in TS 38.840 for ‘heartbeat’ traffic model:**

* **C-DRX cycle 320msec, inactivity timer {200, 80} msec**
* **FR1 On duration: 10 msec**
* **FR2 On duration: 5 msec**

## 2.4. Evaluation on PDCCH blocking rate

One suggestion from ZTE is to discuss the simulation assumption of PDCCH blocking rate, since reducing the BDs and CCEs in the SID will mainly have impact on the UE blocking probability.

In this meeting, [3] [6] [9] [10] [14] [18] [26] give some simulation results. The simulation parameters are shown as following:

|  |  |
| --- | --- |
| AL | {1,2,4,8,16} |
| AL distribution probability | Alt1:[0.4 0.3 0.2 0.05 0.05]  Alt2:[0 0 0.25 0.5 0.25]  Alt3:[1% 23% 49% 26% 1%]  Alt4:[37% 37% 21.5% 4.16% 0.34%]  Alt5:[42% 18% 27% 10% 3%] for RX=2 |
| Candidate for each AL | Alt1: 6, 6, 2, 2, and 2  Alt2: Set the candidates number for different cases  Alt3: the formula from [26] |
| SCS | 15kHz 30kHz 60kHz 120kHz |
| Bandwidth | 10M, 20M, 50M |
| OS | Alt1:2  Alt2:3  Alt3:1 |
| Delay tolerance | 1 or 2 slots |

**Question 9: For the PDCCH blocking rate, which configuration can be used for baseline assumption to evaluate the PDCCH blocking rate? What modifications are needed if any?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | The following is proposed (R1-2006987):   * AL distribution for AL(1,2,4,8) is [79%, 15%, 4%, 1%] , * UE Rx: 2Rx * DCI size: 60bits payload +24 bits CRC * Scenario: Urban macro ISD500m, 2.6GHz * BW: 20MHz * CORESET duration: 2 OS * Candidates for each AL: company report   Comment: there seems to be an large divergence of AL distribution among companies, calibration exercise seems necessary if PDCCH blocking rate is to be evaluated. |
| SONY | Why is the vivo AL distribution so different to the AL distributions of Alt1, Alt4, Alt5 in the table above? It would seem like the AL distribution of Alt1 would be more representative. |
| Futurewei | AL distribution is heavily tied to traffic model, deployment scenario, etc. It seems hard to be able to agree on one set of value. It may be best to have each company providing inputs based on evaluation.  The other parameters are far less important. We suggest the following:  Candidates for each AL: Alt 1: 6, 6, 2, 2, 2,  SCS: 30 KHz  Bandwdidth: 20 MHz for FR1, 100 MHz for FR2  CORESET duration: Alt 1: 2 |
| Ericsson | AL distribution probability: Alt 1 (we are also fine with Alt4)  Candidate for each Al: Alt2  SCS: 30 KHz (FR1); 120 kHz (FR2)  Bandwidth: 20 MHz (FR1) and 50 MHz (FR2)  OS: Alt1 (since we already have the power model for 2-symbol CORESET)  Delay tolerance: 1 |
| Intel | We think we could prioritize wearable use case for PDCCH blocking study since other two use cases include periodic UL heavy traffic for which dynamic scheduled transmission may not be common. We think UMi more accurately represents wearable use case.  Also, considering 20MHz BW, we suggest to use 3OS CORESET and 15kHz in the study, because for other cases of CORESET duration and SCS configuration, number of BDs is already limited due to reduced number of CCEs available. To this end, we suggest following assumption:  BW: 20MHz CORESET duration: 3 OSs (Alt 2) AL distribution: Alt 4 (based on UMi model) SCS: 15 kHz  Candidates: Companies to report |
| Qualcomm | For SCS120kHz (i.e., FR2), **bandwidth = 100 MHz** should be included as baseline. **AL 16** cannot be supported with BW = 50 MHz. BW = 50MHz can be optionally studied for interested companies, but the AL distribution should not include 16. It is better to not imply a decision here for the complexity reduction discussion by not including BW=100MHz in PDCCH evaluation.  2 sets of AL distribution can be studied: set 1 has more prob for low ALs, set 2 has more prob for high ALs.  To directly associate the BD limit and CCE limit with PDCCH blocking rate, the number of candidates per AL can be determined based on the maximum available number of candidates for an AL calculated by the following formula.  Together with a single random AL assigned to each UE in each MO, this formula also avoids complicated overbooking handling in evaluation. |
| Samsung | We think at least the following configuration are needed   * AL distribution probability * Number of candidate for each AL * Delay tolerance   The AL distribution probability will depend on the geometry CDF and the number of Rx antennas (both 1 and 2 should be considered).  We can reuse the agreed SLS configuration from other RedCap SI. |
| Fraunhofer | Study one AL distribution with high probability for low ALs and one with high probability for high ALs: e.g., Alt1 and Alt2  Candidate for each AL: Alt1 or Alt3  SCS: 30kHz (FR1), 120kHz (FR2)  CORESET duration: Alt1 |
| InterDigital | AL distribution probability: Alt 1  Candidate for each Al: Alt2  SCS: 30 KHz (FR1), 120 kHz (FR2)  Bandwidth: 20 MHz (FR1), 50 MHz (FR2)  OS = 2 symbols  Delay tolerance: 1 symbol |
| LG | AL distribution depends on the deployment scenario. But if we have to choose one, we prefer Alt.1 (or Alt.4) as they seem to be more representative.  We prefer the following settings   * AL distribution probability: Alt.1 (or Alt.4) * Candidate for each AL: 6.6.2.2.2 * Bandwidth: 20MHz for FR1, 100MHz for FR2 (also fine with 50MHz) * OS Alt.1 2   Besides, we had an impression that we need to set up some reference number(s) of UEs to check whether the blocking probability of is acceptable or not. |
| Lenovo, Motorola Mobiltiy | Can evaluate two AL distributions representing different operation conditions, e.g. Alt2 and Alt4  Candidate for each AL: Alt2  SCS: 15KHz for FR1, 120KHz for FR2  Bandwidth: 20 MHz (FR1), 50 MHz (FR2)  OS = 3 symbols  Delay tolerance: 2 slots |
| ZTE,Sanechips | **AL distribution probability**: Alt1 or Alt4 can be the baseline and we slightly prefer Alt4. Additionally, since the PDCCH enhancement is considered due to the antenna reduction, Alt 2 for large AL with higher probability can be considered as an important case.  **Candidate for each AL**:Alt1  **SCS and bandwidth:** 15kHz for FR1 with bandwidth 20M, 60kHz for FR2 with bandwidth 100M.  **OS**: Alt1 and Alt2  **Delay tolerance:** 1 slot can be the baseline, and 2 slots also should be considered to calculate the blocking probability. |
| OPPO | A calibration will be helpful for evaluation.  Aggregation distribution would be Alt.4 (e.g. Aggregation 2 will have highest probability)  AL 6.6.2.2.  OS would be 2. |
| Huawei, HiSilicon | The Alt.2 and Alt.3 can be considered for AL distribution.  Alt.2 is preferred for Candidate for each AL.  Bandwidth: 20M for FR1.  2Rx on UE. |
| CATT | AL: it should be derived from SLS and LLS, this is how alt. 5 works  Candidates for each AL: Not sure why do we need the number of candidates for each AL considering we already have the AL distribution.  SCS: 30 kHz  BW: 20 MHz  OS: 1:2  Delay tolerance: 1 slot |

**Summary**

Aggregation level Distribution

|  |  |  |  |
| --- | --- | --- | --- |
| Index |  | Companies | Num. of Companies |
| 1 | Atl.1: [0.4, 0.3, 0.2, 0.05 , 0.05] | SONY, Ericsson, Interdigital, LG, ZTE | 5 |
| 2 | Alt.4: [37% 37% 21.5% 4.16% 0.34%] (based on UMi model) | Intel, Ericsson, LG, ZTE, OPPO | 5 |
| 4 | Alt.1 and Alt.2, Set 1 with high probability for low ALs and Set 2 with high probability for high ALs | Qualcomm, Fraunhofer, Lenovo | 3 |
| 5 | Alt.2 and Alt.3 | Huawei | 1 |
| 6 | Alt.5: 42% 18% 27% 10% 3%] for RX=2 | CATT | 1 |
| 7 | No need to align and each company provides inputs based on evaluation | Futurewei (tied to traffic model, deployment scenario) | 1 |

Number of candidates for each AL

|  |  |  |  |
| --- | --- | --- | --- |
| Index |  | Companies | Num. of Companies |
| 1 | Alt.1: {6, 6, 2, 2, and 2} | Futurewei, Fraunhofer, LG, ZTE, OPPO | 5 |
| 2 | Alt.2: Set the candidates number for different cases | Ericsson, Intel, Interdigital, vivo, Lenovo, Huawei | 6 |
| 3 | Alt.3: | Qualcomm, Fraunhofer | 2 |
| 2 | Others |  |  |

CORESET Duration

|  |  |  |  |
| --- | --- | --- | --- |
| Index |  | Companies | Num. of Companies |
| 1 | Alt.1: 2 symbols | Futurewei, Ericsson, Interdigital, Fraunhofer, vivo, LG, ZTE, OPPO | 8 |
| 2 | Alt.2: 3 symbols | Intel, Lenovo, ZTE | 3 |

SCS, Bandwidth for FR1

|  |  |  |  |
| --- | --- | --- | --- |
| Index |  | Companies | Num. of Companies |
| 1 | 30kHz, 20MHz | Futurewei, Interdigital, vivo, Ericsson, Fraunhofer, LG, Lenovo, CATT | 8 |
| 2 | 15kHz, 20MHZ | Intel, ZTE | 2 |

SCS, Bandwidth for FR2

|  |  |  |  |
| --- | --- | --- | --- |
| Index |  | Companies | Num. of Companies |
| 1 | 120kHz, 100MHz | Futurewei, Qualcomm, LG | 3 |
| 2 | 120kHz, 50MHz | Ericsson, Interdigital, LG, Lenovo, | 4 |
| 3 | 60kHz, 100MHz | ZTE |  |

**Delay toleration:**

|  |  |  |  |
| --- | --- | --- | --- |
| Index |  | Companies | Num. of Companies |
| 1 | 1 slot | Ericsson, Interdigital, ZTE, CATT | 4 |
| 2 | 2 slots | Lenovo, ZTE (can be considered) | 2 |

Hence, the following is proposed following majority views:

**Proposal 9: For the PDCCH blocking rate evaluation, the following was assumed as baseline:**

|  |  |
| --- | --- |
| Parameters | Assumptions |
| Number of candidates for each AL | Each company to report. |
| SCS/BW | FR1: 15KHz or 30KHz/20MHz  FR2: 120KHz/[100]MHz |
| CORESET duration | [2 or 3] symbols |
| Delay toleration (Slot) | [1] |
| ~~Aggregation level Distribution~~ | ~~Atl.1: [0.4, 0.3, 0.2, 0.05 , 0.05] or Alt.4~~  ~~Other values are not precluded.~~ |

