**3GPP TSG RAN WG1 #117 R1-240xxxx**

**Fukuoka, Japan, May 20th – 24th, 2024**

**Agenda item:** 7

**Source:** Moderator (Samsung)

**Title:** Summaryon mDCI based mTRP out-of-order operation

**Document for:** Discussion and Decision

# Introduction

This contribution summarizes companies’ view about draft CR on out-of-order operation for multi-DCI based multi-TRP.

## Relavant contributions

R1-2404074 Discussion on mDCI based mTRP out-of-order operation Samsung

R1-2404075 Draft CR on mDCI based mTRP out-of-order operation Samsung

R1-2404076 Draft CR on mDCI based mTRP out-of-order operation (mirror on Rel-17) Samsung

R1-2404077 Draft CR on mDCI based mTRP out-of-order operation (mirror on Rel-18) Samsung

# Discussion

In Rel-16, multi-DCI based multi-TRP scheme has been specified for both PDSCH reception and PUSCH transmission. One of key features adopted with multi-DCI based multi-TRP is an out-of-order operation, which relaxes timing restriction for scheduling multiple PDSCHs and PUSCHs, as defined in TS38.214-gg0 [1] in the following.

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| 5.1 UE procedure for receiving the physical downlink shared channel  <omit unrelated parts>  When PDCCHs that schedule two PDSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex,* the following operations are allowed:  - For any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start receiving a first PDSCH starting in symbol *j* by a PDCCH associated with a value of *coresetPoolIndex* ending in symbol *i*, the UE can be scheduled to receive a PDSCH starting earlier than the end of the first PDSCH with a PDCCH associated with a different value of *coresetPoolIndex* that ends later than symbol *i*.  - In a given scheduled cell, the UE can receive a first PDSCH in slot *i*, with the corresponding HARQ-ACK assigned to be transmitted in slot *j*, and a second PDSCH associated with a value of *coresetPoolIndex* different from that of the first PDSCH starting later than the first PDSCH with its corresponding HARQ-ACK assigned to be transmitted in a slot before slot *j*.  <omit unrelated parts>  6.1 UE procedure for transmitting the physical uplink shared channel  <omit unrelated parts>  If a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet* for the active BWP of a serving cell and PDCCHs that schedule two non-overlapping in time domain PUSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex,* for any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start a first PUSCH transmission starting in symbol *j* by a PDCCH associated with a value of *coresetPoolIndex* ending in symbol *i*, the UE can be scheduled to transmit a PUSCH starting earlier than the end of the first PUSCH by a PDCCH associated with a different value of *coresetPoolIndex* that ends later than symbol *i*.  A UE is not expected to be scheduled by a PDCCH ending in symbol to transmit a PUSCH on a given serving cell overlapping in time with a transmission occasion, where the UE is allowed to transmit a PUSCH with configured grant according to [10, TS38.321], starting in a symbol on the same serving cell if the end of symbol is not at least symbols before the beginning of symbol . |

In the current specification, the enabling condition of out-of-order operation for both PDSCH and PUSCH is when a UE is configured with two different *coresetPoolIndexes* and two scheduled PDSCHs or PUSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex*, as yellow highlighted in above.

## Question 1. Condition in current specification for out-of-order operation

**Q1. Do you agree the following Observation 1? If not, please provide your view why you don’t agree.**

**Observation 1**: To enable out-of-order operation for PDSCH or PUSCH, the only condition in current specification is when a UE is configured with two different *coresetPoolIndexes* and two scheduled PDSCHs or PUSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex*.

