3GPP TSG RAN WG1 NR Ad-Hoc#2 **R1-1710078**
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Title: Discussion on multi-beam operation for NR-PDCCH

Document for: Discussion and Decision

1. Introduction

Multi-beam operation is a fundamental feature of the NR system design touching all building blocks from initial access channels and signals, to control and data channels. For DL control signaling design, it was agreed that a UE may be configured to monitor the NR-PDCCH on multiple DL beams. Further agreements were achieved at RAN1 #89 on NR-PDCCH design for multi-beam operation [1]:

Agreements:

- Configuration of QCL for UE specific NR-PDCCH is by RRC and MAC-CE signalling
  - Note that MAC-CE is not always needed
  - FFS: necessity of DCI signalling
  - Note: For example, DL RS QCLed with DMRS of PDCCH for delay spread, Doppler spread, Doppler shift, and average delay parameters, spatial parameters
- To receive gNB response for beam failure recovery request, a UE monitors NR PDCCH with the assumption that the corresponding PDCCH DM-RS is spatial QCL'ed with RS of the UE-identified candidate beam(s)
  - FFS whether the candidate beam(s) is identified from a preconfigured set or not
  - Detection of a gNB's response for beam failure recovery request during a time window is supported
    - FFS the time window is configured or pre-determined
    - FFS the number of monitoring occasions within the time window
    - FFS the size/location of the time window
    - If there is no response detected within the window, the UE may perform re-tx of the request
      - FFS details
  - If not detected after a certain number of transmission(s), UE notifies higher layer entities
    - FFS the number of transmission(s) or possibly further in combination with or solely determined by a timer

This contribution discusses configuration and operational aspects of the NR-PDCCH that are specific to multi-beam deployments. General configuration aspects including search space monitoring are treated in a companion contribution [2].

2. Discussion

2.1 Multi-beam operation for the common NR-PDCCH

During the initial cell search procedure, an idle UE acquires a preferred DL TX beam in a given SS block of a suitable cell. The SS blocks in the given cell may be beam swept across time as shown in Figure 1. The UE acquires the PSS/SSS in a given SS block and reads the MIB associated with the same SS block. The MIB transmitted in the PBCH indicates the location of a first common CORESET that would be used to schedule remaining system information (RMSI). The search space defining potential NR-PDCCH candidates for scheduling this RMSI is common to all UEs that acquired the same SS block. For convenience we shall call this first common CORESET an Idle Mode CORESET. The Idle Mode CORESET configuration contained in the MIB should be sufficient for a UE to monitor a common search space for a NR-PDCCH scheduling RMSI.

For a UE-specific CORESET, the associated parameters can be semi-statically configured by RRC signaling. However, in Idle Mode, the UE is not known to the network. Secondly, in terms of the antenna port QCL relationship, the UE may only have measurements of the acquired or selected SS block signals. Thus, the Idle Mode CORESET may be transmitted on the same DL TX beam as the SS block selected during initial cell search.

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Proposal 1: A UE may assume that the DMRS antenna ports for the NR-PDCCH scheduling RMSI are quasi co-located with the PSS/SSS and/or the PBCH DMRS antenna ports.