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | For the aggregation level distribution, we think it does not make sense to make a selection purely based on the vote. We observed following discrepancies from companies results   1. [10] uses urban macro ISD=500m with gNB Tx power 41dBm for 10 MHz bandwidth, 1T1R/1T2R/1T4R, DCI payload size not reported. 2. [14] uses dense urban ISD=200m with gNB Tx power 41dBm for 20MHz, 4T2R, DCI payload 40bits 3. [3][6][26] did not report the simulation assumptions   In addition to the above aspects, e.g. deployment scenario, Tx power, DCI payload size, we see the result makes very much difference dependent on the gNB beamforming assumption, i.e. whether PDCCH is transmitted with broadcast beams (e.g. the SSB beams), or unicast beams (e.g. based on CSI feedback).  We should align the key assumptions before agree on a single AL distribution. If it is not possible to calibrate the assumptions, alternatively, as FutureWei suggested, companies can report their AL distribution with sufficient information on their simulation assumptions. |
| SONY2 | **Comment 1**: In response to the Vivo comment, it seems like the AL distribution is dependent on scenario (as would be expected). How about adopting the approach suggested by Qualcomm: “*2 sets of AL distribution can be studied: set 1 has more prob for low ALs, set 2 has more prob for high ALs*”? We are open to any reasonable AL distributions, but would like to avoid detailed system simulations to derive AL distributions.  **Comment 2**: In proposal 9, there needs to be a unit for the “delay tolerance”. We assume the unit is “slot”, given the tables below.  We would also like clarification on what “delay tolerance / toleration” means. If we have a delay tolerance of 1 slot, does it mean (1) that it is OK if a PDCCH is used in slot *n* or slot *n* + 1, (2) that the PDCCH is used in slot n, or (3) something else? |

**Question 11: Any of Rel-16 power saving techniques should be assumed as baseline for Redcap power evaluation? If so, which techniques should be baseline?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Yes |
| MediaTek | Yes. At least WUS/DCP (DCI format 2\_6) and cross-slot scheduling. Rel-15 BWP adaptation framework (e.g., for adjusting PDCCH periodicity) should also be considered. |
| SONY | Yes. Rel-16 power saving techniques can be assumed as baseline. In particular, WUS/DCP, cross-slot scheduling and BWP framework should be considered. |
| Futurewei | Yes. At least DCI format 2\_6 and cross-slot scheduling |
| Ericsson | Yes. Cross-slot scheduling can be considered. Configured smaller number of BDs/CCEs should also be part of the baseline. |
| Intel | It is not clear what is the intention of saying “assumed as baseline” here. R16 power saving schemes may be optionally supported by RedCap UEs. We do not think those can be considered as baseline. Approaches like BWP-switching based PS schemes would not be possible for RedCap UEs unless they support dynamic BWP switching. Certainly, companies are free to evaluate particular combinations, but we do not think we need to mandate certain features as baseline for our current evaluations. |
| Qualcomm | Yes |
| Samsung | WUS based on DCI format 2\_6 can be considered as baseline. |
| Fraunhofer | Yes. At least DRX adaption and cross-slot scheduling should be baseline. |
| Huawei, HiSilicon | 1. We think currently, only ‘the BD reduction and CCE limit reduction’ is in the scope of RedCap SI. For these two candidates, the evaluation baseline can be simplified. 2. For other Rel-17 power saving dynamic adaptation, the Rel-16 baseline shall be anyway considered as baseline in Rel-17 power saving SI.   Besides the evaluation baseline, we propose to add a note or have conclusion in question 12 that Rel-16 dynamic power saving adaptation techniques can be utilized by RedCap UEs; |
| InterDigital | Yes, at least WUS. |
| Nokia | Yes |
| LG | Yes. At least, DRX adaptation using DCI format 2\_6 and cross-slot scheduling can be assumed as baseline for evaluation. The dormancy operation should not be the baseline, if CA is not supported in Redcap. |
| Lenovo, Motorola Mobility | Yes. C-DRX operation with DCI format 2\_6 and cross-slot scheduling. |
| ZTE,Sanechips | We have the similar concern with Intel. Rel-16 power saving techniques are optionally supported by high layer signaling. The baseline technique would be misunderstood as the mandatory function. Additionally, the feature, DRX adaptation using DCI format 2\_6 and cross slot scheduling, can be supported. |
| OPPO | Yes, we can consider WUS.  But we should keep the number of baseline comparison limited. E.g. one or 2 set of baseline configuration. |
| CATT | Rel-16 DRX adaptation with DCP (DCI with CRC scrambled by PS-RNTI) and SCell dormancy should be the baseline. |

On Q11, companies’ inputs can be summarized as follows:

|  |  |  |  |
| --- | --- | --- | --- |
| Index | Description | Companies | Number of companies |
| 1 | DCI 2\_6, | MTK, SONY, Futurewei, Samsung, Fraunhofer, InterDigital, LG, Lenovo, ZTE, OPPO, CATT | 10 |
| 2 | Cross-slot scheduling | MTK, SONY, Futurewei, Ericsson, Fraunhofer, LG, Lenovo, ZTE | 8 |
| 3 | BWP framework | MTK/SONY (adaptation of periodicity using BWP adaptation framework), | 2 |
| 4 | Others | Ericsson (Configured smaller number of BDs/CCEs), CATT (SCell dormancy) | 1/1 |

One company does not see the need to define baseline of Rel-16 power saving techniques for Rel-17 Redcap power consumption evaluation.

**Proposal 11: The baseline for RedCap power saving evaluation is NR Rel-16 including support for DRX with DCI format 2\_6 and cross-slot scheduling.**

* **Note that: This does not mean DCI format 2-6 and cross-slot scheduling is mandatorily supported for Redcap.**

# 3. Power saving techniques

## 3.1 Candidates of power saving techniques

In general, the power saving techniques can be categorized as follows:

1. Reduced blind decoding (BD) and/or CCE limits
2. Dynamic adaptation of PDCCH monitoring or search space sets
3. Extending the PDCCH monitoring span gap from 1 slot to X slots (X>1)
4. Reduce number of maximum configurable CORESETS per BWP

### Technique 1: Reduced blind decoding (BD) and/or CCE limits

Many contributions discuss the reduced number BDs and/or CCE limits for RedCap devices. In contributions [5,6,14,15,18,19,20,22,23,26], it is proposed to reduce BDs and/or CCEs. [26] further proposed to split limit into CSS and USS and reduce them separately to guarantee the broadcast PDCCH transmission. Furthermore, [4] believes that CCE limit reduction does not provide a substantial power saving benefit and hence propose to reduce BD limit only. Meanwhile, [3,7,8,9,24,25] argue that the number of number of BD and CCEs monitored by a UE can be controlled by network configurations and BD/CCE limits reduction should not be considered for RedCap UEs in Rel-17.

Several contributions [3,5,6,20,22] provide the evaluation results of power saving performance and it was observed that the power saving gain by reducing the number of BD by half is approximately 15%. In addition, the maximum achievable power saving by reducing number of BDs to 1 is about 29% for FR1 [3,6,22] and 28% for FR2 [6] with assuming power consumption model in TR 38.840.

Moreover, contribution [3,5,9,10,18,14,26] evaluated the impact of BD reduction on blocking probability with different assumptions. In general, PDCCH blocking probability depends on various factors including number of UEs which need to be scheduled (this may depend on the traffic), CORESET size (i.e., number of CCEs), number of PDCCH candidates, and PDCCH link performance/coverage (which affects the AL probability). With a number of assumptions, [3] observed that the average blocking probability can increase from 2.8% to 5.4% (increase by a factor of 1.9) for FR1 and increase from 5% to 12% (increase by a factor of 2.3), when reducing the BD limit by half. [10] observed that for RedCap UEs, PDCCH blockage is increased due to reduced number of Rx antennas, which should be carefully study for power saving techniques. In [26], it was observed that the number of CCEs in COERSET becomes the gating factor and BD limit reduction to 25% of the original limit results in loss of one schedulable UE if CCE number is not dominant factor.

In addition, different solutions to mitigate the PDCCH blocking risk were proposed and evaluated, including group scheduling [14,18,26] and compact DCI format [14].

On a high-level, three alternatives were proposed in contributions:

* **Alt.1:** Reducing Rel-15 BDs to smaller values without any other modifications
* **Alt.2:** Reducing Rel-15 BDs to smaller values by DCI size budget reduction
  + This was proposed in contributions [4,5, 8,10,11,14,15,20, 24,27,28]. In [8], it is further proposed that a Redcap UE does not expect to process more than one DCI with the CRC scrambled by C-RNTI.
* **Alt.3:** Reducing Rel-15 BDs to smaller values and introducing new schemes to reduce PDCCH blocking probability, e.g. group scheduling or compact DCI format

**Question 12: Based on the available evaluation results so far (power saving gain vs. PDCCH blocking probability and latency performance), can we draw conclusion to support reduced BDs and/or CCEs for power saving?**

