**3GPP TSG RAN WG1 #112bis-e R1-23xxxxx**

**e-Meeting, April 17th – April 26th, 2023**

**Agenda item:** 9.17.10

**Source:** Moderator (NTT DOCOMO, INC.)

**Title:** [draft] Summary #1 on UE features for MC enhancements

**Document for:** Discussion and Decision

# **Introduction**

This document summarizes contributions submitted to AI 9.17.10 regarding UE features for MC enhancements and captures the following email discussion.

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| [112bis-e-R18-UE\_features-02] Email discussion on UE features for MC-Enh by April 26 – Shinya (DOCOMO)* Check points: April 21, April 26
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According to the initial UE features list from rapporteur [1], there are following feature groups for MC enhancements.

* FGs for multi-cell PUSCH/PDSCH scheduling with a single DCI
	+ 49-1 Multi-cell PDSCH scheduling by DCI format 1\_3 on a scheduling cell included in a set of cells
	+ 49-1a Multi-cell PDSCH scheduling by DCI format 1\_3 on a scheduling cell not included in a set of cells with same SCS/carrier type between scheduling cell and cells in the set
	+ 49-1b Multi-cell PDSCH scheduling by DCI format 1\_3 on a scheduling cell not included in a set of cells with different SCS/carrier type between scheduling cell and cells in the set
	+ 49-2 Multi-cell PUSCH scheduling by DCI format 0\_3 on a scheduling cell included in a set of cells
	+ 49-2a Multi-cell PUSCH scheduling by DCI format 0\_3 on a scheduling cell not included in a set of cells with same SCS/carrier type between scheduling cell and cells in the set
	+ 49-2b Multi-cell PUSCH scheduling by DCI format 0\_3 on a scheduling cell not included in a set of cells with different SCS/carrier type between scheduling cell and cells in the set
	+ 49-3 Monitoring both legacy DCI format(s) (0\_0/1\_0, 0\_1/1\_1 and/or 0\_2/1\_2) and DCI format 0\_3/1\_3 on the same scheduling cell
	+ 49-4 Multiple sets of cells
	+ 49-5 Type 2 HARQ CB support for DCI format 1\_3
	+ 49-5a Trigger Type 3 HARQ CB based feedback using DCI format 1\_3
	+ 49-5b Trigger enhanced Type 3 HARQ CB based feedback using DCI format 1\_3
	+ 49-6 Co-scheduled cell indication based on co-scheduled cell indicator field in DCI format 1\_3/0\_3
* FGs for multi-carrier UL Tx switching scheme
	+ 49-X Supported switching option for each band pair in the band combination for UL Tx switching across more than 2 bands
	+ 49-Y Minimum separation time for two uplink switching on more than 2 bands within any two consecutive reference slots

Similar to Rel-17, the first priority is to stabilize the signaling structure so that RAN2 can start their work. To this end, in this RAN1 meeting, we focus on the FG structure to have common understanding among companies on how to split the WID into FGs and how to group components/features into rows, while controversial contents can be kept as FFS or […]. Other issues, such as reporting type, can be discussed in future meetings.

# **FGs for multi-cell PUSCH/PDSCH scheduling with a single DCI**

In [1], FGs for multi-cell PUSCH/PDSCH scheduling with a single DCI are captured as below.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Features | Index | Feature group | Components | Prerequisite feature groups | Need for the gNB to know if the feature is supported | Applicable to the capability signalling exchange between UEs (Sidelink WI only)”. | **Consequence if the feature is not supported by the UE** | **Type****(the ‘type’ definition from UE features should be based on the granularity of 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | Need of FDD/TDD differentiation | Need of FR1/FR2 differentiation | Capability interpretation for mixture of FDD/TDD and/or FR1/FR2 | Note | Mandatory/Optional |
| 49. NR\_MC\_enh | 49-1 | Multi-cell PDSCH scheduling by DCI format 1\_3 on a scheduling cell included in a set of cells | 1. UE supports monitoring DCI format 1\_3 for DL scheduling where scheduling cell is included in a set of cells in same PUCCH group.
2. Scheduling cell is PCell if set of cells includes PCell, and scheduling cell is one of SCells if set of cells includes only SCells.
3. Scheduling cell and co-scheduled cells have same SCS/carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2).
4. Max number of co-scheduled cells supported by UE is reported with candidate value set of {[2, 3, 4]}
5. UE can be configured with at least one set of cells. Maximum number of sets for a UE in total and maximum number of sets for a same scheduling cell are reported in FG49-4
6. HARQ feedback based on Type 1 HARQ codebook
7. FDRA field based co-scheduled cell indication
 |  | Yes |  | UE does not support multi-cell PDSCH scheduling by DCI format 1\_3 on a scheduling cell included in a set of cells | [Per BC] | N/A | N/A | N/A | [AgreementAt least cases 1-1 and 1-2 on SCS are supported:* Case 1-1: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells including the scheduling cell and same SCS is used among all the co-scheduled cells including the scheduling cell.
* Case 1-2: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells not including the scheduling cell and same SCS is used among all the co-scheduled cells which may be same or different to the SCS of the scheduling cell.]

