
Agenda item: 7.1.3.1

Source: LG Electronics

Title: Remaining issues on downlink control channel

Document for: Discussion and decision

1. Introduction

In this contribution, we discuss some issues related to PDCCH structure, search space, and GC-PDCCH. Section 2.1 ~ 2.x are related to PDCCH structure and search space, and Section 2.x is related to GC-PDCCH.

2. Discussions

2.1. TCI state for SSB/CORESET#0/SS#0

In last meeting, followings were concluded for TCI state for SSB/CORESET#0/SS#0;

Conclusion:

- No new RRC signaling for TCI-state configuration for the CORESET#0 is introduced.
- No new MAC-CE for TCI-state indication for the CORESET#0 is introduced.
- FFS: Whether the existing RRC configuration and/or existing MAC-CE field can be used to configure/indicate dedicated TCI-state or SSB index for the CORESET#0
- FFS: Whether/how to support BFR for the CORESET#0

Regarding the CORESET#0, CFRA/CBRA based TCI-state update is still problematic in terms of its latency and complicated procedure. Moreover, since maximum number of CORESETs in a BWP is 3, the number of available CORESETs is just 2 if CORESET#0 is outdated. So, our suggestion is that a gNB can configure dedicated TCI-state for the CORESET#0 using existing RRC signaling as follows;

To minimize spec impact, a gNB can utilize configured TCI states and CFRA/CBRA procedure for TCI update of CORESET#0. For example, TCI state of CORESET #0 can be updated based on lowest indexed TCI state (which can be called by default TCI state) in a TCI pool (configured for PDSCH) and CFRA/CBRA procedure whichever is the most recent. As the TCI state in the TCI pool can be reconfigured by existing RRC signaling, flexibility of TCI state configuration for CORESET#0 can be guaranteed and there is no impact to RRC signaling, the number of CORESETs and TCI pool configuration. So, we propose the TCI state of CORESET#0 is the most recent one between default TCI state and SSB selected as part of CBRA or CFRA. In addition, at least for CORESET#0/SS set#0, the default TCI state can be restricted to SSB, i.e., lowest index TCI state among TCI states in TCI pool is associated with SSB index.

Proposal 1: The TCI state of CORESET#0/SS set#0 is the most recent one between default TCI state and SSB selected as part of CBRA or CFRA.

Proposal 2: The default TCI state is determined by lowest indexed TCI state in the TCI pool. The default TCI state for CORESET#0/SS set#0 is only an SSB.

2.2. QCL assumption between overlapped CORESETs in time domain

According to previous agreements, each CORESET can have own spatial QCL (i.e., TCI state), and different CORESETs can be overlapped on time and/or frequency domain. It means that CORESETs with different QCL assumptions can be overlapped on a same symbol. Because a UE determines an Rx beam used for monitoring each CORESET by considering TCI state of each CORESET, if multiple CORESETs with different QCL assumptions overlaps on time domain resources (e.g., OFDM symbol), a UE should support

multiple Rx beams or select one Rx beam (or TCI state) by a certain selection rule.

In last meeting, this issue was treated in offline discussion, and the offline proposal is as follows;

Offline proposal:

- For a UE monitors multiple search spaces associated with different CORESETs,
 - if the monitoring occasions of the search spaces are overlapped in time [or are separated less than Threshold-Sched-Offset in time], the UE may assume that the DM-RS of PDCCHs in the search spaces are quasi co-located with the RS(s) in the TCI state with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the lowest CORESET-ID among the CORESETs associated with the search spaces.

Regarding the square bracket, the Threshold-Sched-Offset is related to UE's PDCCH decoding capability, and it determines spatial QCL assumption for corresponding PDSCH buffering. In our understanding, it does not affect PDCCH monitoring on another CORESET. So, we propose to remove the sentence included in the bracket.

Proposal 3: For a UE monitors multiple search spaces associated with different CORESETs, if the monitoring occasions of the search spaces are overlapped in time, the UE may assume that the DM-RS of PDCCHs in the search spaces are quasi co-located with the RS(s) in the TCI state with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the lowest CORESET-ID among the CORESETs associated with the search spaces.

2.3. BFR CORESET/SS set

In last meeting, following agreement was made in MIMO session;

Agreement

Concerning the questions in RAN2 LS (R1-1808166) on BFR

Question 1: After UE sending PRACH for contention-free BFR, does the UE continue monitoring PDCCH candidates in configured search spaces monitored before PRACH, in addition to the search space indicated by recoverySearchSpaceId?

- RAN1 response: Yes, all configured search spaces before dedicated BFR PRACH transmission for BFR are monitored

Question 2: If the answer to Question 1 is "Yes", is the BFR RACH procedure considered successfully completed only if PDCCH is received in search space indicated by recoverySearchSpaceId?

