**3GPP TSG RAN WG1 #104-e R1-210xxxx**

**e-Meeting, January 25th – February 5th, 2021**

**Source: Moderator (ZTE)**

**Title: Summary of [104-e-NR-7.1CRs-02] on Ambiguity Issues for UE Features with Cross-Carrier Operation**

**Agenda item: 7.1**

**Document for:** **Discussion/Decision**

# Introduction

In RAN1#104-e meeting, one email discussion is allocated by chairman to discuss potential ambiguity issues for UE features in case of cross-carrier operation.

[104-e-NR-7.1CRs-02] Discussion on Ambiguity Issues for UE Features with Cross-Carrier Operation – Xingguang (ZTE) by Jan 29

This document is used to collect companies’ views on this issue and summarize the email discussion.

# Background

After extensive discussion in RAN1#102-e and RAN1#103-e meeting, most of Rel-15 UE features with potential ambiguity issue in case of cross-carrier operation have been clarified [1] [2]. The corresponding conclusion/agreements reached during these two meetings are as following.

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| **Conclusion (RAN1#102e)*** Regarding the interpretation of UE capabilities in case of cross-carrier operation, RAN1 clarifies that support of the following UE capability is based on the support of this capability for the band of the scheduled/triggered/indicated cell only.
	+ *aperiodicTRS*
	+ *beamSwitchTiming*
* Regarding the interpretation of UE capabilities in case of cross-carrier operation, RAN1 clarifies that support of the following UE capability is based on both the support of this capability for the band of the scheduled/triggered/indicated cell and the support of this capability for the band of the scheduling/triggering/indicating cell.
	+ *crossCarrierScheduling-SameSCS*

**Agreement (RAN1#103e)**Regarding the interpretation of UE capabilities in case of cross-carrier operation, RAN1 clarifies that support of the following UE capability is based on both the support of this capability for the band of the scheduled/triggered/indicated cell and the support of this capability for the band of the scheduling/triggering/indicating cell.1. ue-SpecificUL-DL-Assignment
2. bwp-DiffNumerology / bwp-SameNumerology

Note: For bwp-DiffNumerology / bwp-SameNumerology, the supported number of BWPs for each band is still based on the indicated number for this band regardless of whether it is a scheduling cell or scheduled cell. |

RAN2 has already updated Section Annex A.5 of TS38.306 to reflect the above conclusion/agreements (copied below).

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| **Annex A.5: General differentiation of capabilities in Cross-Carrier operation**Annex A.5 specifies for which multiple serving cells a UE supporting cross-carrier operation shall support a feature/capability for which it indicates support within the capability signalling.A UE that indicates support for cross-carrier operation in CA (e.g. MCG or SCG):- For the fields for which the UE is allowed to indicate different support for different bands, the UE shall support the feature on the PCell and/or SCell(s) in cross-carrier operation, as specified in tables A.5-1 in accordance to the following rules:- Triggered serving cell: the UE shall support the feature if the UE indicates support of the feature for the band of the scheduled/triggered/indicated serving cell;- Triggering&Triggered serving cells: UE shall support the feature if the UE indicates support of the feature for the band of both the scheduling/triggering/indicating serving cell and the scheduled/triggered/indicated serving cell;Table A.5-1: General UE capabilities for which differentiation is allowed

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| UE-NR-Capability | Classification |
| aperiodicTRS  | Triggered serving cell |
| beamSwitchTiming  | Triggered serving cell |
| bwp-DiffNumerology (NOTE 1) | Triggering&Triggered serving cells |
| bwp-SameNumerology (NOTE 1) | Triggering&Triggered serving cells |
| crossCarrierScheduling-SameSCS | Triggering&Triggered serving cells |
| ue-SpecificUL-DL-Assignment | Triggering&Triggered serving cells |
| NOTE 1: For *bwp-DiffNumerology* and *bwp-SameNumerology*, the supported number of BWPs for each band is still based on the indicated number for this band regardless of whether it is a scheduling cell or scheduled cell. |

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In RAN1#104-e meeting, 5 contributions related to this issue are submitted [3, ZTE] [4, vivo] [5, Apple] [6, Qualcomm] [7, Ericsson]. All the 5 contributions are trying to address the ambiguity issue of *pdcch-MonitoringAnyOccasionsWithSpanGap*, which was discussed in RAN1#103-e meeting without any conclusion. Among them, [3, ZTE] [4, vivo] [5, Apple] [6, Qualcomm] are submitted in AI 5.1 and [7, Ericsson] is submitted in AI 7.2.11, which is mainly discussing how to address the ambiguity issue for Rel-16.