[AgreementFollowings are excluded from multi-cell PDSCH/PUSCH scheduling in Rel-18.* SCell schedules multiple cells including P(S)Cell
* Different SCS among co-scheduled cells
* Different carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2) among co-scheduled cells]

[AgreementThe maximum number of co-scheduled cells by a DCI format 1\_X in Rel-18 is 4.] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-1a | Multi-cell PDSCH scheduling by DCI format 1\_3 on a scheduling cell not included in a set of cells with same SCS/carrier type between scheduling cell and cells in the set | 1. UE supports monitoring DCI format 1\_3 for DL scheduling where scheduling cell is not included in a set of cells in same PUCCH group.
2. Scheduling cell is PCell or SCell, and a set of cells includes only SCells.
3. Scheduling cell and co-scheduled cells have same SCS/carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2).
4. Max number of co-scheduled cells supported by UE is reported with candidate value set of {[2, 3, 4]}
5. UE can be configured with at least one set of cells. Maximum number of sets for a UE in total and maximum number of sets for a same scheduling cell are reported in FG49-4
6. HARQ feedback based on Type 1 HARQ codebook
7. FDRA field based co-scheduled cell indication
 | 6-10 (CCS with same SCS) | Yes |  | UE does not support multi-cell PDSCH scheduling by DCI format 1\_3 on a scheduling cell which is not included in a set of cells with same SCS/carrier type scheduling cell and cells in the set | [Per BC] | N/A | N/A | N/A | [AgreementAt least cases 1-1 and 1-2 on SCS are supported:* Case 1-1: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells including the scheduling cell and same SCS is used among all the co-scheduled cells including the scheduling cell.
* Case 1-2: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells not including the scheduling cell and same SCS is used among all the co-scheduled cells which may be same or different to the SCS of the scheduling cell.]

[AgreementFollowings are excluded from multi-cell PDSCH/PUSCH scheduling in Rel-18.* SCell schedules multiple cells including P(S)Cell
* Different SCS among co-scheduled cells
* Different carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2) among co-scheduled cells]

[AgreementThe maximum number of co-scheduled cells by a DCI format 1\_X in Rel-18 is 4.] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-1b | Multi-cell PDSCH scheduling by DCI format 1\_3 on a scheduling cell not included in a set of cells with different SCS/carrier type between scheduling cell and cells in the set | 1. UE supports monitoring DCI format 1\_3 for DL scheduling where scheduling cell is not included in a set of cells in same PUCCH group.
2. Scheduling cell is PCell or SCell, and a set of cells includes only SCells.
3. Scheduling cell and co-scheduled cells have different SCS/carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2).
4. Max number of co-scheduled cells supported by UE is reported with candidate value set of {[2, 3, 4]}
5. UE can be configured with at least one set of cells. Maximum number of sets for a UE in total and maximum number of sets for a same scheduling cell are reported in FG49-4
6. HARQ feedback based on Type 1 HARQ codebook
7. FDRA field based co-scheduled cell indication
 | 18-5 (DL CCS with different SCS) | Yes |  | UE does not support multi-cell PDSCH scheduling by DCI format 1\_3 on a scheduling cell which is not included in a set of cells with different SCS/carrier type scheduling cell and cells in the set | [Per BC] | N/A | N/A | N/A | [AgreementAt least cases 1-1 and 1-2 on SCS are supported:* Case 1-1: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells including the scheduling cell and same SCS is used among all the co-scheduled cells including the scheduling cell.
* Case 1-2: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells not including the scheduling cell and same SCS is used among all the co-scheduled cells which may be same or different to the SCS of the scheduling cell.]

