3GPP TSG RAN WG1 Meeting #97 **R1-1907354**

Reno, Nevada, US, 13th – 17th, May, 2019

Agenda Item:7.2.6.1

Source: **TCL Communication**

Title: **Ambiguity between PDCCH AL 8 and AL 16**

Document for: Discussion and decision

1. Introduction

In Rel-15 [1], an ambiguity at the UE side is identified between the PDCCH transmission with AL 8 and AL 16 from the gNB, and this problem is resolved by the following agreement:

- *If a UE monitors PDCCH candidates of aggregation levels 8 and 16 with the same starting CCE index and if a detected PDCCH scheduling the PDSCH has aggregation level 8, the resources corresponding to the aggregation level 16 PDCCH candidate and associated PDCCH DM-RS are not available for the PDSCH.*
- *If a PDSCH scheduled by a PDCCH would overlap with resources in the CORESET containing the PDCCH, the resources corresponding to a union of the detected PDCCH that scheduled the PDSCH and associated PDCCH DM-RS are not available for the PDSCH.*
- *When precoderGranularity configured in a CORESET where the PDCCH was detected is equal to allContiguousRBs, the associated PDCCH DM-RS are DM-RS in all REGs of the CORESET. Otherwise, the associated DM-RS are the DM-RS in REGs of the PDCCH.*

However, the ambiguity can happen in more scenarios than the scenario addressed in [1]. Moreover, the approach in [1] causes a waste of resources because even if only PDCCH with AL 8 is used and transmitted in an AL 8 PDCCH candidate which has the same starting CCE with another AL 16 PDCCH, the resources in the other PDCCH candidate with AL 8 inside AL 16 PDCCH are not be used for PDSCH multiplexing.

2. PDCCH AL ambiguity

2.1 Confusion between AL 8 and AL 16 at the UE

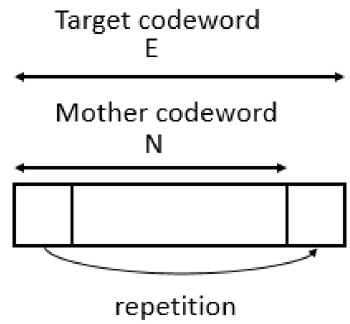

Fig 1. Polar encoding algorithm for long codeword

In Polar encoding algorithm, the longer codeword is generated from a mother codeword based on repetition. A part at the beginning of the mother codeword (maximum length 512) is repeated and added at the end of the mother codeword to create the new codeword with length longer than 512 as shown in Figure 1. PDCCHs with AL 8 and 16 have the codeword length difference greater than 512, thus, they are encoded by following this algorithm.

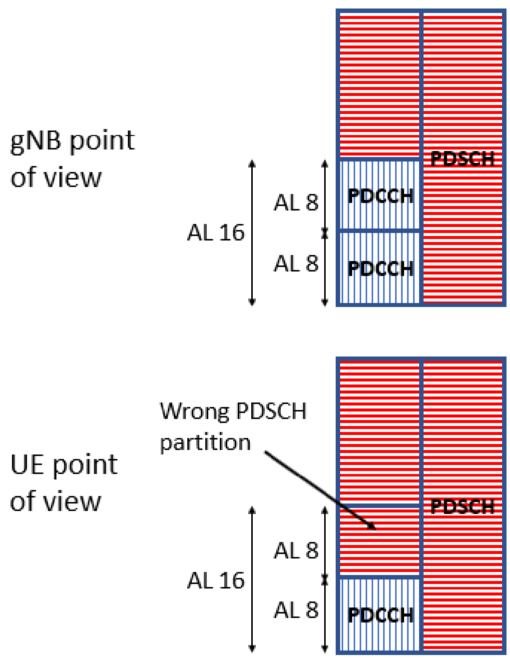

Fig 2. AL 8 and AL 16 ambiguity

Because of repetition-based encoding, the first half of a PDCCH with AL 16 is the same as PDCCH with AL 8. If PDCCH candidates AL 8 and AL 16 overlap and start from the same CCE, there might be an ambiguity between AL 8 and AL 16 at the UE side. One case is when the gNB transmits a PDCCH with AL 16. If SNR is high enough, the UE can decode PDCCH only by trying to decode PDCCH candidate with AL 8. This results in a misunderstanding of PDCCH resource allocation and a partition of PDSCH as shown in Figure 2. A rate matching around the wrong resources degrades PDSCH reliability when the data is multiplexed in the control region as standardized in NR Rel-15. According to the standardized strategy, if the PRB is overlapping and the starting symbol of PDSCH is indicated the same as the PDCCH, the resource elements outside of own candidates will be used for multiplexing data (PDSCH). As the UE was able to decode PDCCH on partial control resources, it will assume the remaining resources part of the PDSCH. This will thus pollute the buffer for PDSCH and may result in inability to decode the transport block due to using incorrect resources for data decoding.

