**3GPP TSG-RAN WG1 #103-e R1-200xxxx**

**e-Meeting, October 26th – November 13th, 2020**

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

**Title: Feature lead summary #9 on reduced PDCCH monitoring**

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

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

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# 1 Introduction

Contributions made under the “reduced PDCCH monitoring” agenda item of the Rel-17 study item on “Study on support of reduced capability NR devices” as well as initial evaluation results in [29] were summarized in FL summary #1 (FLS1) in R1-2008471.

This document captures the following RAN1#103e RedCap email discussion.

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| [103-e-NR-RedCap-03] Email discussion for reduced PDCCH monitoring– Hong (Apple)   * 1st check point: 10/29 * 2nd check point: 11/4 * 3rd check point: 11/10 * Last check point 11/12 |

This summary was organized based on the structure of latest TR 38.875 [1] to document the evaluation results of reduced PDCCH monitoring provided in Phase-2 post-102-e-meeting email thread [102-e-Post-NR-RedCap-01] into section 2. In addition, section 3 intends to discuss potential conclusions for this study item based on the finding in section 2.

Follow the naming convention in this example:

* RedCapPDCCHFLS2-v000.docx
* RedCapPDCCHFLS2-v001-CompanyA.docx
* RedCapPDCCHFLS2-v002-CompanyA-CompanyB.docx
* RedCapPDCCHFLS2-v003-CompanyB-CompanyC.docx

This version of document contains updated proposal tagged FL9.

# 8.2 Reduced PDCCH monitoring

## 8.2.1 Description of feature

**[FL9]**Updated **Proposal 8.2.1-1: Capture the following feature description for Scheme #2 in the TR:**

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| **Scheme #2: Extending the PDCCH monitoring gap to X slots (X>1) in connected mode**  In Rel-15/16 NR, the range of PDCCH monitoring periodicity is configurable, which is in a range of a few symbol (s) to 2560 slots subject to UE capability. Scheme#2 is to extend the minimum separation between two consecutive slots with configured PDCCH candidates to be X slots, where X . |

**If not, what modification is needed?**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| ZTE,sanechips | Y | We are generally fine with the description. However, it is worth to point out that the current scheme2 is focused on extending the time separation between the PDCCH occasion, which actually can be realized by setting the searchspace periodicity. |
| vivo | Y |  |
| Spreadtrum | Y |  |
| Huawei, HiSilicon | Y |  |
| LG | Y | Same view with ZTE. |
| CATT | Y | We are OK with the proposal. We share the same view as ZTE, i.e. it can be realized by proper search space configuration. |
| NEC | Y | We support the FL proposal. |
| Fraunhofer | Y |  |
| Futurewei | Y |  |
| Intel | Y |  |
| Ericsson | Y, with modifications | As a general comment, we should capture the description of the scheme that has been studied in this study item, and not something that we may/may not consider in the future.  In our understanding, what has been studied is extending the minimum configurable gap, which was also the earlier proposal, which was fine with us. We do not think at this last minute we should change the description from “minimum separation between two consecutive slots with configured PDCCH candidates” to “minimum configurable gap (i.e. the minimum separation between two consecutive PDCCH monitoring occasions)”.  Therefore, we propose to revert the wording to the earlier version of this proposal. That is: “Scheme#2 is to extend the minimum separation between two consecutive ~~slots with configured~~ PDCCH monitoring occasions ~~candidates~~ to be X slots, where X>1”. |
| Qualcomm | Y |  |
| Samsung | Y with modification | We prefer previous wording.  In Rel-16, PDCCH monitoring occasion is configured per slot or per span. Previous wording covers both cases. We suggest to modify on top of previous wording.  In Rel-15/16 NR, the range of PDCCH monitoring periodicity is configurable, which is in a range of a few symbol (s) to 2560 slots subject to UE capability. Scheme#2 is to extend the minimum separation between two consecutive ~~slots~~ PDCCH monitoring occasions ( spans or slots with configured PDCCH candidates) to be X slots, where X. |
| Qualcomm2 | Y | Samsung’s comment that “PDCCH monitoring occasion is configured per slot or per span” is correct.  To address both Ericsson and Samsung’s comments, we think the following version complies with both current spec and include the PMO level separation. Similar changes can be made in the **[FL9]** **Proposal 8.2.5-1.**  In Rel-15/16 NR, the range of PDCCH monitoring periodicity is configurable, which is in a range of a few symbol (s) to 2560 slots subject to UE capability. Scheme#2 is to extend the minimum separation between two consecutive ~~slots~~ PDCCH monitoring occasions, spans or slots with configured PDCCH candidates to be X slots, where X. |