- RAN1 response: Yes, only when a PDCCH transmission addressed to C-RNTI is received on the search space indicated by higher layer parameter recoverySearchSpaceId, i.e., SS-BFR, UE considers a contention-free BFR procedure is successfully terminated

It means that a UE is assumed to continue monitoring on all configured search space sets before dedicated BFR PRACH transmission for BFR. From the control channel monitoring perspective, there are two issues on BFR procedure; 1) overlap between BFR CORESET and other CORESET with different TCI state, 2) PDCCH mapping rule on slots including monitoring occasion for BFR CORESET.

Regarding the first issue, during BFR procedure, the UE may monitor CORESETs with outdated TCI state. When BFR-CORESET and other CORESET(s) are monitored on the same time resource with potentially different QCL/TCI information (and thus potentially lead different Rx beam), some handling is necessary. A simple solution is that a UE can skip monitoring old CORESET, if BFR CORESET overlaps with old CORESET in time domain. This is to prioritize BFR-CORESET in case of collision.

Another issue is whether to count CCEs/BDs for BFR-SS under CCE/BD limit. If it is not accounted, it may be that the total number of required CCEs/BDs can be much higher than what UE can support in a slot. We propose to count CCEs/BDs of BFR-SS as well when monitored. If this is assumed, some clarification is necessary. According to previous agreement, CSS has a higher priority compared to USS for PDCCH mapping, and it is assumed that the number of BDs/CCEs for CSSs doesn't exceed each limit. But, in a slot configured to monitor BFR CORESET, the number of BDs/CCEs for BFR CORESET should be considered to PDCCH mapping rule. In order to solve this problem, BFR CORESET/SS set should have highest priority (regardless of SS type) on PDCCH mapping rule, and existing PDCCH mapping rule can be applied to other

SS sets. If this is applied, unless it is ensured that the sum of CCEs of CSS and BFR-SS does not exceed UE's limit, CSS(s) may need to be dropped when BFR-SS is monitored. Not to incur too much configuration flexibility, we propose to drop CSS(s) based on SS set index when BFR-SS is monitored.

Proposal 4: If BFR CORESET overlaps with other CORESET(s) in time domain, a UE is not required to monitor PDCCH candidates in other CORESET(s) at least in case QCL information is different between BFR-CORESET and other CORESET(s).

Proposal 5: The BFR CORESET/SS set has highest priority (regardless of SS type) for PDCCH candidate mapping rule when monitored. CSS(s) associated with other CORESET(s) may be dropped based on SS set index when BFR SS is monitored.

2.4. TCI assumption for PDSCH

In TS38.214 (Section 5.1.5), assumption of TCI state for PDSCH reception is defined as follows;

For both the cases when *tci-PresentInDCI* is set to 'enabled' and *tci-PresentInDCI* is not configured, if the offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold *Threshold-Sched-Offset*, the UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the RS(s) in the TCI state with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the lowest *CORESET-ID* in the latest slot in which one or more CORESETs within the active BWP of the serving cell are configured for the UE. If none of configured TCI states contains 'QCL-TypesD', the UE shall obtain the other QCL assumptions from the indicated TCI states for its scheduled PDSCH irrespective of the time offset between the reception of the DL DCI and the corresponding PDSCH.

According to the description, if the parameter of "*Threshold-Sched-Offset*" is larger than 1 slot, TCI state of PDSCH scheduled by self-slot scheduling is determined by TCI state of CORESET in previous slot. In our view, it is undesirable operation, because CORESETs monitored in different slots can have different TCI states. For example, if a UE monitor USS with a certain TCI state based on CSI-RS in slot #n and CSS with a certain TCI state based on SSB in slot #(n+1), the UE assume TCI state of PDSCH in slot #(n+1) scheduled by CSS in slot #(n+1) is based on CSI-RS. If multiple UEs monitor same PDCCH, each UE has different understanding for TCI state of the PDSCH. In addition, TCI assumption described in current spec is not suitable to low latency service such as URLLC. Therefore, we propose that a UE assume TCI state of PDSCH (when the offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold) follows a TCI state of most recent monitored CORESET. If multiple CORESETs are overlapped on same time domain resource, a UE can select a CORESET for determining TCI state of PDSCH by a rule, e.g., CORESET with lowest index, CORESET associated with a SS set with lowest index.

Proposal 6: For both the cases when *tci-PresentInDCI* is set to 'enabled' and *tci-PresentInDCI* is not configured, if the offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold *Threshold-Sched-Offset*, the UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the RS(s) in the TCI state with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the lowest *CORESET-ID* in the latest monitoring occasion in which one or more CORESETs within the active BWP of the serving cell are configured for the UE.