This problem becomes more severe and happens more frequently in URLLC. Because of high reliability requirement, high ALs are used to ensure a lower block error rate (BLER). Therefore, there is a higher probability that AL 8 and AL 16 are used and it causes an ambiguity.

In case DCI on PDCCH is used as PI, a method to quickly determine AL of the transmitted PDCCH and avoid ambiguity is also necessary so that latency reduces and the eMBB UE decodes PI in the required time.

2.2 Methods to solve ambiguity problem

One way to help the UE differentiate between AL 8 and AL 16 is to use difference DMRS sequences for AL 8 and AL 16. The DMRS sequences can be determined by different cyclic shifted version of a base sequence. Due to the Polar encoding algorithm, there is only ambiguity between AL 8 and AL 16. For this reason, the DMRS sequence is used for AL 1, AL 2 and AL 4 can be reused for AL 8. Thus, the UE can reuse channel estimation from the small AL when it decodes higher AL PDCCH candidates instead of carrying out channel estimation each time. For example, in Figure 3, an AL 8 PDCCH is transmitted from the gNB to the UE. The UE tries blindly to find PDCCH in AL 4 PDCCH candidate 1 and 2. In order to decode these candidates, the UE must do channel estimation based on DMRS in each AL 4 candidate. Because the transmitted PDCCH is AL 8 with different mapping in the encoding algorithm, the UE cannot find a codeword passing CRC in PDCCH candidate 1 and 2. Subsequently, the UE tries a higher AL PDCCH candidate that is AL 8 PDCCH candidate 3. Because the same DMRS sequence is used, the UE can reuse the channel estimation from DMRS of two AL 4 candidates mentioned above to decode PDCCH candidate 3.

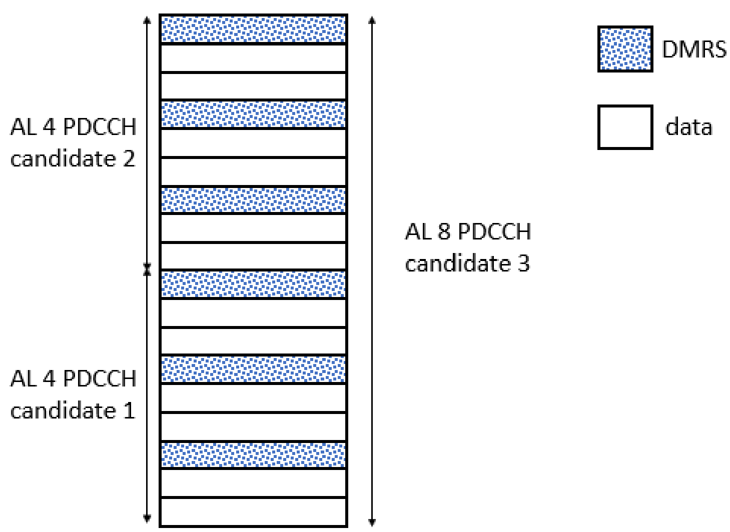

Figure 3. Blind decode AL 4 and AL 8

On the other hand, if an AL 16 PDCCH is transmitted from the gNB to the UE, a second DMRS sequence is used to generate DMRS 2 in Figure 4. DMRS for 2 AL 8 PDCCHs belong to the same DMRS sequence while a different DMRS sequence is used for DMRS 2 of AL 16 PDCCH instead of adding two DMRS of AL 8 PDCCHs to create DMRS 2 as tradition.

Proposal 1:

A special DMRS sequence can be supported for PDCCH to identify AL 16.

When the UE tries blindly AL 8 PDCCH candidate (for example, PDCCH candidate 1), it uses DMRS 1 to do correlation with the received signal. Therefore, it cannot detect DMRS in the candidate because the actual transmitted DMRS is DMRS 2 from a different sequence. Due to a DMRS miss-detection, the UE cannot decode the information inside the AL 8 PDCCH candidate and it avoids the case that the UE can find a codeword passing CRC because of high SNR. Only when the UE uses DMRS 2 to do correlation with the received signal, it can detect the presence of DMRS in PDCCH candidate 3 to carry out channel estimation and decodes the codeword in the candidate. Thanks to these different DMRS sequence between AL 8 and AL 16, the AL ambiguity is solved.