**[FL9] Proposal 8.2.1-2: Can the following sentence commented by one company in GTW session be added into Scheme #2?**

* **Using ‘M’ to denote Rel-15 BD limit per slot and ‘N’ to denote maximum number of BDs per X slot with Scheme #2, N<M\*X to achieve average BD reduction across X slots**

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| **Company** | **Y/N** | **Comments** |
| ZTE,sanechips | Y | We agree to add it back and 2 aspects are considered   1. Sparse the PDCCH monitoring is focused on extending the time separation between the PDCCH occasion as we mentioned. N<M\*X is focused on setting the maximum limit on multi-slots. They are different. Actually, reducing maximum number of BDs in X slots has been discussed and modified many times. Both of them can be used to reduce the averaged BDs per slot. We do not think reducing maximum number of BDs in X slots should be removed at this last moment. 2. Scheme 1 is used to describe the BD reduction per slot, scheme 3 is used to describe the dynamic BD reduction, and scheme 2 is used to describe the BD reduction on multiple slots. Scheme1 and scheme 3 are actually described broadly which does not limit to any specific method. Therefore, the description of scheme2 is just used to describe the research direction in general, instead of focusing on a specific method of extending the time separation, which is so limited. And any candidate solution discussed in scheme2 should not be precluded.   We hope both of them can be included in the SI stage to make a progress, avoiding precluding a good method to reduce the number of BDs in the SID, before we discuss that. |
| vivo | Y | We think it is needed to help illustrate scheme#2 more clearly. We are also fine to further discuss it in the WI phase. |
| Spreadtrum |  | We suggest “to achieve average BD reduction across X slots” to be changed to “to achieve maximum BD reduction per slot”. |
| Huawei, HiSilicon | N | By extending the minimum separation between two consecutive slots with configured PDCCH candidates to be X slots, where X, Scheme#2 can already reduce the PDCCH monitoring. It is not motivated to introduce new concept of multi-slot BD limit. |
| Intel | N |  |

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| CATT | N | Share similar views as HW.  It’s a new capability which is defined per X slots and the BD/CCE number for a slot goes up. It is against the subjective approved for the SI. Currently, the UE can only monitors M BDs per X slot assuming the PDCCH monitoring periodicity is X slot. However, the UE has to monitor X\*M BDs per X slot. It is against the following subjective:  Reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits |
| NEC | N | This may cause some PDCCHs received at the later part of X slot being missed detection because the maximum number of BDs has been used up. |
| Fraunhofer | Y | Same view as vivo. |
| Futurewei | N | Agree with CATT comment that it is not within scope. In addition, we do not see any reason to introduce *N* |
| Ericsson | N |  |
| Qualcomm | N | The reduced maximum BD number on average is already achieved by scheme #1 and current scheme #2 sparse PDCCH monitoring. No need to further define a new BD limit per X slots. |
| Samsung | N | We are not comfortable to add it. ‘N’ to denote maximum number of BDs per X slot with Scheme #2” is misleading. Companies have different understanding. We think it means maximum number of BDs within X slots by UE implementation. UE can relaxed BDs processing timeline to X slots. It doesn’t mean to define BD limits per X slots.  Also, it’s not necessary, as we commented before, if the purpose is to have more than one monitoring occasions, it can be achieved by scheme #1. |

### 8.2.3.2 Latency and Scheduling flexibility

**[FL9] Proposal 8.2.3.2-1: Which of the listed Option1 and Option can be captured into TR 38.875 for section 8.2.3 for scheduling flexibility impacts:**

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| **Option 1:** Scheduling flexibility impact by BD reduction depends on multiple factors at least including BW, Subcarrier Spacing (SCS), CORESET size, AL distribution, channel condition, number of Als per UE, number of UEs that need to be simultaneously scheduled.  **Option 2:** Reduction of BDs reduces scheduling flexibility when scheduling multiple UEs. The ~~Scheduling~~ impact ~~by BD reduction~~ depends on multiple factors at least including BW, Subcarrier Spacing (SCS), CORESET size, AL distribution, channel condition, number of Als per UE, number of UEs that need to be simultaneously scheduled. |