[AgreementFollowings are excluded from multi-cell PDSCH/PUSCH scheduling in Rel-18.* SCell schedules multiple cells including P(S)Cell
* Different SCS among co-scheduled cells
* Different carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2) among co-scheduled cells]

[AgreementThe maximum number of co-scheduled cells by a DCI format 1\_X in Rel-18 is 4.] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-2 | Multi-cell PUSCH scheduling by DCI format 0\_3 on a scheduling cell included in a set of cells | 1. UE supports monitoring DCI format 0\_3 for UL scheduling where scheduling cell is included in a set of cells in same PUCCH group.
2. Scheduling cell is PCell if set of cells includes PCell, and scheduling cell is one of SCells if set of cells includes only SCells.
3. Scheduling cell and co-scheduled cells have same SCS/carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2).
4. Max number of co-scheduled cells supported by UE is reported with candidate value set of {[2, 3, 4]}
5. UE can be configured with at least one set of cells. Maximum number of sets for a UE in total and maximum number of sets for a same scheduling cell are reported in FG49-4
6. FDRA field based co-scheduled cell indication
 |  | Yes |  | UE does not support multi-cell PUSCH scheduling by DCI format 0\_3 on a scheduling cell included in a set of cells | [Per BC] | N/A | N/A | N/A | [AgreementAt least cases 1-1 and 1-2 on SCS are supported:* Case 1-1: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells including the scheduling cell and same SCS is used among all the co-scheduled cells including the scheduling cell.
* Case 1-2: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells not including the scheduling cell and same SCS is used among all the co-scheduled cells which may be same or different to the SCS of the scheduling cell.]

[AgreementFollowings are excluded from multi-cell PDSCH/PUSCH scheduling in Rel-18.* SCell schedules multiple cells including P(S)Cell
* Different SCS among co-scheduled cells
* Different carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2) among co-scheduled cells]

[AgreementThe maximum number of co-scheduled cells by a DCI format 0\_X in Rel-18 is 4.] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-2a | Multi-cell PUSCH scheduling by DCI format 0\_3 on a scheduling cell not included in a set of cells with same SCS/carrier type between scheduling cell and cells in the set | 1. UE supports monitoring DCI format 0\_3 for UL scheduling where scheduling cell is not included in a set of cells in same PUCCH group.
2. Scheduling cell is PCell or SCell, and a set of cells includes only SCells.
3. Scheduling cell and co-scheduled cells have same SCS/carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2).
4. Max number of co-scheduled cells supported by UE is reported with candidate value set of {[2, 3, 4]}
5. UE can be configured with at least one set of cells. Maximum number of sets for a UE in total and maximum number of sets for a same scheduling cell are reported in FG49-4
6. FDRA field based co-scheduled cell indication
 | 6-10 (CCS with same SCS) | Yes |  | UE does not support multi-cell PUSCH scheduling by DCI format 0\_3 on a scheduling cell which is not included in a set of cells with same SCS/carrier type scheduling cell and cells in the set | [Per BC] | N/A | N/A | N/A | [AgreementAt least cases 1-1 and 1-2 on SCS are supported:* Case 1-1: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells including the scheduling cell and same SCS is used among all the co-scheduled cells including the scheduling cell.
* Case 1-2: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells not including the scheduling cell and same SCS is used among all the co-scheduled cells which may be same or different to the SCS of the scheduling cell.]

[AgreementFollowings are excluded from multi-cell PDSCH/PUSCH scheduling in Rel-18.* SCell schedules multiple cells including P(S)Cell
* Different SCS among co-scheduled cells
* Different carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2) among co-scheduled cells]

[AgreementThe maximum number of co-scheduled cells by a DCI format 0\_X in Rel-18 is 4.] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-2b | Multi-cell PUSCH scheduling by DCI format 0\_3 on a scheduling cell not included in a set of cells with different SCS/carrier type between scheduling cell and cells in the set | 1. UE supports monitoring DCI format 0\_3 for UL scheduling where scheduling cell is not included in a set of cells in same PUCCH group.
2. Scheduling cell is PCell or SCell, and a set of cells includes only SCells.
3. Scheduling cell and co-scheduled cells have different SCS/carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2).
4. UE can be configured with at least one set of cells. Maximum number of sets for a UE in total and maximum number of sets for a same scheduling cell are reported in FG49-4
5. FDRA field based co-scheduled cell indication
 | 18-5b (CCS with different SCS) | Yes |  | UE does not support multi-cell PUSCH scheduling by DCI format 0\_3 on a scheduling cell which is not included in a set of cells with different SCS/carrier type scheduling cell and cells in the set | [Per BC] | N/A | N/A | N/A | [AgreementAt least cases 1-1 and 1-2 on SCS are supported:* Case 1-1: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells including the scheduling cell and same SCS is used among all the co-scheduled cells including the scheduling cell.
* Case 1-2: A DCI format 0-X/1-X on a scheduling cell can schedule multiple cells not including the scheduling cell and same SCS is used among all the co-scheduled cells which may be same or different to the SCS of the scheduling cell.]