* **If yes, which schemes among three alternatives can be supported for reduced PDCCH monitoring?**
* **If no, what modification is needed or any new solutions under this area to further study?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Vivo | We think both alt 1 and alt 2 can be studied further. If we have accurate power model for RedCap (as outcome of the discussion in Question 3), there should be a fair comparison between alt 1 here and Technical 3 Extending the PDCCH monitoring span gap from 1 slot to X slots (X>1) considering the power saving benefit and complexity reduction, and the down-selection should be based on the evaluation results.  Regarding alt 3, compact DCI format is already in spec so RedCap UE can support it if there is a need, for example due to coverage recovery, therefore it seems no need to decide anything. On group scheduling, we are not sure whether it is in scope of the current SID or not, as it does not seem to match any of the objectives. |
| OPPO | It is in the Sope of SI. We prefer Alt2. Alt-3 can be further considered. |
| Xiaomi | For the purpose of power saving, we think the existing solution e.g., configure the BD via NW is sufficient. |
| Fraunhofer | Alt.3. We think that the PDCCH blocking probability is a severe issue that should be targeted by additional schemes. |
| MediaTek | No.  We believe it is premature to conclude on supporting reduced BDs and/or CCEs without having technical discussion of the provided evaluations.  On important point that we would like to highlight is that the evaluation results show power saving that can be achieved by reducing the **configured** #CCEs/#BDs rather than the reduction in **UE capability** for monitoring the #CCEs/#BDs.  Hence, there is no evaluation that provided evidence of power saving by reducing the UE capability of PDCCH monitoring. |
| Futurewei | Any reduction of BD monitoring needs to be done without affecting blocking. In that sense, Alt.2 can be considered if significant benefits can be shown |
| Ericsson | No need to reduce the existing BD and CCE limits for the purpose of power saving. The UE power consumption depends on the number of actually performed BD attempts not the maximum limits. Network can control the number of required BDs and PDCCH monitoring by proper configurations according to use case requirements without any need for specification changes. Such network configurations include using suitable number of different ALs and PDCCH candidates for each AL, and increasing the PDCCH monitoring periodicity.  Regarding DCI size budget reduction, although this technique can reduce the number of required BDs, it has the following issues:   1. significant impact on specifications as new DCI size alignment procedure and DCI formats may need to be introduced 2. limits scheduling flexibility.   Moreover, the power saving by DCI size budget reduction gain may not be significant. For example, by reducing the DCI size budget from “3+1” to “2+1”, the average number of BDs can be reduced by around 25% which leads to less than 7% power saving.  Meanwhile, gNB can consider RedCap UE capability, and also configure UE to monitor different DCI formats potentially with different sizes in a way that is suitable for RedCap UEs.  Finally, we note the BD limit for Rel-8 LTE is the same as Rel-15 NR for 15 kHz SCS (BD limit is 44). Hence, the existing BD limits can be reasonable for RedCap. |
| Panasonic | We can draw the conclusion that not to support reduced BDs and CCEs. |
| CATT | Alt.2 and Alt.3 are our preference.  Actually no matter the reduction on maximum number of BD and CCEs is supported or not, PDCCH blocking is still a serious issue need to be studied, e.g. more large AL is needed considering the reduction of Rx, the bandwidth is limited, the number of RedCap UE is numerous in the system. Group scheduling is a straightforward way to reduce PDCCH overhead, which reduces blocking possibility. |
| CMCC | We prefer Alt2 and Alt3.  PDCCH blocking and PDCCH overhead is an important issue in RedCap, especially the BD/CCE limits is further reduced and the limited bandwidth. We think group scheduling including one DCI scheduling multiple TBs for one UE or one DCI scheduling multiple UEs can both be considered to reduce the PDCCH blocking and PDCCH overhead. |
| InterDigital | Dynamic adaptation of BD and/or CCE limits can be considered for reduced PDCCH monitoring. |
| WILUS | Alt.2. if DCI formats are size-aligned, it gives a way for gNB to configure small # of BDs/CCEs without PDCCH blocking issues. |
| Sequans | Agree with MediaTek – we need more evidence and technical discussion to conclude on supporting one of the proposed alternatives. |
| Lenovo, Motorola Mobility | Reducing the number of BDs by reducing DCI size budget is preferred, since it is expected to have less impact on PDCCH blockage. Besides, Alt.3 can also be studied, and no need to restrict to the techniques in the example, i.e., prefer to remove the examples. |
| Samsung | We support smaller number of BDs and CCE limits for RedCap UEs. At least for the CCE limits, that is a consequence of the maximum bandwidth limit. Additional reductions can be considered for power saving gains from both reduced processing complexity and relaxed processing time. We also support to consider reductions in PDCCH blocking that can be a bottleneck for scheduling, and potentially result to a continuously increasing buffer, even without any PDCCH candidate/CCE reductions, due to the large numbers of RedCap UEs. PDCCH overhead is also a key design consideration because of the reduced number of UE receiver antennas and the small TBs associated with traffic types for RedCap UEs. |
| DOCOMO | No. We agree with MediaTek that it is too early to conclude on supporting any specific solutions at this stage. Also agree with Ericsson that the numbers of actually performed BDs and CCEs in a PDCCH monitoring occasion can be configured by CORESET/search space set configurations. |
| Qualcomm | For RedCap power saving, Alt. 1 can be assumed as a baseline and also take the potential further PDCCH reduction and control overhead reduction into consideration. For that further DCI size alignment and scheduling with less PDCCH can be studied. |
| Huawei, HiSilicon | Yes, we can draw conclusion to support reduced BD. But reduced CCE needs more justification for power saving.  Among the three alternatives, we support Alt.2. And compact DCI format in Alt.3 can be further discussed.   * Alt.1 will increase PDCCH blocking rate, which will impact the network performance. Therefore we have concern on supporting Alt.1. * Alt. 2 does not reduce the number of monitored PDCCH candidates and therefore, shall not impact the network scheduling flexibility. * The benefit of Alt.3 needs to be justified compared with the Alt.2. Besides, we think the compact DCI format can be also in the scope of Alt.2, considering anyway we need to discuss the DCI formats for RedCap. |
| Intel | In our view, Alt 1 can be considered as starting point. At the same time, options to reduce impact on user blocking and reducing PDCCH overhead should be pursued. In this sense, we are fine with Alt 3 as well. However, we suggest to remove particular examples from Alt 3 at this stage.  Regarding Alt2, although we are supportive of DCI size budget reduction, this should be seen as a supplementary mechanism that can reduce #s of BDs, but does not necessarily guarantee BD number reduction.  Moreover, **it is premature to exclude CCE limit reduction from consideration at this stage**. At least one alternative should be as follows:   * **Alt.1a:** Reducing Rel-15 BDs and CCEs to smaller values without any other modifications   Several companies have shown interest in CCE limit reduction. As we also indicated in our response to revision of power consumption model, a number of BDs may use a wide range of CCEs, and certainly larger number of CCEs may result in more power consumption which may not be reflected accurately just by considering a given number of BDs. |
| Sharp | We agree to consider Alt. 2 and 3, but the effect on blocking probability should be more clearly evaluated. |
| Spreadtrum | Alt1, Alt2 and Alt 3 can be supported for reduced PDCCH monitoring. |
| ZTE | Yes, the power saving gain by reducing the BDs larger than 10% can be observed at least. Especially for some special case, the power saving gain larger than 20% can be expected in our simulation. Additionally, considering modified traffic model, some adaptation methods and CCEs number taken into PS evaluation consideration, more power saving gain can be expected.  From our opinion, Alt.1 and Alt.2 should be supported because these alternatives are the effective methods in the scope to save power consumption.  Additionally. since many companies seems to expect to configure the BDs or CCEs according to different conditions and ‘without any other modifications ’ seems to be impossible, we’d like to modify the description as   * **Alt.1:** Reducing Rel-15 BDs to smaller values   As for the PDCCH blocking probability, it seems to be not a big problem according to current simulation from [6] and [26]. Therefore, Alt.3 can be de-prioritized. |
| Nokia | Alt 1: NO to a simple reduction of UE BD/CCE limits  Alt 2/3: MAYBE subject to further study  Our biggest concerns are the relatively small power gains compared to other techniques, and the costs of achieving those gains in terms of:  Increased blocking probability  Decreased scheduling flexibility |
| LG | No. The power saving gain by reducing the number of BDs/CCEs can be achieved by gNB configuration. Either we conclude to not support it or to evaluate further the benefits and the impact on the PDCCH blocking probability is preferred.  Regarding the evaluations results on the PDCCH blocking probability, there seems to be no convergence yet on whether the PDCCH blocking probability is acceptable or not. As the results may lead to different conclusions depending on the number of UEs, we need to discuss the reference number of UEs to check the increase of the PDCCH blocking probability. |
| SONY | We would not want to preclude any of Alt1, Alt2, Alt3 during the study item. i.e. the study should consider all of Alt1, Alt2, Alt3. |

### Technique 2: Dynamic adaptation of PDCCH monitoring

Several contributions [5,7,10,12,15,18,19,23] discuss how to support dynamically PDCCH monitoring, which include DCI-based approach (e.g. enhanced DCI format 2\_6 or scheduling DCI format) or timer-based approach [5]. It was observed that similar proposals are being discussed in Rel-17 power saving study item. However, it maybe still desirable to discuss it in both items as different conclusions maybe made considering different power saving requirements of RedCap and power saving WI. Obviously, the standard efforts can be shared if it is approved under both agendas.

**Question 13: Can dynamic adaptation of PDCCH monitoring or search space set be supported for Redcap device to reduce PDCCH monitoring power? If not, why?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Following the WID, the dynamic adaptation of PDCCH minoring or search space set switching belongs to the power saving WID, and it is understood that the power saving WID provide general features which applicable to both normal and redcap UEs. With this understanding, we think technique 2 should be dropped in Redcap discussion to avoid duplicate work. |
| OPPO | Could be out of Sope. SI said: “Reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits”. It is just limit of capability, not dynamic scheduling. Also, it seems can take care by Power Saving WI. Just want to avoid duplicated dissussing. |
| Xiaomi | Yes. Any solution for the power saving should not be precluded |
| Fraunhofer | Yes. Our understanding is that this procedure reduces the blind decoding overhead significantly especially, if there is no data for the RedCap UE. |
| MediaTek | This is out of the scope of RedCap SI. This should be discussed in the power saving WI if needed. |
| Futurewei | Agree with OPPO’s analysis that it is not within Redcap scope (but should be okay in power savings) |
| Ericsson | This does not seem to be in the scope according to the SID. |
| Panasonic | Yes, it should be supported as to reduce the wake-up time contribute the power reduction more than to reduce the number of BDs. |
| CATT | Dynamic adaptation of PDCCH monitoring or search space set is beneficial for power saving. It’s a generic power saving technique can be applied to any supporting UEs. As mentioned by several companies, it should be handled by PS WI. |
| CMCC | Yes, we think the dynamic PDCCH monitoring can be supported for RedCap UE. But as the discussion by many companies, this issue can be discussed in Power saving WI but the power saving technique can be used by RedCap UE as well. |
| InterDigital | We believe that dynamic adaptation of PDCCH monitoring is essential for power saving. However, since this technique will be treated in the Power Saving WI, we can drop it from the RedCap SI to prevent duplicate work. |
| WILUS | Our understanding is dynamic adaptation of PDCCH monitoring is out of scope and it would be better to discuss this issue in power savings WI. |
| Sequans | Seems to be out of the scope considering RedCap SID – it could be discussed in plenary if it is worth adding in scope and if possible/efficient to share standard efforts with power saving WI. |
| Lenovo, Motorola Mobility | Dynamic adaptation of PDCCH monitoring and/or search space set can be studied under RedCap SI in the context of RedCap devices. |
| Samsung | We think dynamic adaptation on PDCCH monitoring related to BDs and CCE limits can be discussed in RedCap as it is within the scope of the SID. General adaptation on PDCCH monitoring, such as SS set switching and/or adaptation of PDCCH monitoring periodicity, should be discussed in the R17 PS WI. |
| DOCOMO | This is out of scope of RedCap, but can be discussed in power saving WI. |
| Qualcomm | Dynamic PDCCH adaptation falls in the area of Rel-17 power saving enhancement WI. Companies may discuss whether this is in the scope of RedCap agenda. To avoid repetition of efforts, it should be studied in power saving enhancement WI. |
| Huawei, HiSilicon | It may be beneficial for RedCap UE to support dynamic adaptation of PDCCH monitoring or search space set. For example, when there is no traffic, the RedCap UE can be indicated to skip or reduce PDCCH monitoring for a while. When traffic arrives, the monitoring can recover to normal mode.  However, we think it is more proper to discuss the details in Rel-17 Power Saving WI. |
| Intel | In our view, this can be studied in R17 PS WI |
| Sharp | We agree with oppo’ opinion. |
| Spreadtrum | Partially agree OPPO. Need further justification. |
| ZTE | Similar with vivo, in order to avoid duplicate work and keep the technique in the scope, It can be de-prioritized. |
| Nokia | We think this is only in scope of this SI, if we can show there are REDCAP specific modifications required, otherwise we think it should be discussed in the Rel-17 Power Saving WI. |
| LG | They can be supported if it is adopted in Rel-17 NR PS WI. This is to be discussed in the PS WI, and we had a consensus not to have a duplicate work b/w the PS WI and RedCap SI/WI. |
| SONY | Reducing PDCCH monitoring reduces the number of blind decodes, so we understand that it is in the scope of the SID. This is likely to be studied in the Rel-17 PS WI anyway, so can be considered there. |