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| **Company** | **Comments** |
| ZTE,sanechips | Option 1. We have no strong view here.”the impact depends ...” seems not so clear, since which kind of impact may be missing. |
| vivo | *Option 1. The multiple factors as listed there are equally important.* |
| Spreadtrum | Option 1. |
| Huawei, HiSilicon | Option 1 is supported by us.  The first sentence in Option2 is not correct. There are observation agreed to see that there is no PDCCH blocking rate increase if DCI size budget is also reduced with the BD reduction. |
| MediaTek | Option 2 |
| NEC | Option 1 |
| Fraunhofer | Option 2 |
| Futurewei | Option 1 |
| Intel | Option 1  Did you intend to write “number of ALs per candidate”, not “number of ALs per UE”? |
| Ericsson | Option 2 (for Scheme #1)  To be more acceptable to other companies and to also capture the impacts of Scheme #1a (which is agreed to be captured as one of the alternatives in Friday’s GTW), we propose the following changes to Option 2:  **Option 2:** Reduction of BDs may reduce~~s~~ scheduling flexibility when scheduling multiple UEs. The ~~Scheduling~~ impact ~~by BD reduction~~ depends on multiple factors at least including BW, Subcarrier Spacing (SCS), CORESET size, AL distribution, channel condition, number of Als per UE, number of UEs that need to be simultaneously scheduled, extent of DCI size budget reduction, etc.  In our understanding, both Option 1 and Option 2 reflect the impacts of Scheme #1. For Scheme #2, for instance, there can be significant impact on the scheduling flexibility depending on the value of *X*. Therefore, we suggest the FL to clarify this in the proposal/agreement. |
| Qualcomm | Option 1 |
| Samsung | Option 1 |

**[FL9] Proposal 8.2.3.2-2: Capturing the following into TR 38.875 for latency impact:**

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| The latency impact due to BD reduction may largely depend on PDCCH blocking rate performance impact. If the PDCCH blocking rate is increased by BD reduction, the latency performance is expected to be increased; Otherwise, BD reduction has no impact on the latency. |

* **FL strongly stresses that please note that this is the last round of email discussion. Without consensus on this section may cause the incompletion of this study item.**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| ZTE,sanechips | Y |  |
| vivo | Y for sake of progress |  |
| Spreadtrum | Y |  |
|  |  |  |
| Huawei, HiSilicon | Y |  |
| LG | Y |  |
| CATT | Y |  |
| MediaTek | Y |  |
| NEC | Y |  |
| Fraunhofer | Y |  |
| Futurewei | Y |  |
| Intel | Y |  |
| Ericsson | Y (for scheme #1) | In our understanding this TP is only applicable to Scheme #1. For Scheme #2, for instance, there will be latency impact depending on the value of *X*. For scheme #3, in our understanding, the latency/scheduling flexibility study was performed. Therefore, we suggest the FL to clarify this in the proposal/agreement. |
| Qualcomm | Y |  |
| Samsung | Y |  |

## 8.2.5 Analysis of specification impacts

**[FL9]** **Proposal 8.2.5-1: Capturing the following into TR 38.875 for section 8.2.5**

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| * Depending on the considered techniques, for scheme with reducing maximum number of PDCCH candidates, specification impact may include reducing the limit on maximum number of PDCCH candidates, reducing the DCI size budget, modification to DCI size alignment rule and DCI format design, to minimize the PDCCH blocking rate impact. * For Extending the PDCCH monitoring gap to X slots (X), the minimum separation between two consecutive PDCCH monitoring occasion is increased from 1 slot to X>1 slots and X needs to be specified. * For dynamic adaptation of PDCCH BD parameters in connected mode, specification impacts may include mechanisms used to dynamically adapt PDCCH BD parameters e.g., maximum number of BDs per PDCCH monitoring occasion and minimum time separation between two consecutive PDCCH monitoring occasions. * Additional specification impacts may include reducing DCI size budget, DCI format design for multiple PDSCHs scheduling, modification to PDCCH candidates dropping rule, to minimize the PDCCH blocking rate impact and avoid network restriction. |

**If not, what modification is needed to add it into TR?**

* **FL strongly stresses that please note that this is the last round of email discussion. Without consensus on this section may cause the incompletion of this study item.**