2.5. The BD/CCE limit for CA case

In our understanding, there are two principles for PDCCH mapping of CA case regardless of scheduling type (i.e., self-scheduling or cross-carrier scheduling); 1) for PCell, non-CA limits for BD/CCE is applied and overbooking is allowed, 2) for SCell, NW ensures non overbooking, so a UE doesn't need to count BDs/CCEs. Actually, in last meeting, it was concluded that at least for self-scheduling and for cross-carrier scheduling with the same numerology for all the DL serving cells, total number of CCEs or BDs corresponding to the remaining PDCCH candidates after PDCCH candidates are dropped based on the non-CA limit for the PCell (PSCell) and the configured PDCCH candidates for SCells is guaranteed by network to be no more than the CA limit. According to the conclusion, self-scheduling with different numerologies is still FFS.

In the case of self-scheduling with different numerologies, according to previous agreements, the limit of BD/CCE is defined for each numerology. In this case, if there are SCells which is configured to same numerology with PCell, it is ambiguous how to determine the BD/CCE limit of PCell in order to apply PDCCH mapping rule. Following options can be considered to determine the limit of PCell;

Option 1) The limit of non-CA case

For a PCell, in order to allow more scheduling flexibility compared to SCells, a non-CA limit can be applied. In this option, the BD/CCE limit of PCell can be fixed as a non-CA limit and the total BD and CCE to SCell(s) with numerology i is determined by $\text{Floor}\{(X_i/(X_0+X_1+X_2+X_3))*(M_i \text{ or } N_i)^*(y-1)\}$. (In this formula, PCell is not included in X_i , X_0 , X_1 , X_2 , and X_3 .) This option is simple and consistent for scheduling and PDCCH mapping of PCell.

Option 2) The limit based on agreed formula

In this option, it can be assumed that the limit of PCell is determined by “ $\text{limit}_{\text{PCell}} / X_{\text{PCell}}$ ” assuming BD/channel estimation budgets are evenly distributed across cells with the same numerology i . (where $\text{limit}_{\text{PCell}}$ means the limit of the numerology including PCell, X_{PCell} means the number of DL-CCs with the numerology including PCell.) Then, for SCells using the numerology, the limit is given by “ $\text{limit}_{\text{PCell}} - \text{limit}_{\text{PCell}} / X_{\text{PCell}}$ ”.

In order to achieve scheduling flexibility of PCell, option 1 is preferable. In addition, the number of BDs/channel estimations configured to SCell with a numerology i may not be evenly distributed across SCells. It's up to the network to ensure the total does not exceed the maximum and for each carrier, non-CA limit applies. As long as both conditions are met, any number of BDs/channel estimation to a cell is supported.

Proposal 7: The BD/CCE limit for a PCell is always same with non-CA limit of corresponding numerology.

Proposal 8: The total number of BD/CCE to SCell(s) with numerology i is determined by $\text{Floor}\{(X_i/(X_0+X_1+X_2+X_3))*(M_i \text{ or } N_i)^*(y-1)\}$. (where X_j means the number of SCells with numerology j)

3. Conclusion

In this contribution, followings are proposed

Proposal 1: The TCI state of CORESET#0/SS set#0 is the most recent one between default TCI state and SSB selected as part of CBRA or CFRA.

Proposal 2: The default TCI state is determined by lowest indexed TCI state in the TCI pool. The default TCI state for CORESET#0/SS set#0 is only an SSB.

Proposal 3: For a UE monitors multiple search spaces associated with different CORESETs, if the monitoring occasions of the search spaces are overlapped in time, the UE may assume that the DM-RS of PDCCHs in the search spaces are quasi co-located with the RS(s) in the TCI state with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the lowest CORESET-ID among the CORESETs associated with the search spaces.

Proposal 4: If BFR CORESET overlaps with other CORESET(s) in time domain, a UE is not required to monitor PDCCH candidates in other CORESET(s) at least in case QCL information is different between BFR-CORESET and other CORESET(s).

Proposal 5: The BFR CORESET/SS set has highest priority (regardless of SS type) for PDCCH candidate mapping rule when monitored. CSS(s) associated with other CORESET(s) may be dropped based on SS set index when BFR SS is monitored.

Proposal 6: For both the cases when tci-PresentInDCI is set to 'enabled' and tci-PresentInDCI is not configured, if the offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold Threshold-Sched-Offset, the UE may assume that the DM-RS ports of PDSCH of a serving cell are quasi co-located with the RS(s) in the TCI state with respect to the QCL parameter(s) used for PDCCH quasi co-location indication of the lowest CORESET-ID in the latest monitoring

occasion in which one or more CORESETs within the active BWP of the serving cell are configured for the UE.

Proposal 7: The BD/CCE limit for a PCell is always same with non-CA limit of corresponding numerology.

Proposal 8: The total number of BD/CCE to SCell(s) with numerology i is determined by $\text{Floor}\{(X_i/(X_0+X_1+X_2+X_3)) \cdot (M_i \text{ or } N_i)^{(y-1)}\}$. (where X_j means the number of SCells with numerology j)