Regarding Q13, almost all companies, including those who discussed this solution in contribution, preferred to further discuss it in Rel-17 Power Saving WI due to two reasons: 1) avoid duplicated standard efforts; 2) it seems out of RedCap study item scope. In addition, most responses mentioned that this solution, if standardized in power saving WI, can be supported for RedCap devices to reduce power consumption.

**Proposal 13: Discussion on dynamic adaptation of PDCCH monitoring technique for power saving is deprioritized under Redcap SI.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree (Y/N)** | **Comments** |
| Ericsson | Y |  |
| Intel | Y | **We agree to the conclusion proposed in last GTW:** Using dynamic adaptation of PDCCH monitoring technique for power saving ~~not exclusively~~ for RedCap UEs is not studied further under the Redcap SI.  Those techniques can be pursued in PS enh. WI |
| DOCOMO | Y |  |
| Xiaomi | Y |  |
| Qualcomm | Partially Y | Our understanding is dynamic adaptation of PDCCH monitoring technique is deprioritized with the assumption that Rel-17 power saving enhancement will handle it. |
| LG | Y |  |
| Samsung | Partially Y | It’s not clear to us what dynamic adaptation of PDCCH monitoring technique may include. We agree the adaptation on PDCCH monitoring, such as SS set switching and/or PDCCH monitoring periodicity is out of scope. But we think direct adaptation on maximum number of PDCCH candidates/CCE limits is within the scope of the SID. We do not see any reason or technical concerns to block dynamic adaptation based technique in general.  We are general fine with the proposed concussion in last GTW, but we suggest to add a note.  -Note: dynamic adaptation based technique for smaller number of blind decodes and CCE limit is not precluded. |
| CMCC | Y | The dynamic adaptation of PDCCH monitoring technique for power saving should also be supported for RedCap. |
| Huawei, HiSilicon | Needs some update to agree | We are generally fine for the proposal but we need to avoid the misunderstanding that dynamic adaptation of PDCCH monitoring in Rel-16/17 are also deprioritized for RedCap UEs. Therefore, we suggest the following update:  **Proposal 13: Discussion on dynamic adaptation of PDCCH monitoring technique for power saving is deprioritized under Redcap SI.**   * Rel-16 dynamic power saving adaptation techniques can be used for RedCap UEs; * This does not preclude the usage of power saving adaptation in other Rel-17 WI/SI; |
| Sharp | Y |  |
| Spreadtrum | Y |  |
| ZTE,Sanechips | Y |  |
| CATT | Y | It should be handled by Rel-17 power saving agenda. |
| MediaTek | Y | Should be discussed in R17 PS WI if needed. |
| InterDigital | Partially Y | Agree with Samsung comments. |
| Qualcomm | Partially Y | Our understanding is dynamic adaptation of PDCCH monitoring technique is deprioritized with the assumption that Rel-17 power saving enhancement will handle it.  [Update] However, we agree with Samsung’s view that there may be a need to study dynamic adaptation that may be *RedCap specific* (e.g.., because of stationary UEs and UL heavy traffic models). Such techniques may not be discussed/missed in the Rel-17 PS WI because of lack of motivation. Some of these techniques may be directly related to BD/CCE limit reduction which is in the scope of this SID. Hence, we endorse Samsung’s revised proposal. |
| SONY | Y | OK with the Samsung update. The Rel-17 PS WI can discuss more generic adaptation of PDCCH monitoring. |
| InterDigital | Partially Y | We share the same views as Samsung. Adaptation of maximum number of PDCCH candidates/CCE limits is within the scope of the SID. |
| Nokia | Partially Y | Support Samsung’s note/clarification |
| Lenovo, Motorola Mobility | N | Here, as for dynamic adaptation of PDCCH monitoring, we refer to necessary techniques to allow scheduling flexibility while reducing BD/CCE limit for RedCap UEs. |

### Technique 3: Extending the PDCCH monitoring span gap from 1 slot to X slots (X>1)

In [5,18], it was proposed to extend the PDCCH monitoring span from 1 slot to X slots to reduce power consumption. More especially, [5] observed that the power consumption was further reduced if cross-slot scheduling is enabled together with span gap extension. In [18], power saving gain and latency performance were evaluated with power consumption model discussed in section 2.2.

**Question 14: Can PDCCH monitoring span gap extension be supported or further studied for Redcap device to reduce PDCCH monitoring power? If not, what modification is needed? why?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | We support to further evaluate technical 3 and to compare with alt 1 or alt 2 in technical 1 based on the refined power model for RedCap UEs. |
| OPPO | Yes |
| Xiaomi | Can be further studied |
| Fraunhofer | Yes. Assuming that the RedCap UE can perform a certain number of BDs per slot, larger number of BDs can be still achieved if the span gap is increased. Hence, allowing for more scheduling flexibility while keeping the BD complexity low. Furthermore, we also agree that this feature can be combined with cross-slot scheduling to even further reduce power consumption. |
| MediaTek | This should be considered under Technique 1.  Technically, it is a reduction of the supported #CCEs/#BDs by changing the duration from slot to multiple slots. |
| Futurewei | When cross slot scheduling is used, we do not see how this can improve power consumption. |
| Ericsson | This does not seem to be in the scope according to the SID. |
| Panasonic | We are not so sure the meaning of "PDCCH monitoring span gap extension". We see the merit of the larger gap between monitoring occasions like wake-up in every 2 or 4 slots. |
| CATT | Can be further studied. |
| CMCC | Can be further studied. |
| InterDigital | We are fine with studying this further. |
| WILUS | Yes, can be further studied. |
| Sequans | We also see this as part of Technique 1 as it essentially considers extending the Rel-16 limits for span gap. Could be considered however after the necessary evidence and technical discussion required for Technique 1, as mentioned in Q6. |
| Lenovo, Motorola Mobility | Reducing the number of BDs per slot and network implementation (i.e. search space configuration) can equivalently realize extension of span gap to multiple slots. Thus, we don’t think separate discussion/specification effort is needed for this. |
| Samsung | Yes. To extend the PDCCH monitoring span gap is directly equivalent to reducing the maximum numbers of BDs and CCEs regarding the power per time unit. |
| DOCOMO | Yes, it can be further studied |
| Qualcomm | The PDCCH monitoring span extension achieve similar effect to sparse PDCCH periodicity. For that, it is within the scope of Rel-17 power saving enhancement and should be studied there. It is not clear how additional benefit can be gained from the monitoring span extension. |
| Huawei, HiSilicon | Not yet.  The introduction of PDCCH monitoring span to RedCap UE needs to be justified. In our view, if we increase the PDCCH monitoring periodicity and use cross-slot scheduling, the PDCCH processing can be relaxed. The PDCCH monitoring adaptation shall be already discussed in Power saving WI. |
| Intel | Please refer to our response to Q. 4. Also, agree with Qualcomm that “extending PDCCH monitoring span gap from 1 slot to X slots” effectively aims to realize power saving via sparse PDCCH monitoring. In this case, again, this may be seen to fall within the scope of Rel-17 PS WI than something specific to RedCap. |
| Sharp | Yes, we agree to extend the PDCCH monitoring span from 1 to X slots. In this case, the power consumption model should be modified accordingly. |
| ZTE | This item can be considered under the Alt.1 in Technique 1, which can be the prerequisite for the span gap extension. |
| Nokia | Share the opinion of Qualcomm. |
| LG | No. The concept of span gap has been introduced for more complex processing capability (e.g., PDCCH mapping rule, BD/CCE limit). We don’t see a benefit to extend this concept to RedCap UEs for which we prefer to fix the span gap to 1 slot for reduced cost/complexity. |
| SONY | We are OK for companies to study this further, but would like to see more details of benefits in relation to other schemes (e.g. gap between monitoring occasions, cross-slot scheduling) |

### Technique 4: Reduced number of maximum configurable CORESETS per BWP

In Rel-16, a UE is expected to actively monitor a number of up to 3 CORESETs and 10 search space sets. In [5,14,26], it is proposed to study reduction of the maximum configurable CORESETs per BWP. [5] clarifies that the power consumption reduction comes from the lower UE complexity for channel tracking of different TCI states. For [26], it is mainly motivated by the fact of no need for RedCap devices to support such flexible configuration, which also causes unnecessary signaling overhead in case of massive Redcap device connections.