The description of *pdcch-MonitoringAnyOccasionsWithSpanGap* from TS38.306 is as below.

| ***pdcch-MonitoringAnyOccasionsWithSpanGap***Indicates whether the UE supports PDCCH search space monitoring occasions in any symbol of the slot with minimum time separation between two consecutive transmissions of PDCCH with span up to two OFDM symbols for two OFDM symbols or span up to three OFDM symbols for four and seven OFDM symbols. Value set1 indicates the supported value set (X,Y) is (7,3), value set2 indicates the supported value set (X,Y) is (4,3) and (7,3) and value set 3 indicates the supported value set (X,Y) is (2,2), (4,3) and (7,3). | FS | No | N/A | N/A |
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The corresponding UE feature description is as below.

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| 3-5b |  All PDCCH monitoring occasion can be any OFDM symbol(s) of a slot for Case 2 with a span gap | PDCCH monitoring occasions of FG-3-1, plus additional PDCCH monitoring occasion(s) can be any OFDM symbol(s) of a slot for Case 2, and for any two PDCCH monitoring occasions belonging to different spans, where at least one of them is not the monitoring occasions of FG-3-1, in same or different search spaces, there is a minimum time separation of X OFDM symbols (including the cross-slot boundary case) between the start of two spans, where each span is of length up to Y consecutive OFDM symbols of a slot. Spans do not overlap. Every span is contained in a single slot. The same span pattern repeats in every slot. The separation between consecutive spans within and across slots may be unequal but the same (X, Y) limit must be satisfied by all spans. Every monitoring occasion is fully contained in one span. In order to determine a suitable span pattern, first a bitmap b(l), 0<=l<=13 is generated, where b(l)=1 if symbol l of any slot is part of a monitoring occasion, b(l)=0 otherwise. The first span in the span pattern begins at the smallest l for which b(l)=1. The next span in the span pattern begins at the smallest l not included in the previous span(s) for which b(l)=1. The span duration is max{maximum value of all CORESET durations, minimum value of Y in the UE reported candidate value} except possibly the last span in a slot which can be of shorter duration. A particular PDCCH monitoring configuration meets the UE capability limitation if the span arrangement satisfies the gap separation for at least one (X, Y) in the UE reported candidate value set in every slot, including cross slot boundary.For the set of monitoring occasions which are within the same span:* Processing one unicast DCI scheduling DL and one unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for FDD
* Processing one unicast DCI scheduling DL and two unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for TDD
* Processing two unicast DCI scheduling DL and one unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for TDD

The number of different start symbol indices of spans for all PDCCH monitoring occasions per slot, including PDCCH monitoring occasions of FG-3-1, is no more than floor(14/X) (X is minimum among values reported by UE).The number of different start symbol indices of PDCCH monitoring occasions per slot including PDCCH monitoring occasions of FG-3-1, is no more than 7.The number of different start symbol indices of PDCCH monitoring occasions per half-slot including PDCCH monitoring occasions of FG-3-1 is no more than 4 in SCell. |

# Discussion

As mentioned by companies, basically, there are three different interpretations as shown below to interpret the UE capabilities with such ambiguity issue. In the following discussion in this paper, we use the Interpretation1, Interpretation2 and Interpretation3 to clarify this ambiguity issue.

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| **Interpretation1**: Support of this UE capability is based on the support of this capability for the band of the scheduled/triggered/indicated cell only.**Interpretation2**: Support of this UE capability is based on the support of this capability for the band of the scheduling/triggering/indicating cell only.**Interpretation3**: Support of this UE capability is based on the support of this capability for both the band of the scheduled/triggered/indicated cell and the band of the scheduling/triggering/indicating cell. |

Basically, there are two different views from different perspective.

On one hand, it seems this FG is about UE capability on PDCCH monitoring and PDCCH reception and has nothing to do with the scheduled cell. Besides, cross-carrier operation for *pdcch-MonitoringAnyOccasionsWithSpanGap* only happens when cross-carrier scheduling is configured. UE can already control the scheduling cell and scheduled cell by the FG for cross-carrier scheduling (*crossCarrierScheduling-SameSCS*). From this perspective, Interpretation 2 seems to be the reasonable solution.

On the other hand, UE vendors argued that this FG involves both the scheduling cell and the scheduled cell. If Interpretation 2 is adopted, UE can’t control the number of scheduled cells supporting scheduling via FG3-5b. For example, assuming that UE reports band combination Band A + Band B + Band C, if UE supports cross-carrier scheduling via FG3-5b from Band A to Band B, but it cannot support cross-carrier scheduling via FG3-5b from Band A to (Band B + Band C), in this case, UE has to under report its capability. From this perspective, Interpretation 3 seems to be the reasonable solution. One concern about Interpretation 3 is that, in case of cross-carrier scheduling from FR1 to FR2 via this FG3-5b, UE has to support FG3-5b for both FR1 carrier and FR2 carrier, which makes it more difficult for UEs to implement this feature for cross-carrier scheduling from FR1 to FR2.