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| **Company** | **Y/N** | **Comments** |
| ZTE,sanechips | Y | A modification may be needed for the second paragraph if Proposal 8.2.1-2 is agreed. |
| vivo | Y |  |
| Spreadtrum | Y |  |
| Huawei, HiSilicon | Y |  |
| CATT | Y |  |
| MediaTek | Y |  |
| NEC | Y |  |
| Fraunhofer | Y |  |
| Futurewei | Y |  |
| intel | Y with minor change | * Depending on the considered techniques, for scheme with reducing maximum number of PDCCH candidates, specification impact may include reducing the limit on maximum number of PDCCH candidates, reducing the DCI size budget, modification to DCI size alignment rule and/or DCI format design, to minimize the PDCCH blocking rate impact.   Without ‘or’ , it may seem all of these impacts are jointly possible. |
| Ericsson | N | As a 5th bullet, the following should be added:  “If BD reduction/extension of the PDCCH monitoring gap is achieved using existing Rel-15/16 configurations without any specified restriction for RedCap, specification changes are not required.”  With this added bullet, we are fine with the text proposal, otherwise we cannot accept the proposal.  In the 4th bullet, we suggest a minor update:  - Additional specification impacts may include reducing DCI size budget, DCI format design for multiple PDSCHs scheduling, modification to PDCCH candidates dropping rule, to minimize the PDCCH blocking rate impact and ~~avoid~~ network restriction. |
| Qualcomm | Y with minor modification | Minor updates are made to align with scheme #1 per slot BD limit and scheme #2 wording   * For Extending the PDCCH monitoring gap to X slots (X), the minimum separation between two consecutive slots with configured PDCCH candidates ~~PDCCH monitoring occasion~~ is increased ~~from 1 slot~~ to X>1 slots and X needs to be specified. * For dynamic adaptation of PDCCH BD parameters in connected mode, specification impacts may include mechanisms used to dynamically adapt PDCCH BD parameters e.g., maximum number of BDs per slot ~~PDCCH monitoring occasion~~ and minimum time separation between two consecutive slots with configured PDCCH candidates ~~PDCCH monitoring occasions~~. |
| Samsung | Y with minor change | In the first paragraph, the part about minimizing PDCCH blocking rate starting from reducing DCI size budget is redundant with the last paragraph, thus can be deleted.  The impact on minimizing PDCCH blocking probability is common to all candidate schemes.  Depending on the considered techniques, for scheme with reducing maximum number of PDCCH candidates, specification impact may include reducing the limit on maximum number of PDCCH candidates. ~~reducing the DCI size budget, modification to DCI size alignment rule and DCI format design, to minimize the PDCCH blocking rate impact.~~ |
| Qualcomm2 | Update | Similar to **[FL9]**Updated **Proposal 8.2.1-1:,** the 2nd and 3rd bullets can be updated   * For Extending the PDCCH monitoring gap to X slots (X), the minimum separation between two consecutive PDCCH monitoring occasions, spans or slots configured with PDCCH candidates is increased from 1 slot to X>1 slots and X needs to be specified. * For dynamic adaptation of PDCCH BD parameters in connected mode, specification impacts may include mechanisms used to dynamically adapt PDCCH BD parameters e.g., maximum number of BDs per PDCCH monitoring occasion, span or slot and minimum time separation between two consecutive PDCCH monitoring occasions, spans or slots configured with PDCCH candidates. |

# 12. Conclusion

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| The PDCCH monitoring reduction for RedCap UEs has been studied. The study includes the evaluation of power saving benefit, system performance impacts, coexistence impacts, potential schemes and the corresponding specification impacts.  The power saving benefit by PDCCH monitoring reduction for RedCap UEs has been evaluated based on the agreed power model and traffic model, with the results and observations captured in section 8.2.2.  The system performance impact has been evaluated using PDCCH blocking rate as the metric, with the results and observations captured in section 8.2.3. In addition, scheduling flexibility and latency impacts have also been studied in Section 8.2.3.  Three candidate schemes for PDCCH monitoring reduction have been identified and studied with the corresponding coexistence and specification impacts captured in sections 8.2.4 and section 8.2.5, respectively.  Based on the study, it is recommended by RAN1 to specify PDCCH monitoring reduction scheme(s) with minimized PDCCH blocking rate in Rel-17 to avoid the network scheduling impact. |