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| MTK | Yes |
| Ericsson | Yes, but the UE will have to support the ‘multiDCI-MultiTRP-r16’ feature in order to configure two different *coresetPoolIndexes*. Note that the UE capability part (e.g., something like ‘subject to UE capability’) is not mentioned in the yellow highlighted text. |
| QC | Yes |
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Regarding UE capability, there is a basic feature for multi-DCI based multi-TRP scheme, *multiDCI-MultTRP-r16*, which means UE can operate based on multi-DCI based multi-TRP which is enabled by having two different *coresetPoolIndexes* defined in TS38.306 [2] asfollows.

| ***multiDCI-MultiTRP-r16***  Indicates whether the UE supports multi-DCI based multi-TRP PDSCH/PUSCH operation and support of fully/partially overlapping PDSCHs in time and non-overlapping in frequency. This capability applies only to BWPs where two values of *coresetPoolIndex* are configured. The capability signalling contains the following:  - *maxNumberCORESET-r16* indicates maximum number of CORESETs configured per BWP per cell in addition to CORESET 0 for multi-DCI based multi-TRP PDSCH/PUSCH operation.  - *maxNumberCORESETPerPoolIndex-r16* indicates maximum number of CORESETs configured per *coresetPoolIndex* per BWP per cell in addition to CORESET 0 for multi-DCI based multi-TRP PDSCH/PUSCH operation.  - *maxNumberUnicastPDSCH-PerPool-r16* indicates maximum number of unicast PDSCHs per *coresetPoolIndex* per slot.  NOTE 1: A UE may assume that its maximum receive timing difference between the DL transmissions from two TRPs is within a Cyclic Prefix.  NOTE 2: Processing capability 2 is not supported in any CC if at least one CC is configured with two values of *coresetPoolIndex*.  NOTE 3: If UE reports value N1 for *maxNumberCORESET-r16*, that means UE supports up to min (N1+1, 5) CORESETs in total (including CORESET#0) if there is CORESET#0, and supports maximal N1 CORESETs if there is no CORESET#0.  NOTE 4: If UE reports value N2 for *maxNumberCORESETPerPoolIndex-r16*, that means UE supports up to min (N2+1, 3) CORESETs in total (including CORESET#0) for a TRP if there is CORESET#0, and supports maximal N2 CORESETs for another TRP if there is no CORESET#0.  NOTE 5: For the multi-DCI based multi-TRP PUSCH operation, the maximum number of unicast PUSCHs that UE can support per slot is based on *pusch-ProcessingType1-DifferentTB-PerSlot*, and it is counted across both *coresetPoolIndex* of TRPs. | FSPC | No | N/A | N/A |
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Also, as additional optional features, out-of-order operation for PDSCH and PUSCH require separate UE capabilities, *outOfOrderOperationDL-r16* and *outOfOrderOperationUL-r16* which cannot be covered by a basic feature defined in TS38.306 [2] as follows. Since a UE can report such UE capabilities separately with a basic feature, if gNB would like to schedule PDSCH or PUSCH to a UE based on out-of-order operation, it requires a relevant UE capability reporting from the UE. Otherwise, gNB scheduling shall be based on in-order operation. In other words, if a UE only reports *multiDCI-MultiTRP-r16* but does not report either *outOfOrderOperationDL-r16* or *outOfOrderOperationUL-r16*, it means that the UE can be configured with two different *coresetPoolIndexes*, but the UE cannot be scheduled by out-of-order operation from gNB.

| ***outOfOrderOperationDL-r16***  Indicates whether the UE supports out of order operation for DL. The UE that indicates support of this feature shall support *multiDCI-MultiTRP-r16*. The capability signalling comprises the following parameters:  *- supportPDCCH-ToPDSCH-r16* indicates support out-of-order operation for PDCCH to PDSCH;  *- supportPDSCH-ToHARQ-ACK-r16* indicates support out-of-order operation for PDSCH to HARQ-ACK. | Band | No | N/A | N/A |
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| ***outOfOrderOperationUL-r16***  Indicates whether the UE supports out of order operation for UL. The UE that indicates support of this feature shall support *multiDCI-MultiTRP-r16.*  Note: Same closed loop index for power control across PUSCHs associated with different *CORESETPoolIndex* values is not supported by a UE indicating the support of this feature when TPC accumulation is enabled. | Band | No | N/A | N/A |

## Question 2. Interpretation on a basic feature, *multiDCI-MultiTRP-r16*

**Q2. Do you agree the following Observation 2? If not, please provide your view why you don’t agree.**

**Observation 2**: A basic UE capability, *multiDCI-MultiTRP-r16*, is defined for a UE to support multi-DCI based multi-TRP scheme with configuration of two different *coresetPoolIndexes*.