**Question 15: For RedCap, can the maximum number of configurable CORESETs per BWP be reduced? If not, why?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Vivo | We think it is worthwhile to consider reduce the maximum number of CORESET per BWP from 3 to 2. |
| OPPO | No. It seems also out of scope. |
| Xiaomi | More clear evidence is needed. At current stage, we think this can be achieved by configuration. |
| Fraunhofer | This can be studied. However, at the current point we don’t see a major benefit of reducing the number of CORESETs only. Alternatively, constraints to the CORESETs can be studied. |
| MediaTek | This is out of the scope of RedCap SI. This should be discussed in the power saving WI if needed. |
| Futurewei | It is not fully clear that it is within scope of the SI:” *Study UE power saving and battery lifetime enhancement for reduced capability UEs in applicable use cases (e.g. delay tolerant) [RAN2, RAN1]:*  *• Reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits [RAN1].”*  The wording does not include reducing the number of CORESET. In our view, this should be discussed in the power saving WI |
| Ericsson | No, we do not expect power saving by reducing number of CORESETs. Also, it can impact scheduling flexibility. |
| CATT | Don’t see the necessity. The maximum number of configurable CORESETs per BWP doesn’t relevant to the number of BD or CCE. |
| CMCC | No. |
| InterDigital | We do not see clear benefits from this. |
| WILUS | No needed. The UE power consumption depends on the actually monitored PDCCH candidates, not # of configured CORESETs/Search spaces. |
| Sequans | Also out of the scope of RedCap SID. More evidence is needed if it’s worth considering adding in RedCap scope (and also why consider here instead of addressing in power saving WI). |
| Lenovo, Motorola Mobility | Along with DCI size budget, the max number of CORESETs configured for a UE can be reduced, for low complexity operation and accordingly, less power consumption. |
| Samsung | We are negative about reducing the maximum number of configurable CORESETs. It does not affect UE complexity and can result to increased PDCCH blocking or decreased robustness in FR2. The network should have the flexibility to configure CORESETs to the UE as in Rel-16. |
| DOCOMO | This is out of scope of RedCap |
| Qualcomm | The actual supported number of CORESETs can be UE capability. A single CORESET can be used to mimic LTE type of control region especially because RedCap BW is limited and network may not want to further split the BW into multiple CORESETs. |
| Huawei, HiSilicon | No.  First of all, it is the number of configured CORESET instead of the maximum number of CORESET that impacts UE power consumption. Second, the reason why smaller number of CORESET can potentially provide power gain is that the number of BD/CCE is reduced accordingly.  As we explained in our contribution, the reduction of PDCCH candidates shall impact the network scheduling flexibility and therefore it is not preferred. The restriction on the number of DCI format sizes can achieve the benefit without the impact on network flexibility. |
| Intel | We are open to consider further reduction of maximum number of CORESETs/SS sets monitored per BWP |
| Sharp | We don’t agree with this proposal. |
| ZTE | According to the current spec, the number of CORESETs per BWP is configurable. The specification impacts for reducing the maximum number of CORESETs seems to be not clear. Moreover, we don’t see the obvious power saving gain since no evidence prove that. |
| Nokia | No. Beyond the scope of this SI. |
| LG | No. Not sure of the benefit. |
|  |  |

Regarding Question 15, Companies views can be grouped into two options as follows:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Description | Companies | Num. of Companies |
| Opt.1 | Yes | Vivo, Fraunhofer, Lenovo, Qualcomm (UE capability) | 4 |
| Opt.2 | No | Xiaomi, OPPO (out of scope), MTK (out of scope), Futurewei(seems out of scope), Ericsson, CATT, CMCC, Interdigital, WILUS, Sequans (Out of scope), Samsung, DoCoMo, Huawei, Sharp, ZTE, Nokia, LG | 17 |

One company responded to be open for this technique.

It is clearly majority views to not further discuss this technique. To better utilized the limited time unit for this agenda and make discussion more focus, the following was therefore proposed by FL:

**Proposal 15: Discussion on reduced maximum number of configurable CORESET technique for power saving is deprioritized ~~under Redcap~~ SI in Redcap power saving sub-agenda.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree (Y/N)** | **Comments** |
| Ericsson | Y |  |
| Intel | Y | Fine with the proposal. However, we would like to clarify one detail. Currently, an NR UE is only mandated to support a maximum of one configurable CORESET per DL BWP in addition to CORESET 0. We assume this would correspond to the baseline requirement for RedCap UEs even if we do not pursue further reduction in maximum number of configurable CORESETs in a BWP. |
| DOCOMO | Y |  |
| Xiaomi | Y |  |
| Qualcomm | Partially Y | Reduced number of CORESETs is related to both power saving and complexity reduction. Maybe it has a big effect to complexity reduction. It is fine to deprioritize this discussion in power saving. |
| LG | Y |  |
| Samsung | Y |  |
| CMCC | Y |  |
| Huawei, HiSilicon | Y |  |
| Sharp | Y |  |
| Spreadtrum | Y |  |
| ZTE,Sanechips | Y |  |
| CATT | Y |  |
| MediaTek | Y |  |
| InterDigital | Y |  |
| Nokia | Y |  |
| Lenovo, Motorola Mobility | Okay to agree. | This can be discussed later during the WI phase as part of capability discussions. |

Other PDCCH monitoring reduction techniques for FR2 have also been discussed in [26]. [5] further proposed to decouple the configuration of DL non-fallback DCI and UL non-fallback DCI monitoring. In [7], it was proposed to enhance DCI format 2\_6 to allow skipping multiple On periods. FL kindly reminds that only one meeting is left for this study item and realistic scoping of proposals is needed.

**Question 16: Should any other techniques for reduced PDCCH monitoring be studied, in addition to the 5 techniques identified and listed? If yes, explain and motivate.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Vivo | We think decoupling of DL non-fallback DCI and UL non-fallback DCI monitoring is a simple way to achieve BD or size reduction. It can be useful for the asymmetric DL/UL traffic cases, e.g. industrial sensors, or video surveillance, etc.  The spec impact is minor and should be easily be implemented. |
| Xiaomi | Yes. Any solution for the power saving should not be precluded. For example, Multi-TB scheduling or pre-configured transmission is good in the scenario with low mobility. And these solutions are adopted in the MTC/NB-IoT project. |
| MediaTek | Any other techniques that beyond the SI scope (“*Reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits*”) shouldn’t be considered in this SI. Such techniques should be discussed in the power saving WI if needed. |
| Futurewei | As FL pointed out, with only one meeting left, we need to focus our work. Thus, at this stage, we are reluctant to consider any additional technique |
| Ericsson | No |
| Panasonic | Related to question 8 of reducing PDCCH monitoring by span gap extension, even under such condition, it is preferable for gNB to schedule all slots to keep the user throughput. In order to allow such operation, one PDCCH schedule multiple TBs over multiple slots should be supported. |
| CATT | Similar views as MTK and Futurewei. |
| WILUS | Interaction of PDCCH coverage recovery can be further considered. If RAN1 agrees to support a new technique for PDCCH coverage recovery (e.g., repetition), then it may affect PDCCH monitoring. |
| Lenovo, Motorola Mobility | We think decoupling DL non-fallback DCI monitoring from UL non-fallback DCI monitoring should be considered in order to reduce BD. |
| Samsung | We are open to techniques for reducing the blocking probability, the PDCCH overhead, and/or the number of BDs and CCE limits during SI phase. Given the time limit, it’s better to identify the techniques with high priority in this meeting. |
| DOCOMO | Agree with MediaTek. |
| Qualcomm | Techniques that can reduce the amount of PDCCHs required for UL and DL scheduling can also be studied. These techniques can help reduce the required number of BDs/CCEs for DL/UL data scheduling and hence reduce PDCCH blocking probability when BD/CCE limits are reduced.  Additional techniques (it is understood that certain techniques may be discussed in Rel-17 power saving enhancement based on splitting of task between the two agendas) to be studied/considered:   1. Ways to have additional DL control between sparsely configured SS occasions (reducing the “average” UE searches), e.g.:    1. By dynamically or on-demand configuring SS set occasions    2. By piggy-backing DL control signalling on existing SCH messages (DG or SPS)   Motivation: There may be some RedCap-specific characteristics and use cases that motivates the study of power savings techniques separate from the power savings SI. For e.g., UL heavy traffic models as well as large latency requirements for RedCap may motivate using reduced PDCCH monitoring occasions in time (i.e., reduced search space periodicity) to allow for more UL traffic opportunities (for TDD system) and at the same time reduce UE power consumption (by reducing PDCCH monitoring). However, there may be cases where we need some DL control in between these sparse SS due to: traffic or beam management (TCI/SRI updates).   1. Reduce the “average” UE PDCCH monitoring by utilizing preconfigured (PDCCH-less)   Motivation: reduce the “average” BD monitoring. Stationary conditions for RedCap   1. Dynamically change parameters for semi-static periodic messages (search space sets, SPS, CG) based on the current environment and the spatial needs   Motivation: beam overloading and blockage mitigation + reduced unnecessary BD   1. MUP (multiple user packets) in single PDSCH which is indicated by single PDSCH 2. Motivation: single PDCCH can indicate multiple TBs for different users. It reduces the PDCCH blocking probability very much when BD/CCE limits are reduced. |
| Huawei, HiSilicon | No.  In our view, the discussion in RAN1 should focus on technique 1 (i.e., reduced BD/CCE). Then if necessary, the discussion can be triggered by RAN2 about the RAN2 power saving schemes, including eDRX and RRM relaxation. After that, the useful schemes in other Rel-17 SID/WID can be reviewed for RedCap, such as Rel-17 Power Saving and Rel-17 Small Data.  Other solutions should not be discussed at this stage. |
| Intel | For new schemes/enhancements, we also suggest to consider multi-TB scheduling by a single DCI to help with reducing PDCCH blocking. |
| Sharp | We don’t think other techniques should be studied due to the time limitation. |
| ZTE | We need to focus on the SID scope. |
| Nokia | Given the limited time and the R17 Power Saving WI, we understand if this cannot be pursued further in this SI. |
| LG | No. Similar view with the FL. Given the limited time for this SI, we prefer not to expand the scope of our discussion. |
| SONY | This question refers to “5 techniques identified and listed”. Is “5” a typo? We only see 4 techniques listed in section 3.1 |

# References

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8. [R1-2005591](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005591.zip) Power savings for RedCap UEs FUTUREWEI
9. [R1-2005638](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005638.zip) Discussion on reduced PDCCH monitoring for NR RedCap UEs MediaTek Inc.
10. [R1-2005715](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005715.zip) Discussion on PDCCH monitoring reduction CATT
11. [R1-2005771](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005771.zip) Reduced PDCCH monitoring TCL Communication Ltd.
12. [R1-2005778](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005778.zip) Reduced PDCCH monitoring for REDCAP NR devices NEC
13. [R1-2005779](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005779.zip) Reduced PDCCH Monitoring for RedCap UEs Fraunhofer HHI, Fraunhofer IIS
14. [R1-2005881](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005881.zip) On reduced PDCCH monitoring for RedCap UEs Intel Corporation
15. [R1-2005933](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005933.zip) PDCCH monitoring at reduced capability UE Lenovo, Motorola Mobility
16. [R1-2005969](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005969.zip) Discussion on reduced PDCCH monitoring for reduced capability device Beijing Xiaomi Software Tech
17. [R1-2006037](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006037.zip) Discussion on reduced monitoring for PDCCH OPPO
18. [R1-2006153](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006153.zip) Reduced PDCCH monitoring Samsung
19. [R1-2006218](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006218.zip) Discussion on reduced PDCCH monitoring CMCC
20. [R1-2006286](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006286.zip) Discussion on reduced PDCCH monitoring Spreadtrum Communications
21. [R1-2006307](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006307.zip) Discussion on PDCCH monitoring for reduced capability NR devices LG Electronics
22. [R1-2006525](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006525.zip) Reduced PDCCH Monitoring for RedCap Devices Apple
23. [R1-2006539](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006539.zip) Reduced PDCCH monitoring for reduced capability NR devices InterDigital, Inc.
24. [R1-2006683](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006683.zip) Reduced PDCCH monitoring for RedCap UE Sequans Communications
25. [R1-2006734](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006734.zip) Discussion on reduced PDCCH monitoring for RedCap NTT DOCOMO, INC.
26. [R1-2006812](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006812.zip) PDCCH Monitoring Reduction and Power Saving for RedCap Devices Qualcomm Incorporated
27. [R1-2006839](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006839.zip) PDCCH Monitoring for Reduced Capability Devices GDCNI
28. [R1-2006890](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006890.zip) Discussion on PDCCH monitoring for RedCap UE WILUS Inc.
29. [R1-2006947](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006947.zip) On power saving and battery lifetime enhancement for NR Redcap devices Sony
30. 3GPP TR 38.840 Study on User Equipment (UE) power saving in NR