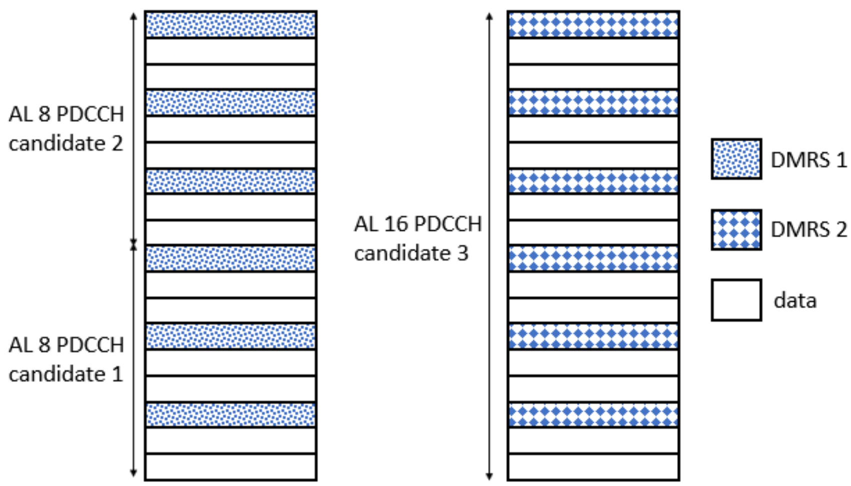

Figure 4. Blind decode AL 8 and AL 16

Another way to solve the ambiguity is to ask the UE to check the presence of DMRS of PDSCH in the corresponding AL 8 candidates.

In Figure 5, AL 8 PDCCH is transmitted from the gNB to the UE. If the UE is able to decode this PDCCH in an AL 8 PDCCH, it will check DMRS in the other AL 8 candidate corresponding to a common AL 16 to make sure that the transmitted PDCCH is not AL 16. As in Figure 5, the UE will detect DMRS of PDSCH and knows the presence of PDSCH in that candidate to do rate matching when decoding PDSCH.

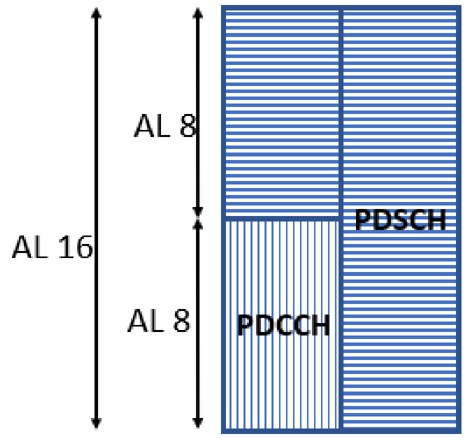

Figure 5. AL 8 PDCCH and PDSCH multiplexing

On the other hand, in Figure 6, AL 16 PDCCH is transmitted from the gNB to the UE. If the channel is good and the UE can find the correct codeword only by using AL 8 candidate, it will not find DMRS of PDSCH in the other AL 8 candidate corresponding to AL 16. Thus, it excludes this resource from PDSCH rate matching.

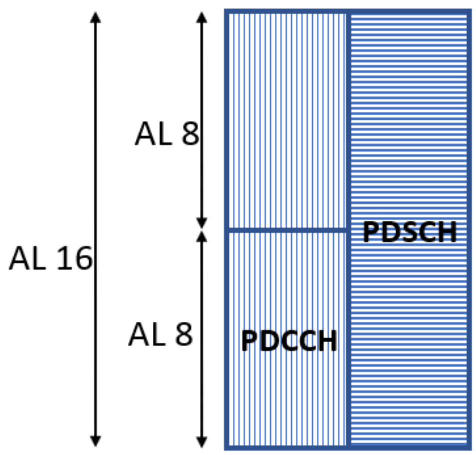

Figure 6. AL 16 PDCCH and PDSCH multiplexing

<u>Proposal 2:</u>

The UE implementation can resolve the AL8-AL16 ambiguity by PDCCH DMRS detection without any specification impact.

This option is better in the sense that it has no specification impact and it allows the utilization of resource in the control region for the data transfer. Nevertheless for URLLC services, where the QoS targets may be very high, it may be an issue and in this case, our Proposal 1 is a good candidate to resolve AL8-AL16 confusion.

3. Conclusions

The following proposals have been made in this document.

Proposal 1: A special DMRS sequence can be supported for PDCCH to identify AL 16.

Proposal 2: The UE implementation can resolve the AL8-AL16 ambiguity by PDCCH DMRS detection without any specification impact.

4. References

[1] TR 38.214 v15.3.0