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| MTK | Yes |
| Ericsson | Yes |
| Apple | Yes |
| QC | Yes |
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## Question 3. Interpretation on UE capability for out-of-order operation

**Q3. Do you agree the following Observation 3? If not, please provide your view why you don’t agree.**

**Observation 3**: To support out-of-order operation for PDSCH and PUSCH, separate UE capabilities, *outOfOrderOperationDL-r16* and *outOfOrderOperationUL-r16*, are defined which are not covered by a basic UE capability.

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| MTK | Yes |
| Ericsson | Yes |
| Apple | Yes |
| QC | Yes |
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## Question 4. Possible case on UE capability reporting

**Q4. Do you agree the following Observation 4? If not, please provide your view why you don’t agree.**

**Observation 4**: There could be a case when a UE reports a basic capability, *multiDCI-MultiTRP-r16,* but does not report additional optional features for out-of-order operation, *outOfOrderOperationDL-r16* and/or *outOfOrderOperationUL-r16.* In this case, the UE can support multi-DCI based multi-TRP scheme, but cannot support out-of-order operation.

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| MTK | Yes |
| Ericsson | Yes |
| QC | Yes |
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Based on above observations, a TP is proposed in R1-2404075 which fully captures necessary conditions enabling out-of-order operation for PDSCH and PUSCH scheduling.

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| ***Reason for change:*** | To enable out-of-order operation for PDSCH or PUSCH, the only condition in current specification is when a UE is configured with two different *coresetPoolIndexes* and two scheduled PDSCHs or PUSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex*. A basic UE capability, *multiDCI-MultiTRP-r16*, is defined for a UE to support multi-DCI based multi-TRP scheme with configuration of two different *coresetPoolIndexes*. To support out-of-order operation for PDSCH and PUSCH, separate UE capabilities, *outOfOrderOperationDL-r16* and *outOfOrderOperationUL-r16*, are defined which are not covered by a basic UE capability. Then, there could be a case when a UE reports a basic capability, *multiDCI-MultiTRP-r16,* but does not report additional optional features for out-of-order operation, *outOfOrderOperationDL-r16* and/or *outOfOrderOperationUL-r16.* In this case, the UE can support multi-DCI based multi-TRP scheme, but cannot support out-of-order operation. Hence, we would like to add a condition, when a UE reports such optional capability supporting out-of-order operation, in the specification to enable out-of-order operation. |
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| ***Summary of change:*** | To enable out-of-order operation, add a condition like when a UE reports such optional capability supporting out-of-order operation. |
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| ***Consequences if not approved:*** | Based on current specification, a UE reporting a basic capability, *multiDCI-MultiTRP-r16,* but not reporting additional optional features for out-of-order operation, *outOfOrderOperationDL-r16* and/or *outOfOrderOperationUL-r16*, shall support out-of-order operation, which is not aligned with UE capability signaling structure. |