# Appendix

## 2.1 Traffic model

The traffic model for ‘heartbeat’ remains open. Two models are proposed and summarized as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Payload (Bytes) | Mean Arrival Rate | Note |
| Option 1 [4] | FTP model 3 | 100 | 300 s | The application layer message from client to server to inform that the service is still alive. |
| Option 2 [18] | Periodic deterministic traffic | 64 | 100 ms |  |

Company clarified that parameters in [18] is used for process monitoring and based on periodic deterministic communication instead of FTP-3 model. One company clarified that [4] focus on the heartbeat packet in the application layer from client to server, which intends for the wearable devices. One company suggests to study both models as they target to different use cases of wearable devices. Opt.1 was preferred by 3 companies but suggest going with a smaller mean-arrival rate e.g. 60s for heartbeat.

**Question 1: For ‘heartbeat’ study, can we use FTP-3 traffic model?**

* **If yes, what values can be considered for payload size and mean inter-arrival rate?**
* **If not, what traffic model can be used for ‘heartbeat’ study and corresponding parameters value?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | If there is a need to study ‘heartbeat’ traffic, we are fine with option 2 |
| MediaTek | No.  We don’t see it essential to consider the ‘heartbeat’ traffic. The scope for power saving in this SI is very limited, and the considered traffic models are sufficient for baseline evaluations. |
| Moderator | We had agreement made in last meeting:   * For evaluation of UE power saving, for wearables, **use the traffic models FTP model 3 and VoIP from TR 38.840 to characterize the wearables service types including IM, VoIP, heartbeat, etc.** with proper modification of at least packet size and mean inter-arrival time. Values are FFS.   Following this agreement, the discussion point is not whether support it, as it has been agreed to support as above. What we need to decide which values to use. |
| SONY | Our preference: {FTP3, payload = 100 bytes, mean inter-arrival time = 60 seconds}  For an application layer heartbeat message, we would expect some variance in the arrival times of the packets, hence we do not prefer a periodic deterministic traffic model.  We should be talking a “mean inter-arrival time” rather than a “mean arrival rate”. |
| Futurewei | The payload for each model would work. However, the mean arrival rate of both models may need to be revised (one is high, one is low) |
| Ericsson | Yes. Payload (Bytes): 100; mean inter-arrival rate: 60 s. For the sake of progressing of the study, we are also fine with 300 s mean inter-arrival rate. |
| Intel | We think FTP 3 model can be used according to agreement in last meeting and we are fine with payload size. But, mean inter-arrival rate of 300s seems too high. 60s seems more reasonable. |
| Qualcomm | We do not think a dedicated mode is needed for heartbeat traffic. Then there is no need to determine such a model. If companies insist to use a model for heartbeat, it can reuse TR 38.840 instant message (IM) traffic model. If heartbeat model with long inter-arrival time needs to be studied, we can reuse the “background sync” use case already agreed in Rel-16 TR:  For background app sync application, for power consumption evaluation purpose, it can be assumed that idle mode operations (inclusive of page detection, RRM, deep sleep and transition overhead) contributes to X% of the use case power. The remaining portion is contributed by intermittent RRC connections due to background activities (FFS: value of X) |
| Samsung | We agree heartbeat is also FTP-3 traffic model.  We already agreed that other ~~Instant~~ traffic models based on FTP model 3 are not precluded and companies to report the mean inter-arrival time and packet size if other ~~instant~~ traffic models are assumed in evaluation. No need to agree on or study exact values of mean inter-arrival time and packet size for heartbeat traffic. Companies have the freedom to determine the model by themselves.  The agreement from last meeting just considers heartbeat as one example of wearables use cases, it doesn’t mean we have to define the traffic model for all wearables use cases. |
| Huawei, HiSilicon | Yes, we can use FTP-3 traffic model.  For Heartbeat traffic, for Opt.1, we think 300s more fits the realistic traffic we observed in wearable devices like smart watch. But we are open to further compromise, e.g. to a value of 60s~150s. |
| InterDigital. | Yes, we can use FTP3 traffic model.  100 bytes and 60 s. looks ok to us. |
| Nokia | Yes – use the FTP3 model. Values: Payload 100 Bytes. Mean Arrival rate 60s. |
| ZTE,Sanechips | Yes, FTP3-model can be used for ‘heartbeat’ study. The payload size 100bytes can be used. As for the Mean Arrival Rate, we prefer 60s. |
| OPPO | If the necessity is identified, option2 is preferred |
| CATT | We do not see the need to have dedicated model for heartbeat. The FTP3 and instant message defined in TR38.840 could be used for heartbeat traffic model |
| SONY2 | We are basically OK with the proposal below, but can we please use “inter-arrival time”, rather than “inter-arrival rate”? “inter-arrival time” is the term that is used in TR38.840.  **Proposal 1: For power consumption evaluation, use FTP-3 model with 100 Bytes packet size and 60s mean inter-arrival ~~rate~~ time as baseline for ‘heartbeat’ traffic.**  If, on the other hand, we really want to talk about “rates”, could we please use “…100 bytes packet size and a mean inter-arrival rate of one packet every 60s…”. |

## 2.2. Power consumption model

A few contributions [5,14,18,24] discussed the need to modify power consumption model in TR 38.840. In section 8.1 of TR 38.840, the UE power consumption model with different power state as listed in Table was agreed with a set of reference configuration assumptions, which includes the following:

* SCS: 30kHz
* System Bandwidth: 100 MHz
* PDCCH: 2 symbols, 56 maximum number of CCEs, 36 PDCCH blind decoding
* Antenna configuration: 4 Rx
* UE processing capability 1

On top of this basic model, different power scaling schemes were defined to adapt to different configurations of bandwidth, CA, antenna number, cross-slot scheduling and PDSCH-only.

Table below summarizes issues identified for scaling factors of the power consumption model in TR 38.840, which may motivate certain modifications to evaluate the power consumption of RedCap devices:

|  |  |  |
| --- | --- | --- |
| Issue Index | Description | Contribution |
| 1 | The power consumption for a “PDCCH-only” monitoring slot is the same for same-slot and cross-slot scheduling cases, i.e. max {100\*0.4/ 70\*0.4, 50, 45}. [5] | [5] |
| 2 | After applying scaling factor of bandwidth and antenna number, the power assumption for RedCap can be less than the micro-sleep value (i.e. 45). | [5,18,24] |
| 3 | The scaling factor for 2 Rx to 1Rx was missed | [5] |
| 4 | 3-OS CORESET and number of CCEs were not modelled in PS model of TR 38.840 | [14] |

[5,14] propose to define new scaling factor to address the identified issues. While, for simplicity purpose and taking into account the time left for this SI, [18] suggest reusing power consumption model in TR 38.840 without using scaling factor for power saving evaluation of RedCap SI. At least for issue 2, FL view is that it can be easily addressed by using max (xx, 45) operation.