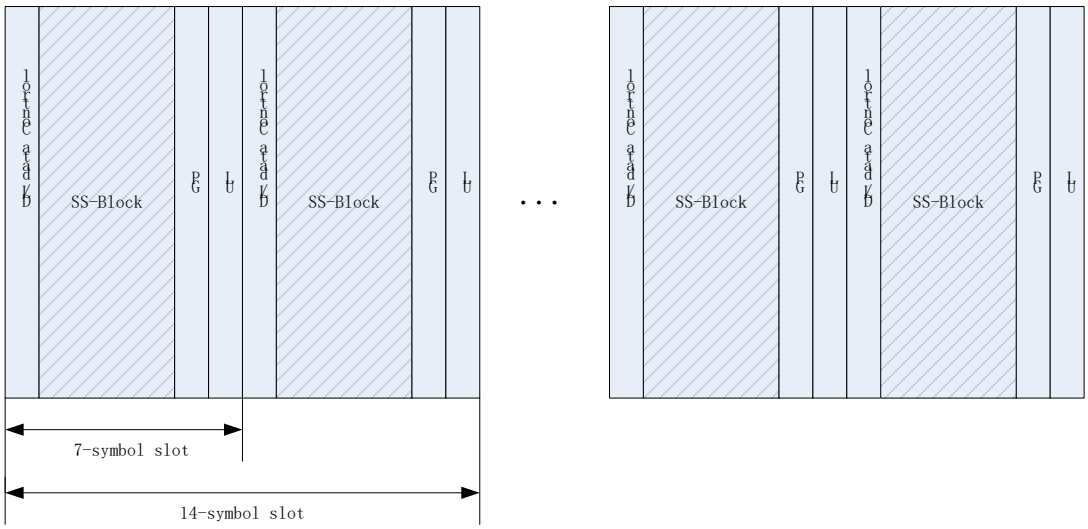


Figure1: Example for SS-block transmission

To reduce resource allocation while guaranteeing sufficient reliability only essential system information is contained in the MIB transmitted on the NR-PBCH. Consequently, the, the Idle Mode CORESET configuration information carried in the MIB should be as small as possible. This can be accomplished by defining some configuration parameters in the specifications and/or implicitly signaling some parameters.

One possible solution is the idle mode CORESET associated with an SS block is always transmitted within the same duration of the SS block in the SS burst set period. The monitoring occasion is exactly same as the SS block. For analog beam sweeping, the CORESET is transmitted on the same beam where the associated SS block is transmitted and no additional OFDM symbols are needed in order to transmit this CORESET. In addition, this can reduce the configuration information needed in the MIB. For example, the time and frequency resources are fixed in the specification as an offset to the SS block. The other parameters such as the number of search space candidates, the CCE-to-REG and PDCCH-to-CCE mapping schemes can be fixed in the specification. The DMRS configuration including number of antenna ports can be fixed in the specification, whereas the monitoring occasions are by definition according to the beam sweeping cycle. An illustration is shown in Figure 2 for a 14-symbol slot where two SS blocks are transmitted each consisting of PSS, SSS and two PBCH symbols. In addition, the last two symbols are reserved for a guard period and UL respectively.

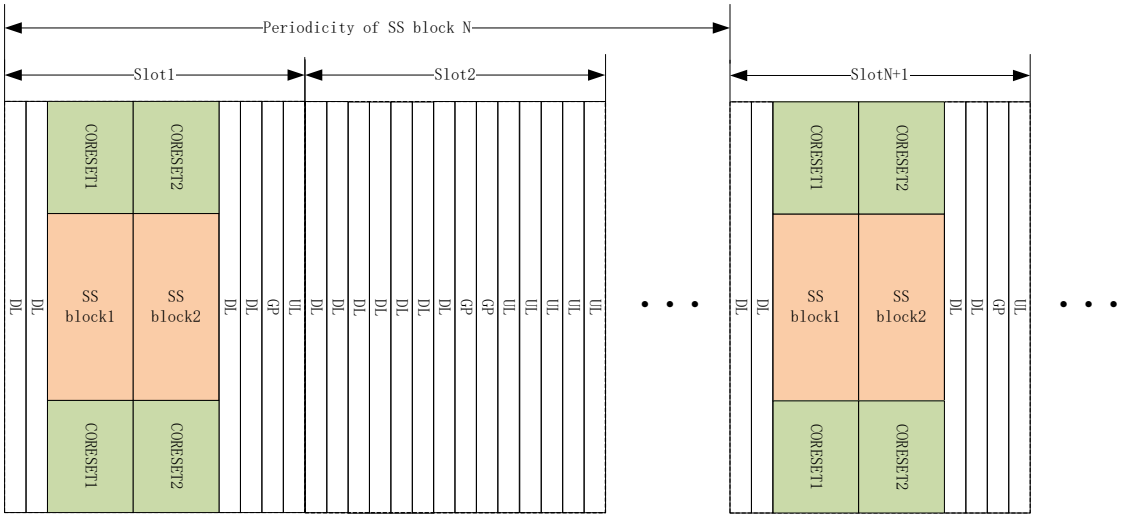


Figure2: First CORESET linked to SS-block

One possible drawback is that the UE may only monitor for NR-PDCCH scheduling RMSI according to the beam sweeping duty cycle, i.e. the SS burst set duty cycle. Another limitation that can be observed in Figure 2is that the

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system bandwidth must support mapping of the Idle Mode CORESET outside the SS block bandwidth, which is not applicable for a small system bandwidth of e.g. 5MHz.