**[FL9] Q 12-1: Which of the paragraphs above can be captured into TR 38.875 clause 12 for conclusion?**

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| --- | --- |
| **Company** | **Comments** |
| ZTE,sanechips | All the above paragraphs can be captured into the TR. |
| vivo | *All* |
| Spreadtrum | All |
| Huawei, HiSilicon | We would like to add the following revisions for the third paragraph and last paragraph to capture operators’ concern.  The third paragraph:  The system performance impact has been evaluated using PDCCH blocking rate as the metric, with the results and observations captured in section 8.2.3. In addition, scheduling flexibility and latency impacts have also been studied in Section 8.2.3. In section 8.2.3, It can be observed that some of the candidate solutions can provide 50% maximum PDCCH candidates reduction with 0% increment of PDCCH blocking rate.  The last paragraph:  Based on the study, it is recommended by RAN1 to specify PDCCH monitoring reduction scheme(s) with ~~minimized~~ targets for zero increment of PDCCH blocking rate in Rel-17 to avoid the network scheduling impact. |
| LG | Firstly, the recommendation in the conclusion is too broad or abstract in this conclusion. We need to be more specific about what is recommended or not recommended.  From our perspective, the power saving gain less than 10% is not enough to recommend for RedCap WI, especially considering the small net gain over what we can achieve with the existing techniques and configurations to reduce the power consumption, and also considering the impact on the PDCCH blocking rate which is also not small.  We also think Scheme #2 and Scheme #3 are out of scope of this SI which are not relevant for recommendation in conclusion. Scheme #1 can be considered but the additional gain that can be achieved with Scheme#1 over what can already be achieved by existing Rel-15/16 network configuration is not clear.  Some companies mentioned that the power saving gain is very important in use cases such as wearables. But if you think about the LTE IoT, the extended (e.g., years of) battery life can only be achieved by the techniques such as extended DRX which has already been started in RAN2.  For those reasons above, from our perspective, it is hard to recommend to specify any of the new schemes from the RedCap SI in RAN1. Therefore we prefer to remove the last sentence. |
| CATT | All |
| MediaTek | Not the last sentence (i.e. recommendation of the schemes)  The power saving by BDs limit reduction can already be achieved using existing R15/16 configurations (e.g., PDCCH candidates and DCI sizes to monitor) without an impact to the system performance.  Also, with the existing mechanisms in R15/16 that can be used for power saving (e.g. cross-slot scheduling, larger PDCCH monitoring periodicity) the impact of the configured (or supported) PDCCH candidates on the power consumption is marginal (~1.6% for 30KHz as we shown in our results in R1-2008511). |
| NEC | All |
| Fraunhofer | All |
| Futurewei | The conclusion as proposed is too vague. We agree with changes proposed by Huawei.  For the last paragraph, in addition: schemes 2 and 3 are not within scope, thus need to be excluded. Thus, we propose to modify as follows:  Based on the study, it is recommended by RAN1 to specify PDCCH monitoring reduction scheme(s) based on scheme 1 with ~~minimized~~ targets for zero increment of PDCCH blocking rate in Rel-17 to avoid the network scheduling impact.  Note: generally speaking, the power saving gains of blind decoding reductions are low. We would thus also be okay with the last paragraph stating that “*there is no consensus to recommend by RAN1 to specify PDCCH monitoring reduction scheme(s) with minimized PDCCH blocking rate in Rel-17”* |
| Intel | All. It would be great if we state the recommendation to be more inline with the description of the WID to make it more clear.  Based on the study, it is recommended by RAN1 to specify PDCCH monitoring reduction scheme(s) to obtain smaller BD numbers, ensuring minimum system impact such as blocking rate increase is not significant. ~~with minimized PDCCH blocking rate in Rel-17 to avoid the network scheduling impact~~.  WID description:  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]. |
| Ericsson | 1st paragraph: OK  2nd paragraph: OK  3rd paragraph: partially OK (In our understanding, the scheduling flexibility impacts have only been captured for Scheme #1. This fact should be reflected. So, we suggest to simply add “for Scheme 1” in the end of this paragraph.  4th paragraph: OK (as a compromise)  5th paragraph: NOT OK. We have already provided detailed reasons in our earlier response on why PDCCH monitoring reduction should not be recommended. Therefore, we suggest to simply remove the last paragraph, or update it as follows: ~~Based on the study, it is recommended by RAN1 to specify PDCCH monitoring reduction scheme(s) with minimized PDCCH blocking rate in Rel-17 to avoid the network scheduling impact.~~ There is no consensus in RAN1 to recommend specifying reduced PDCCH monitoring reduction scheme(s) in Rel-17.  We do not see a need to include the blocking probability results from one source company in the conclusion section. This doesn’t represent a full picture and risks being misleading. |
| Qualcomm | All |
| Samsung | All. |