**Question 2: Can we reuse the power consumption model in TR 38.840 without applying scaling factor? If not, which modifications are needed, e.g. what values of scaling factor should introduce?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | We identified following issues when reusing the existing power model and scaling factor in TR38.840   1. If the existing bandwidth scaling (Scaling of X MHz = 0.4 + 0.6 \* (X - 20) / 80) is applied, the PDCCH-only monitoring power for 20MHz will be 40, which is lower than the micro sleep power (45), this is unreasonable. Even if we following the rule in TR38.840 “If the power after scaling is smaller than the BWP transition power, assume the BWP transition power as the output of scaling unless otherwise justified.”, the power for 20MHz PDCCH only is still too close to micro sleep. Some adjustment is needed, for example, lower the micro sleep power for 20MHz? 2. There is no scaling factor for 2Rx to 1Rx currently available. Suggest to consider 0.7 as the scaling factor which is the same as FR2, i.e. 1Rx power is 0.7 of 2Rx power. Furthermore, the existing micro sleep power does not scale with number of Rx, which seems to be unrealistic, suggest to also consider Rx scaling for micro sleep power. 3. If we follow the existing power scaling rule, for 20MHz, the PDCCH-only power for same-slot scheduling will be 100\*0.4 = 40 and PDCCH-only power for cross-slot scheduling will be 40\*0.7 = 28. There are two problems, firstly both of them are lower than the BWP switching or micro-sleep power, which is unreasonable. Secondly if we follow the rule in TR38.840 “If the power after scaling is smaller than the BWP transition power, assume the BWP transition power as the output of scaling unless otherwise justified.” both same-slot and cross-slot power will be the same as BWP switching power, i.e. 50, which is also unreasonable. Refinement for the power model is needed to obtain a reasonable outcome. |
| OPPO | We are fine with the missing part of model, Then the “3” is definitely fine to us. The 1 and 2 is also seems to be reasonable. We propose to reduce the options of further configurations. |
| Xiaomi | Some update is needed. At least issue 3 should be addressed. |
| Futurewei | Power model of 36.840 is the baseline. Modifications are needed. The solution proposed by Vivo for 2) is a good solution. For 1) and 3), a solution is to scale the microsleep power is needed and can be as simple as scaling the microsleep power |
| SONY | The issues raised by vivo are reasonable and need to be addressed. |
| Ericsson | Reuse the power consumption model and scaling factors in TR 38.840, and consider max(xx, 45) operation to avoid having values less micro-sleep power. |
| Panasonic | DCCH-only model should be revisited. Technically, we agree the issue#1, 2, 4 for PDCCH monitoring power model. Particularly on issue 4, the OFDM symbol number and positions can both be extended if possible. On issue 3, it is not simply scaling as RF part takes larger portion. We don't agree FL view on max (xx, 45) operation. |
| CATT | We agree with FL’s suggestion on issue 2. For issue 4, maybe it can be deprioritized as 1) not sure about the impact of power saving for 3-OS CORESET 2) number of CCEs is not considered in TR38.840 as it only impact the channel estimation, not sure how can we convert the complexity of CE into power saving. |
| CMCC | Fine with vivo’s view. |
| InterDigital | We agree that these issues should be addressed. For issue (2), we can follow ViVo’s recommendation. For issue (1), whether to reduce the microsleep power for 20 MHz or to follow FL’s recommendation ( max(xx, 45) ) needs further discusison. After issue (1) is resolved, issue (3) can be discussed. |
| Sequans | Some modifications are needed. Issues 2 and 3 seem reasonable to consider. |
| Lenovo, Motorola Mobility | Micro-sleep value can be adjusted considering 20MHz BW, and need to agree on scaling factor for 2Rx to 1 Rx. |
| Samsung | We think it’s not OK to reuse the scaling rule in TR38.840. The scaling factor regarding reduced number of BW and antennas are suitable for PDCCH based adaptation. But for RedCap cases, the reduction on power consumption relative to eMBB is determined by reduced complexity and UE capability. In our view, if scaling is needed, it should be applied to any power state, including sleep state. So, for the benefit of evaluation simplicity, we suggest to reuse the relative power models in TR38.840, and skip power scaling due to reduced UE operation BW and antennas for the baseline of RedCap.  To evaluate power saving from PDCCH monitoring reduction, the scaling rule of BDs in TR 38.840 can be a starting point. |
| Qualcomm | In addition to the above proposals, if a BW below 20MHz is adopted for RedCap devices, the corresponding power scaling for BW < 20MHz also needs to be defined. |
| Huawei, HiSilicon | 1. Regarding the proposal in [18], it would be impossible to compare the power consumption of RedCap UEs with normal eMBB UE. If we just use the model without the scaling in 38.840, a relative ratio of gain could be obtained but it is difficult to understand how much real power consumption benefit could be introduced for the RedCap devices in deployment without a reference to the power consumption of eMBB UE. Furthermore, Rel-16 power saving schemes and Rel-17 enhancements should be utilized for RedCap UEs, it would be impossible to evaluate the final obtained power saving gain when Rel-16 power saving techniques, Rel-17 power saving enhancement (e.g. the IDLE mode power saving) and the BD reductions in RedCap are used simultaneously. Therefore, we should use the same power model, including the scaling rules in TR 38.840, which we have discussed much in Rel-16. 2. If companies have concern on the micro sleep, we think we can reuse the power model and scaling rules in TR 38.840 but keep open to just remove the microsleep state in RedCap or define a smaller value for micro sleep state (e.g. 30) for RedCap UE. |
| Intel | The power consumption model can be revised taking the following points into account:   * Micro-sleep power should depend on RF parameters such as reduction in BW and number of antennas. Otherwise, comparison with respect to scaled PDCCH-only power is not valid. Micro-sleep power should be scaled as well. * Power consumption due to number of CCEs used for PDCCH monitoring certainly correlates with number of BDs. However, that may not be quite accurate always. In fact, if larger ALs need to be configured within a given number of candidates, number of CCEs is expected to be large. Hence, a given number of candidates may use a wide range of number of CCEs, leading to different power consumption. Depending on deployment scenario, larger ALs maybe needed for RedCap UEs at least for coverage enhancement purposes. Hence, some considerations in this regard is necessary. * Agree with above comments from vivo on scaling due to antenna adaptation and we are fine with the suggestion. |
| Sharp | Modification is needed, as pointed out by vivo. |
| Spreadtrum | For issue 2, we shared the same views with Vivo that some modification is needed. It is possible that for the Redcap UEs the micro sleep power in 20MHz is lower than that in 100MHz, so some adjustment is needed either micro sleep power or scaling factors. |
| ZTE | We think some modification are needed. The details are as follows:   * For issue 2, it is preferred to modify the bandwidth scaling formula 0.4 + 0.6 \* (X - 20) / 80, since the baseline bandwidth for Redap UE is no longer the same with NR UE. * For issue 1, the power consumption for a “PDCCH-only” monitoring slot can be the same for same-slot and cross-slot scheduling cases. However, max {100\*0.4/ 70\*0.4, 50, 45} is adopted depends on whether we modify the bandwidth scaling factor. We prefer to modify the bandwidth scaling formula to solve issue1 and issue2 simultaneously. * For issue 3, we think it is de-prioritized. The simulation results based on 2 Rx is enough. * For issue 4, 3-OS CORESET and number of CCEs can be considered to be modelled in PS model of TR 38.840, since 3-OS CORESET and CCEs number have an impact on power saving. |
| Nokia | Issue 2: Agree that some adjustment is required.  Issue 3: Agree that some scaling is required – vivo’s suggestion is acceptable. |

In addition, power model modification is needed to evaluate some power saving schemes proposed for RedCap devices. In [18], it was proposed to adopt the following power consumption model to study the power saving performance of extended span gap X (e.g. X>1 slot).

Where is the power for PDCCH monitoring without relaxation, i.e. PDCCH only. is the power for respective activity excluding PDCCH processing. Concrete examples of this equation were also provided in [18]

**Question 6: For evaluation of extended span gap X slots (X>1) proposal e.g. in [18], can we extend the power consumption model by using equation 1 above? If not, what modification is needed?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Vivo | As discussed in [18], the is the micro sleep power, however, if we scale the with reduced BW, e.g. 20MHz, the outcome will be constant regardless of X value, i.e. always equals to , which again justifies to refine the micro sleep power according to reduced BW and Rx.  could be a simple way to model the extended span gap X, however, as discussed in our paper [5], we think more accurate approach would be to split the power contribution to Rx power and baseband power. Assuming cross-slot scheduling and only one MO=3Os per X slots, the Rx power is only considered in the 3OSs for RF reception but the baseband power for PDCCH processing can be scaled by 1/X. |
| OPPO | We are supportive for the extension into X. The equation 1 is ok |
| Futurewei | It is unclear if the extended gap is within the SID:  *• Reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits [RAN1].”*  The extended gap does not reduce the number of blind decodes, it spreads them over time. Thus, RAN1 does not need to study |
| SONY | The extended span gap scheme seems to be a single company proposal [18] and we don’t need to prioritise a power model for this.  The “PDCCH only” energy in TR38.840 accounts for some RF power and some baseband power in a slot. If the processing is extended across a span of more than one slot, the baseband power would be spread across the slots, but the RF power wouldn’t. Hence Pt / X doesn’t seem to be the right way to account for processing across a span. |
| Ericsson | The proposed model is OK if extended gap needs to be evaluated. However, this model is not accurate, based on this model for X greater than a threshold then increasing the span gap will not help in power saving (P=Ps), which is not reasonable.  Alternatively, we propose the following model: P(X) = (Ps+(Pt-Ps)/X), where power consumption of a state by excluding PDCCH part (if it is included), and Pt is power consumption of the state. This ensures that the power consumption is always greater than Ps. Some results:   * For X=1 we get P=Pt, which is correct. * In “PDCCH-only” (includes PDCCH+micro-sleep in the slot), Pt=100, Ps = Pmicro=45, then for X=2 we have P=45+55/2=72.5. * In “PDCCH+PDCCH” for FR1, Pt=300, Ps = Ppdsch-only=280, then for X=2 we have P=280+20/2=290. * For very large value of X, P becomes Ps, which is reasonable. |
| Panasonic | Power consumption model for relaxed PDCCH decoding was discussed in power saving SI in Rel.16 but not concluded. It would not be required to have such new model. |
| Samsung | We think it’s necessary to consider scaling rule regarding extended PDCCH processing over X slots. The and are the relative power of baseline configuration. As explained in our reply to Q3, the scaling rules in TR38.840 regarding reduced antennas and BWP are not applicable to determine the values for and . There should still be significant power difference betwen and for RedCap baseline configuration. |
| Qualcomm | Power consumption of PDCCH processing may not be further reduced when the processing timeline is further relaxed. It is not clear why a cross-slot scheduling PDCCH-only power consumption cannot be directly used here. We do not think this formula is needed. |
| Huawei, HiSilicon | If X=4 slots, Pt/X would be 25, and the final power consumption would be the same as that of micro sleep. We think this is not reasonable assumption.  According to the discussion in Rel-16, the voltage of the chipset could be reduced and therefore the power consumption can be reduced. The power consumption is not a linear function of the timeline relaxed.  On the other hand, in our view, if we want to model the power scaling model for relaxed PDCCH processing, we should directly model “power scaling due to PDCCH processing relaxation”. The extension of ‘span’ should not be introduced in power model here. |
| Intel | We are not clear on the necessity of enhancing span based PDCCH monitoring for RedCap since it is not obvious that the power consumption reduces linearly as suggested as a function of the gaps between two consecutive sets of PDCCH MOs. Thus, we do not think this model is necessary. |
| Sharp | More accurate power consumption model should be studied for evaluating the span gap issue, for example the proposed model from Ericsson. |
| ZTE | We prefer that the power consumption model focus on one slot, and extended span gap X slots can be de-prioritized due to the limited conference time. |
| Nokia | A more accurate power consumption model should be studied. The proposed model from Ericsson should be further investigated. |
| LG | First of all, it should be clarified whether extended span gap (i.e., X > 1 slot) needs to be discussed in this SI. The concept of span gap might require more complex processing capability (e.g., PDCCH mapping rule, BD/CCE limit). So, our suggestion is to fix the span gap to 1 slot in REDCAP SI, and the formula (1) is not needed. |
| InterDigital | The model from Ericsson can be studied. |
| CATT | We don’t see any modification of power model is needed without any justification, which were discussed intensively with justification on every model during Rel-16 UE power saving study. |

On Q5, responses from companies can be categorized as follows:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Description | Companies | Num. of Companies |
| Category-1 | Support and discuss the proper model | Vivo, OPPO, Ericsson, Samsung, Sharp, Nokia, | 6 |
| Category-2 | No need to discuss | Futurewei, Sony, Panasonic, Qualcomm, Intel, ZTE, LGe | 7 |