## Question#1: Cross-carrier scheduling with the same SCS

For Rel-15, only cross-carrier with same SCS in the scheduling cell and scheduled cell is supported. Thus, the concern of making it more difficult for UE to support cross-carrier scheduling from FR1 to FR2 seems doesn’t exist in Rel-15. Based on companies input, it seems companies are fine to take Interpretation3 for *pdcch-MonitoringAnyOccasionsWithSpanGap* for cross-carrier scheduling with the same SCS.

**Question#1:**

Is it ok to take Interpretation3 for *pdcch-MonitoringAnyOccasionsWithSpanGap* for cross-carrier scheduling with **same** **SCS** in the scheduling cell and the scheduled cell?

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| Company | Comments |
| vivo | We are OK to this proposal. |
| ZTE | We are ok with this proposal. |
| Apple | We are okay with this proposal |
| Qualcomm | Yes. |
| Samsung | We are OK with this proposal. |
| Intel | We are OK with this proposal. |
| Huawei | Yes |
| MediaTek | Yes |

## Question#2: Cross-carrier scheduling with different SCSs

For cross-carrier scheduling with different SCSs in the scheduling cell and scheduled cell, [4, vivo] proposes to take Interpretation2 and [7, Ericsson] proposes to introduce a Rel-16 UE capability signalling to indicate which Interpretation of Interpretations 2 and 3 is supported for FG3-5b.

Based on companies’ input, it seems Interpretation2 cannot address UE vendors’ concern on losing control of the number of scheduled cells. Thus, from moderator’s perspective, proposal from [7, Ericsson] seems to be a good compromise, i.e., introducing a Rel-16 UE capability signalling to indicate which Interpretation of Interpretations 2 and 3 is supported for FG3-5b.

**Question#2:**

Is it ok to introduce a **Rel-16 UE capability signalling** to indicate which Interpretation of Interpretations 2 and 3 is supported for *pdcch-MonitoringAnyOccasionsWithSpanGap* for cross-carrier scheduling with **different** **SCSs** in the scheduling cell and the scheduled cell?

- If YES, please input your detailed design of this UE capability.

- If NO, please input your concerns and your solutions.

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| Company | Comments |
| vivo | Technically we are not sure if Interpretations 3 can control the number of scheduled cells. For example, if the capability is indicated for both {A, B} and {A, C} in a BC, then automatically {B, C} becomes support of this feature. How can it control the number of scheduled cells?Anyway, we are also open to introduce a new UE capability in Rel-16 for this issue, but have some questions:* 1. Can this email thread discuss and/or agree a Rel-16 spec change, given it is a Rel-15 maintenance discussion?
	2. If yes, should we design the details of this UE capability? Or, we should only agree to introduce a new UE capability and the details should be handled by UE feature AI?

So maybe we should get some guidelines from chairman before making the decision? |
| ZTE | We are open to introduce Rel-16 UE capability to indicate which Interpretation of Interpretations 2 and 3 is supported for *pdcch-MonitoringAnyOccasionsWithSpanGap*. The UE capability can be a per-UE capability.Regarding the question mentioned by vivo above, for BC A+B+C, if a UE reports support of FG 3-5b for both A and B, then it can control that FG 3-5b is only used within A and B.Regarding the reason why we discuss Rel-16 UE capability here, it because companies have concern on directly taking Interpretation3 for Rel-16, In my view, they may prefer to have a joint conclusion/agreements for Rel-15 and Rel-16 instead of just agreeing on Rel-15. But anyway, we can first focus on whether or not to have this UE capability during the 1st round of discussion. If companies are fine to introduce this UE capability, then we can further discuss whether to keep the Rel-16 UE feature discussion here or move it to Rel-16 UE feature session. |
| Apple | We are fine to introduce new UE capability for cross carrier scheduling with different SCS with FG3-5b. There are two major things we need to differentiate * With FG3-5b, if UE supports FR1 scheduling FR1, does UE has to support FR1 scheduling FR2 and vice versa
* With FG3-5b, if UE supports FR1 scheduling FR2, does UE has to support FR2 scheduling FR1 and vice versa