To reduce the latency when monitoring for PDCCH scheduling the RMSI, it may be possible to transmit the Idle Mode CORESET associated with an SS block with a digital beam. In this case, the location of the Idle Mode CORESET is not tightly linked to the location of the SS block. For example, it can be located in the first one or more symbols of a slot even though the SS block is located elsewhere in the same slot or even in another slot. Also, multiple monitoring occasions could be configured within the period of the SS burst set duty cycle. An illustration is shown in Figure 3 for a 14 symbol slot, where it can be seen that two SS blocks are transmitted in this slot and each associated CORESET is mapped to the beginning of the slot. In order to reduce the MIB overhead, time and frequency allocation can be indicated by a field in the MIB pointing to an index in a table of candidate locations. Preferably, the table could indicate the necessary configuration parameters jointly. This second solution allows more flexibility for the network because in some cases the DL beams may simply be different digital beams and thus, the Idle mode CORESETs associated with the transmitted SS blocks in an SS burst set can be transmitted with different digital beams in the same set of OFDM symbols as shown in Figure 3(b). It is also up to the gNB implementation whether to use analog beams in other symbols and map the different Idle Mode CORESETs to different symbols as shown in Figure 3(a).

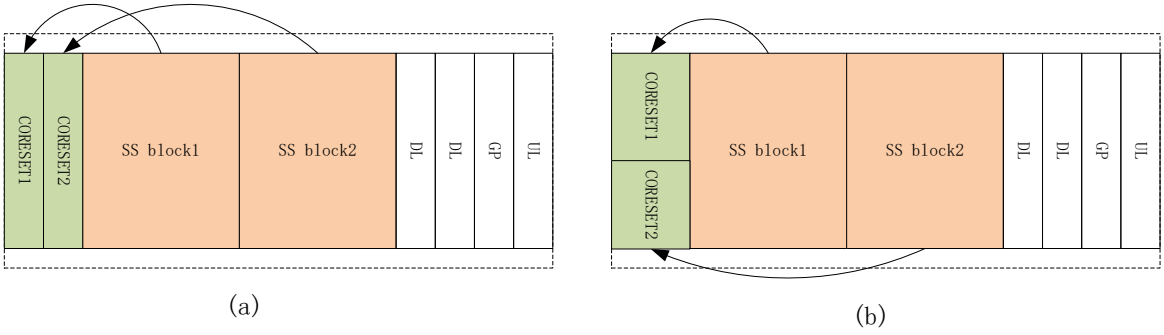


Figure3: First CORESET configured by MIB

Note that this is a more general case of the first option, wherein the time/frequency location of the first CORESET is not confined to the same OFDM symbols as the SS-block. When the CORESET is located at the beginning of a slot as shown in Figure 3, multiple CORESETS can be configured, each corresponding to a SS block. Different initial CORESETS are allowed to overlap and it is up to the gNB/TRP to determine which NR-PDCCH is actually transmitted in the overlapping region. From the UE's perspective it is only aware of one group-common CORESET and the UE attempts to decode its NR-PDCCH assuming it is on the same TX beam as its SS-block.

Proposal 2: the time-frequency location of a first CORESET used for scheduling at least remaining system information can be indicated as an offset with respect to the NR-PBCH in an acquired SS block.

On top of the above first CORESET linked to an SS block, a second common CORESET in Idle Mode could also be considered. The second common CORESET is to allow a different set of configuration parameters and/or monitoring occasions for this CORESET compared to the (first) Idle Mode CORESET. Different methods could be considered to configure the second common CORESET, e.g. RMSI, RA Msg2 or RA Msg4. Digital beamforming is used to transmit PDCCH candidates in this second CORESET. Alternatively, note that this digital beamforming could be based on hybrid beamforming and the beam could be the same as that used for analog beam sweeping. One advantage is that the UE does not have to wait for a long time to receive dedicated RRC signaling due to the SS burst set cycle. Moreover, this second CORESET is still group-common since it is linked to the set of PRACH resources associated with an SS block. As mentioned previously, the gNB may transmit a second common CORESET using a DL TX beam that is quasi co-located with the SS block during the non-beam sweeping time of a slot.

Proposal 3: A second common CORESET could be considered in order to obtain more flexibility.