**Proposal 6: making the following conclusion:**

* **It is up to each company to report power consumption model if power saving performance of extended span gap X (e.g. X>1 slot) is evaluated.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree (Y/N)** | **Comments** |
| Vivo | Y |  |
| MediaTek | N | It is not clear to us how the extended span gap X slots (X>1) works. For example, for the PDCCH limit is per 2 slots (instead of one slot as in R15), does this imply:   * Option-1: The gNB can’t configure the UE with PDCCH monitoring of 1 slot periodicity? * Option-2: the gNB can configure the UE with PDCCH monitoring of 1 slot periodicity, but the limit need to be distributed.   The power consumption model will modified based on which option is considered.  We think Option-2 will not require any modification to the power model. |
| SONY | Y | We would hope that a company that proposes an extended span gap would (1) clearly explain what they mean by extended span gap, (2) indicate the mechanism for an extended span gap to reduce power consumption and (3) propose a power consumption model that is compatible with the mechanism in “(2)”. We think that the proposal is consistent with this way of working. |
| Futurewei | N | We first need to discuss whether extended gap is within scope of SID |
| Ericsson | N | Considering no model is agreed, and as it is doubtful whether this technique is in the study item scope, we prefer not to study this. |
| Intel | N | It is not clear why such agreement is necessary. Proponents can always study and show evaluations and assumptions for their proposals. Span based monitoring should not be considered as baseline that needs some model development. |
| Qualcomm | Y |  |
| Samsung | Partially Y | We think the power model for extended span gap, (X>1), is needed in order to evaluate the performance of potential techniques to support reduced PDCCH candidates/CCE limits per time unit (X > 1).  The power model for cross-slot scheduling only considers PDSCH buffering skipping, it doesn’t consider PDCCH processing relaxation over a longer time duration.  We are OK with the updated model proposed from Ericson in the second round of email discussion. If it’s difficult to agree on any model this meeting, we suggest to at least encourage companies to study and further discuss in next meeting. |
| Fraunhofer | Y | For the beginning it is acceptable that companies report their power consumption model.  However, for further studies we think that it is important to have a common basis for evaluating the extended span gap. Otherwise the comparability of the results will be limited. Ericsson’s proposal seems reasonable to us. |
| Huawei, HiSilicon | N | Agree with other companies that we should firstly discuss what the extended span gap is and whether it is in the scope. |
| InteDigital | Y | Agree with FH comments. |
| Nokia | N | Need to discuss if this is within scope of the SID |
| LG | N | Without this conclusion, companies will do exactly the same as the proposed conclusion intends to say if they think extending the span gap would be needed. |
| Lenovo, Motorola Mobility | N | We don’t’ think this proposal is necessary. |
| ZTE,Sanechips | N | The extended span gap mechanism to saving power needs more clarification. |
| OPPO | Y | The span gap evaluation will help to modeling the CCE limits over multiple slot cases. |
| CATT | N | Rel-16 power saving study also captured the power saving results of multi-slot scheduling in TR38.840 similar to extended span gap. I wonder what is new in power saving for extended span gap. |

## 2.5 Support of Rel-16 power saving techniques

Several contributions [4,8,26] propose to evaluate which Rel-16 power saving technique(s) can be supported for RedCap devices, which includes DRX adaptation based on DCI format 2\_6, cross-slot scheduling, adaptation of MIMO layers, RRM relaxation for neighbor cells, dormant SCell and UE assistance information. [4,8] proposed that RedCap devices can utilize all of them for power saving purpose, except UE-assist information (2nd priority in [8]) and dormant SCell subject to the conclusion on CA support of RedCap devices.

**Question 10: Can Rel-16 power saving techniques be optionally supported by RedCap device? If so, which techniques can be optionally supported?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Technically we think DCI format 2\_6, cross-slot scheduling, RRM relaxation, UE assistant information can be beneficial for RedCap UEs thus may be supported. However, given all these Rel-16 UE power saving features are optional for UE, a Redcap UE can decide to support none, some or all of them, which is a product choice. Unless we would like to make some of the features “mandatory” for RedCap UEs (which we believe there is no such need), we do not see much need to decide anything for Question 5. |
| OPPO | We consider this is more like UE capability issue and the basline comparison issue. |
| Xiaomi | Even though some Redcap UEs would stay in RRC\_IDLE and RRC\_INACTIVE modes most of time, it is equally important to reduce the power consumption during RRC\_CONNECTED mode.  The R16 UE power saving is mainly focused on RRC-Connected mode, including power saving signal/channel for C-DRX, enhancement on the cross-slot scheduling, DL maximum MIMO layer adaptation and UE assistance information. For idle mode, RRM measurement relaxation for the neighbour cell is specified. We think at least the following schemes can be taken for Redcap UEs.   * Power saving signal/channel for C-DRX; * Enhancement on the cross-slot scheduling; * UE assistance information: C-DRX parameters, RRC state transition; * RRM relaxation for idle/inactive mode;   In the meanwhile, some schemes might not suitable for Redcap UEs. As the Redcap UEs might not adopt CA, it seems power saving signal/channel working as SCell group dormancy indication is not necessary. Some UE assistance information as mentioned above, such as C-DRX parameters are applicable for Redcap while the maximum number of SCells, maximum aggregated BW and maximum MIMO layer might not be applicable since Redcap UEs with low cost/complexity will work with UE bandwidth reduction and reduced number of UE antennas. Besides, DL maximum MIMO layer adaptation might not be needed if a Redcap UE only support limited number of receive antennas to 2RX or 1RX. However, currently RAN1 is discussing the antenna configurations for Redcap UEs. We can wait for more inputs.  It is also worthwhile to notice that some possible enhancements can be considered to cate for Redcap devices. An example is that WUS applied to multiple DRX Ondurations was excluded for eMBB users in R16 as people showed concerns about the delay. However, it should be noted that a 1-to-N mapping is advantageous for the Redcap UE power savings if the UE will not consider the delay to be critical especially for IoT scenarios. |
| Fraunhofer | Yes, RedCap UEs should make use of Rel-16 power saving techniques. Adaption of MIMO layers, RRM relaxation for neighbour cells and DRX adaptation may provide benefits if used optionally. However, Cross-slot scheduling should be mandatory for all RedCap UEs as it shows substantial gains and the increase in complexity is negligible. |
| MediaTek | Yes, certainly RedCap UEs will make use of Rel-16 power saving features. Also, we expect the RedCap UEs to make use of other power saving feature that would be introduced in Rel-17.  It is infeasible to achieve the targeted power saving without Rel-16/Rel-17 features.  We don’t see any justification to not utilize such features. |
| Futurewei | It is unclear if the question is for evaluation or for what is supported. As it is the case for any new release, we should assume the rel-16 techniques are available and used when considering a new technique for redcap. i.e., should not avoid existing techniques to promote a new technique.  All optional techniques for NR are by default still optional and available to RedCap. We are OK to say that CA related ones are (maybe) not supported (like dormant cell), but that can be decided later. So the decision is whether these techniques are either included in the eval (yes) or recommended for redcap (yes). |
| Ericsson | Yes. DRX adaptation, cross-slot scheduling, and UE assisted information can be optionally supported. Also, if RedCap supports CA, Dormant BWP can be considered. Adaptation of MIMO layers may be supported depending on the number of the number of RedCap antennas and UE capability. |
| Panasonic | All power saving techniques in Rel-16 can be supported except CA related function. |
| CATT | We share the similar views as vivo and oppo. |
| CMCC | Yes. DCI format 2\_6, cross-slot scheduling, RRM relaxation for neighbor cells, and UE assistance information can be supported. In addition the support of adaptation of MIMO layers and dormant SCell is related to RedCap UE capability i.e., whether to support multiple BWPs, support of CA and number of antenna which can be discussed later. |
| InterDigital | These techniques can be optionally supported by a RedCap UE. |
| WILUS | At least, cross-slot scheduling and DRX adaptation would be helpful for RedCap UE, thus we are ok to support these features optionally for RedCap UE. Further enhancements of these features are obviously out of scope. So it is an UE capability issue not a technical issue. |
| Sequans | All Rel-16 (and eventually Rel-17) power saving techniques should be able to be supported by RedCap device. We think that two other questions should be clarified instead:   1. If any Rel-16 power saving technique(s) should be mandatory for RedCap UEs 2. Which, if any, Rel-16 power saving technique(s) should be considered as supported by reference UE in order to set a more proper baseline to evaluate performance of candidate power saving techniques for RedCap UEs. |
| Lenovo, Motorola Mobility | We think at least wake-up indication via DCI format 2\_6 and cross-slot scheduling should be supported by RedCap UEs. |
| Samsung | Most of R16 UE power saving schemes can be supported for RedCap, including WUS for C-DRX, adaptation on cross-slot scheduling, BWP switching based adaption on MIMO layers (if UE antennas is larger than 1).  Dormancy and non-dormancy BWP switching for SCells is an exception as CA is not applicable for RedCap. |
| DOCOMO | Yes, RedCap UE can support Rel-16 power saving techniques as optional. Dormant SCell is not necessary if CA is not applied to RedCap. |
| Qualcomm | We agree that these Rel-16 power saving techniques can be considered at least for RedCap power consumption. However, support of some features may not be preferred from complexity reduction perspective. Because of this, answer of this question should also take into account RedCap complexity reduction. Also, optional features for Rel-16 should still maintain optional. |
| Huawei, HiSilicon | In Rel-16 Power Saving WI, many useful mechanisms were justified to provide power saving gain and no impact on the complexity of the UE. RedCap UEs may also suffer from unnecessary PDCCH monitoring, unnecessary signal buffering etc. So the mechanisms specified in Rel-16 Power Saving WI should be utilized by RedCap device.  As we analysed in our contribution [4], the following mechanisms can be utilized by RedCap UEs:   * PDCCH based wake-up indication * Cross-slot scheduling * maximum MIMO layer adaptation * RRM relaxation for neighbour cell (RAN2/RAN4) * UE assistance information specified in Rel-16 |
| Intel | In our view, R16 power saving schemes can be optionally supported. However, their applicability needs to be justified at first, such as whether dynamic adaptation for power saving is necessary for RedCap UEs or not, given low complexity requirement. In our view, semi-static adaptation may suffice in most cases. |
| Sharp | RedCap UE could support Rel-16 power saving techniques. But it needs to be clarified which are optional and which are mandatory. |
| Spreadtrum | All Rel-16 power saving techniques be optionally supported by RedCap device. |
| ZTE | Yes, the R16 power saving techniques in RAN1 includes PDCCH-based(except the sCell dormancy) power saving signal/channel, cross slot scheduling, and UE adaptation to maximum number of MIMO layers. The above all techniques can be optionally supported.  As for the RRM relaxation and UE assistant information, RAN2 would make the decision. |
| Nokia | RedCap UE can support Rel-16 power saving techniques. Though Dormant SCell is may not be necessary if RedCap do not support CA. Note, we should also consider Rel-15 techniques like BWP switching.  In addition, we should be open to Release 17 Power Saving features techniques also being applicable to REDCAP. |
| LG | The DRX adaptation using DCI format 2\_6 and cross-slot scheduling can be supported by REDCAP device. We can further consider optionally supporting MIMO layer adaptation for some service types. And the dormancy operation is not needed, if CA is not supported by REDCAP device. |
| CATT | Rel-16 power saving techniques should be supported by RedCap UE as the starting point. |

Some companies point out it is unclear the discussion point here, i.e. for evaluation purpose or RedCap UE capability. The intention here actually is for evaluation scope i.e. whether we need to assume Rel-16 power saving schemes as baselines when evaluating the benefit of new schemes.