[AgreementFollowings are excluded from multi-cell PDSCH/PUSCH scheduling in Rel-18.* SCell schedules multiple cells including P(S)Cell
* Different SCS among co-scheduled cells
* Different carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2) among co-scheduled cells]

[AgreementThe maximum number of co-scheduled cells by a DCI format 0\_X in Rel-18 is 4.] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-3 | Monitoring both legacy DCI format(s) (0\_0/1\_0, 0\_1/1\_1 and/or 0\_2/1\_2) and DCI format 0\_3/1\_3 on the same scheduling cell | Monitoring both legacy DCI format(s) (0\_0/1\_0, 0\_1/1\_1 and/or 0\_2/1\_2) and DCI format 0\_3/1\_3 on the same scheduling cell | At least one of {49-1, 49-1a, 49-1b, 49-2, 49-2a, 49-2b} | Yes |  | UE does not support monitoring both legacy DCI format(s) (0\_1/1\_1 and/or 0\_2/1\_2) and DCI format 0\_3/1\_3 on the same scheduling cell | [Per UE] | No | No | No | [AgreementFor any cell within a set of cells which can be co-scheduled by a DCI format 0\_X/1\_X, RAN1 specification supports monitoring the DCI format 0\_X/1\_X and DCI format 0\_0/1\_0, 0\_1/1\_1, and/or 0\_2/1\_2 (if supported by the UE), if configured from a same scheduling cell. * The DCI format 0\_X/1\_X and the DCI format 0\_0/1\_0/0\_1/1\_1/0\_2/1\_2 can be monitored simultaneously. ]

[Note: this FG is referring to FG11-1a] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-4 | Multiple sets of cells | 1. Max number of sets of cells supported by UE in total is reported with candidate value set of {[2, 3, 4]}
2. Max number of sets of cells supported by UE for a same scheduling cell is reported with candidate value set of {[1, 2, 3, 4]}
 | At least one of {49-1, 49-1a, 49-1b, 49-2, 49-2a, 49-2b} | Yes |  |  |  |  |  |  | [AgreementFollowing is supported in Rel-18 multi-cell scheduling* A UE can be configured one or multiple sets of cells with each set configured for multi-cell scheduling using DCI format 0\_X/1\_X.
	+ Up to 4 sets of cells can be configured per PUCCH group.
	+ Up to N sets of cells can be configured and respectively scheduled by DCI format 0\_X/1\_X from a same scheduling cell.
		- The value of N is reported as UE capability.]
 |  |
| 49. NR\_MC\_enh | 49-5 | Type 2 HARQ CB support for DCI format 1\_3 | HARQ feedback based on Type 2 HARQ codebook for PDSCHs scheduled by DCI format 1\_3 | At least one of {49-1, 49-1a, 49-1b} | Yes |  | UE does not support HARQ feedback based on Type 2 HARQ codebook for PDSCHs scheduled by DCI format 1\_3 | [Per UE] | No | No | No | [AgreementHARQ-ACK codebook types (Type-1, Rel-15 Type-2, Rel-16 Type-3, Rel-17 Type-3) are applicable when multi-cell PDSCH scheduling is configured.][AgreementFor Type-2 HARQ-ACK codebook, two sub-codebooks are generated with a first sub-codebook comprising HARQ-ACK information bits for PDSCH(s) scheduled by DCI(s) with each scheduling a single cell and a second sub-codebook comprising HARQ-ACK information bits for PDSCH(s) scheduled by DCI(s) with each scheduling more than one cell. * Separate DAI counting for DCI(s) with each scheduling a single cell and DCI(s) with each scheduling more than one cell.
* Type-2 HARQ-ACK codebook is generated by concatenating the first sub-codebook and the second sub-codebook.]