We can further discuss the details, such as resolution of the new FG, for example {FR1 scheduling FR2, FR2 scheduling FR1, FR1 scheduling FR1, FR2 scheduling FR2}We may also need to consider the difference between{low SCS scheduling high SCS, high SCS scheduling low SCS}If we agree to introduce a new UE capability, it does not have to be restricted to interpretation 2/3 anymore. |
| Qualcomm | It is OK to introduce the new UE capability although we think it is not necessary. Then we need to discuss the detailed combinations of cases as raised by Apple.If the new capability is not introduced, we think interoperation 3 is good. Otherwise, the UE operation for same and different SCS cross-carrier scheduling is different which is not desirable.  |
| Samsung | We are fine to introduce the new UE capability. We still prefer interpretation 3 but we cannot narrow down the difference of opinion between interpretation 3 and interpretation 2. Therefore, we can consider the new UE feature in aspects of cross-carrier scheduling flexibility and control of the scheduled cells. We are also fine to discuss the Apple’s details of the new UE FG as the baseline. |
| Intel | We are OK to introduce the new UE capability. Fine to discuss the issues from Apple too.  |
| Huawei | Our understanding is that the intention to introduce a new UE capability is to have a further refined UE capability. From that perspective, it does not have to be restricted to choice of different interpretations. The case mentioned by Apple can also be discussed but maybe it is proper for the proponent to provide detailed proposals under the UE capability agenda.  |
| MediaTek | We prefer Option 3 to have consistent behaviour for cross-carrier scheduling with same and different numerology. But we are also fine to introduce the new UE capability. And as commented by Huawei, the details can be discussed under UE capability agenda. |

## Question#3: Other comments if any

**Question#3:**

If you have any other comments, please indicate them below.

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| Company | Comments |
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# Conclusion

TBD

# Reference

1. RAN1#102-e meeting report.
2. RAN1#103-e chairman note.
3. R1-2100084, Discussion on Ambiguity Issues for UE Features with Cross-Carrier Operation, ZTE
4. R1-2100404, Discussion on UE FG ambiguity in case of cross-carrier operation, vivo
5. R1-2101339, Clarification of FG3-5b with Cross Carrier Operation, Apple
6. R1-2101433, Clarification on UE Features with Cross-Carrier Operation, Qualcomm Incorporated
7. R1-2100522, Remaining details of Rel-16 NR UE features, Ericsson

# Appendix: Observations and Proposals

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| Company | Proposals |
| [3, ZTE] | Proposal 1: * RAN1 adopts Interpretation2 or Interpretation3 for pdcch-MonitoringAnyOccasionsWithSpanGap to clarify the ambiguity issue in case of cross-carrier operation.
* Note: For pdcch-MonitoringAnyOccasionsWithSpanGap, UE needs to indicate the supported set (set1, set2 or set 3) for each band individually and the supported set is determined by the scheduling cell.
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| [4, vivo] | Proposal 1: In case of cross-carrier operation with same SCS (i.e., crossCarrierScheduling-SameSCS is reported), the support of UE capability pdcch-MonitoringAnyOccasionsWithSpanGap is reported for both bands of the scheduled and the scheduling cells (i.e., Interpretation3), while the supported span set is determined by the band of the scheduling cell (i.e., Interpretation2).Proposal 2: In case of cross-carrier operation with mix SCSs SCS (i.e., crossCarrierSchedulingDL-DiffSCS-r16/crossCarrierSchedulingUL-DiffSCS-r16 is reported for the BC), the support of UE capability pdcch-MonitoringAnyOccasionsWithSpanGap is reported for the band of the scheduling cells (i.e., Interpretation2). |
| [5, Apple] | Proposal 1: Clarify that the support of the following feature is based on the support of this feature for both scheduling/triggering/indicating cell and scheduled/triggered/indicated cell.* FG3-5b, i.e., pdcch-MonitoringAnyOccasionsWithSpanGap
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| [6, Qualcomm] | Observation 1: FG 3-5b is mainly useful for the cross-carrier scheduling scenario with the same SCS between the scheduling and scheduled cells. For different SCS cases* If the scheduling cell has a higher SCS than the scheduled cell, the Rel-15 single span UE capability FG 3-1 can already support scheduling multiple TBs in the same scheduled cell slot
* If the scheduling cell has a lower SCS than the scheduled cell, the Rel-16 single span UE capability FG 18-5c/d was defined to schedule multiple TBs by PDCCHs from the same scheduling cell slot.

Proposal 1: Regarding the interpretation of UE capabilities in case of cross-carrier operation, support of FG 3-5b (pdcch-MonitoringAnyOccasionsWithSpanGap) is based on the support of this capability for both the band of the scheduled cell and the band of the scheduling cell. If reported value set (X, Y) in FG 3-5b is different between the band of the scheduled cell and the band of the scheduling cell, the value set (X, Y) reported for the scheduling cell is applied. |
| [7, Ericsson] | 1. For Rel16, introduce UE capability signalling to indicate which Interpretation of Interpretations 2 and 3 is supported for FG3-5b (i.e., pdcch-MonitoringAnyOccasionsWithSpanGap) support for cross-carrier scheduling between different SCS (i.e. crossCarrierScheduling-OtherSCS).
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