**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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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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## 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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## 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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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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# 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)"