**TP in Clause 5.1 and 6.1 in TS38.214-gg0**

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| 5.1 UE procedure for receiving the physical downlink shared channel  < Unchanged parts are omitted >  Except for the case when a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet* and PDCCHs that schedule two PDSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex* and the UE reports its capability of *outOfOrderOperationDL-r16,* in a given scheduled cell, the UE is not expected to receive a first PDSCH and a second PDSCH, starting later than the first PDSCH, with its corresponding HARQ-ACK assigned to be transmitted on a resource ending before the start of a different resource for the HARQ-ACK assigned to be transmitted for the first PDSCH, where the two resources are in different slots for the associated HARQ-ACK transmissions, each slot is composed of symbols [4] or a number of symbols indicated by *subslotLengthForPUCCH* if provided, and the HARQ-ACK for the two PDSCHs are associated with the HARQ-ACK codebook of the same priority. Except for the case when a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet* and PDCCHs that schedule two PDSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex* and the UE reports its capability of *outOfOrderOperationDL-r16,* in a given scheduled cell, the UE is not expected to receive a first PDSCH, and a second PDSCH, starting later than the first PDSCH, with its corresponding HARQ-ACK assigned to be transmitted on a resource ending before the start of a different resource for the HARQ-ACK assigned to be transmitted for the first PDSCH if the HARQ-ACK for the two PDSCHs are associated with HARQ-ACK codebooks of different priorities.  < Unchanged parts are omitted >  When PDCCHs that schedule two PDSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex* and the UE reports its capability of *outOfOrderOperationDL-r16,* the following operations are allowed:  - For any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start receiving a first PDSCH starting in symbol *j* by a PDCCH associated with a value of *coresetPoolIndex* ending in symbol *i*, the UE can be scheduled to receive a PDSCH starting earlier than the end of the first PDSCH with a PDCCH associated with a different value of *coresetPoolIndex* that ends later than symbol *i*.  - In a given scheduled cell, the UE can receive a first PDSCH in slot *i*, with the corresponding HARQ-ACK assigned to be transmitted in slot *j*, and a second PDSCH associated with a value of *coresetPoolIndex* different from that of the first PDSCH starting later than the first PDSCH with its corresponding HARQ-ACK assigned to be transmitted in a slot before slot *j*.  < Unchanged parts are omitted >  6.1 UE procedure for transmitting the physical uplink shared channel  < Unchanged parts are omitted >  Except for the case when a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet* for the active BWP of a serving cell and PDCCHs that schedule two non-overlapping in time domain PUSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex* and the UE reports its capability of *outOfOrderOperationUL-r16,* for any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start a first PUSCH transmission starting in symbol *j* by a PDCCH ending in symbol *i*, the UE is not expected to be scheduled to transmit a PUSCH starting earlier than the end of the first PUSCH by a PDCCH that ends later than symbol *i*.  < Unchanged parts are omitted >  If a UE is configured by higher layer parameter *PDCCH-Config* that contains two different values of *coresetPoolIndex* in *ControlResourceSet* for the active BWP of a serving cell and PDCCHs that schedule two non-overlapping in time domain PUSCHs are associated to different *ControlResourceSets* having different values of *coresetPoolIndex* and the UE reports its capability of *outOfOrderOperationUL-r16,* for any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start a first PUSCH transmission starting in symbol *j* by a PDCCH associated with a value of *coresetPoolIndex* ending in symbol *i*, the UE can be scheduled to transmit a PUSCH starting earlier than the end of the first PUSCH by a PDCCH associated with a different value of *coresetPoolIndex* that ends later than symbol *i*. |

## Question 5. TP

**Q5. Do you agree the above TP? If not, please provide your view why you don’t agree.**

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| MTK | Generally fine with the TP. |
| Ericsson | The gNB has to respect the capabilities that the UE’s report. It is well understood that the gNB cannot schedule out-of-order PDSCHs or PUSCHs, if the UE doesn’t support ‘outOfOrderOperationDL-r16’ and ‘outOfOrderOperationUL-r16’, respectively. Then, the question is whether we should start to explicitly writing ‘if the UE support its capability of yyyy’ in 38.214. There are probably a lot of other features that would need similar changes. If we start adding similar changes to all these features, this could lead to a lot of changes. Hence, we don’t see the TP as an essential correction. |
| QC | No. We tend to agree with Ericsson. Firstly, whether to support out-of-order operation should be subject to UE capability which is already defined in TS 38.306. The question is whether we need to capture the UE capability in TS 38.314. In our view, it is not necessary to capture all the UE FGs in RAN1 spec. |
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# Conclusion

TBD

# References

1. 3GPP TS 38.214 V16.16.0 (gg0): "NR; Physical layer procedures for data (Release 16)"
2. 3GPP TS 38.306 V16.16.0 (gg0): "NR; User Equipment (UE) radio access capabilities (Release 16)"