2.2 Multi-beam operation for the UE-specific NR-PDCCH

It was agreed that a UE may monitor the NR-PDCCH on multiple beams. This may be accomplished by configuring beam-specific CORESETs as shown in Figure 4(a). The CORESETs may also be mapped on different OFDM symbols in case of analog beams. The CORESET configuration contains a QCL parameter associating the DMRS antenna ports with a beam management RS. Alternatively, multiple beams may be used for search space candidates associated with a

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single CORESET. In this case multiple QCL parameters are needed to associate different subsets of NR-PDCCH candidates with different beam management RS configurations. An illustration is shown in Figure 4(b).

The set of monitoring occasions can be configured independently for each DL beam. This allows the gNB to manage the average number of blind decodes in a slot when a UE is configured to monitor the NR-PDCCH on multiple DL beams.

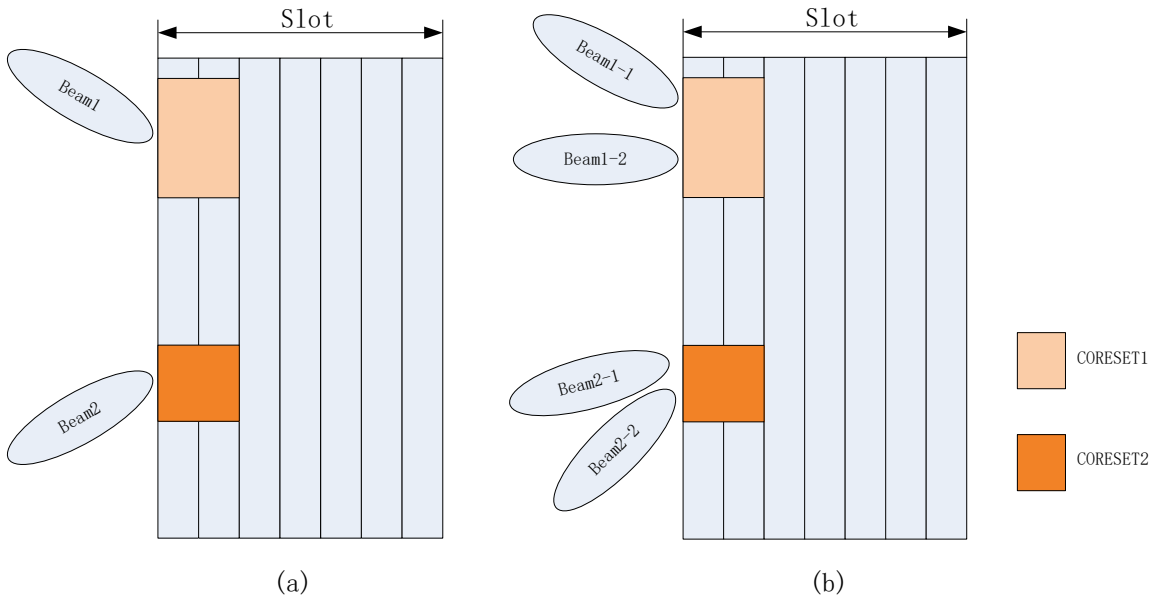


Figure4: Beam operation for UE-specific NR-PDCCH

Proposal 4: A UE may be configured with one or more QCL parameters for a CORESET. The monitoring occasions for search space candidates associated with different QCL parameters can be configured independently.

3. Conclusion

In this contribution, we discuss the multi-beam operation for NR-PDCCH. The following proposals could be achieved:

- **Proposal 1:** A UE may assume that the DMRS antenna ports for the NR-PDCCH scheduling RMSI are quasi co-located with the PSS/SSS and/or the PBCH DMRS antenna ports.
- **Proposal 2:** The time-frequency location of a first CORESET used for scheduling at least remaining system information can be indicated as an offset with respect to the NR-PBCH in an acquired SS block.
- **Proposal 3:** A second common CORESET could be considered in order to obtain more flexibility.
- **Proposal 4:** A UE may be configured with one or more QCL parameters for a CORESET. The monitoring occasions for search space candidates associated with different QCL parameters can be configured independently.

4. Reference

[1]. RAN1#89 Chairman's meeting notes, 19th – 24th May 2017
[2]. R1-17010076, "Configuration aspects of the NR-PDCCH", CATT, RAN1 #NR_AH2, 27th – 30th June, 2017