[Note: this FG is referring to FG5-24] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-5a | Trigger Type 3 HARQ CB based feedback using DCI format 1\_3 | Trigger Type 3 HARQ CB based feedback using DCI format 1\_3 | 10-16 (Type 3 HARQ CB), At least one of {49-1, 49-1a, 49-1b} | Yes |  | UE does not support HARQ feedback based on Type 3 HARQ codebook triggered by DCI format 1\_3 | [Per band] | N/A | N/A | N/A | [AgreementHARQ-ACK codebook types (Type-1, Rel-15 Type-2, Rel-16 Type-3, Rel-17 Type-3) are applicable when multi-cell PDSCH scheduling is configured.][Note: this FG is referring to FG10-16] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-5b | Trigger enhanced Type 3 HARQ CB based feedback using DCI format 1\_3 | Trigger enhanced Type 3 HARQ CB based feedback using DCI format 1\_3 | 25-6 (Enhanced Type 3 HARQ CB), At least one of {49-1, 49-1a, 49-1b} | Yes |  | UE does not support HARQ feedback based on enhanced Type 3 HARQ codebook triggered by DCI format 1\_3 | [Per band] | N/A | N/A | N/A | [AgreementHARQ-ACK codebook types (Type-1, Rel-15 Type-2, Rel-16 Type-3, Rel-17 Type-3) are applicable when multi-cell PDSCH scheduling is configured.][Note: this FG is referring to FG25-6] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-6 | Co-scheduled cell indication based on co-scheduled cell indicator field in DCI format 1\_3/0\_3 | Co-scheduled cell indication based on co-scheduled cell indicator field in DCI format 1\_3/0\_3* Combinations of co-scheduled cells are configured via RRC
 | At least one of {49-1, 49-1a, 49-1b, 49-2, 49-2a, 49-2b} | Yes |  | UE does not support co-scheduled cell indication based on co-scheduled cell indicator field in DCI format 1\_3/0\_3 | [Per UE] | No | No | No | [AgreementFor a set of cells which is configured for multi-cell scheduling using DCI format 0\_X and DCI format 1\_X, support the following: •If table defining combinations of co-scheduled cells for the set of cells is configured, O an indicator in the DCI is included and points to one row of the table.O The table is configured by RRC signaling for the set of cells.] | Optional with capability signaling |

Following inputs are provided in contributions for the RAN1#112bis-e meeting.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| [2] | vivo | UE capabilities can be classified as basic capabilities and optional capabilities. Basic capabilities for R18 multi-carrier scheduling (mc-scheduling) are to ensure that the basic features and essential functions of mc-scheduling are supported by UE, while optional capabilities may be related to some advanced features or fancy designs.As per RAN1 agreement, a series of legacy DCI fields are carried by mc-DCI, including some related to optional capability signalling reporting. Further discussion is needed regarding whether support of those fields and corresponding features in mc-DCI should be mandated or optional. Here is one method for determining basic and optional fields/features: 1. Basic features are the ones that have existed since R15, or their corresponding fields are mandatorily present in fallback DCI or non-fallback DCI, such as PDCCH monitoring/TDRA/FDRA/HARQ, etc.
2. Optional features are usually requiring optional R15-17 UE capabilities reporting.

The basic capability of R18 mc-scheduling should include the monitoring of DCI format 0\_X/1\_X. Additionally, as per RAN1 agreement, separate reporting for the maximum number of the supported co-scheduled cells for UL and DL is needed considering that the UE’s capabilities of uplink CA and downlink CA may be asymmetric.Regarding PDCCH monitoring of DCI format 0\_X/1\_X, it is agreed that the BD/CCE of mc-DCI is counted on the reference cell, which may also be configured with sc-DCI monitoring. The monitoring capability of mc-DCI and sc-DCI should share the legacy R17 BD/CCE limit. For basic UE, decoding both mc-DCI and sc-DCI simultaneously for the same reference cell should not be mandatory. Separate monitoring of mc-DCI and s-c-DCI is sufficient in most cases while supporting such kind of simultaneous monitor requires additional hardware processing capability. **Proposal 1. Simultaneous monitoring of both DCI format 0\_0/0\_1/0\_2(if supported) and DCI format 0\_X simultaneously for the same reference cell is an optional feature for mc-scheduling.****Proposal 2. Simultaneous monitoring of both DCI format 1\_0/1\_1/1\_2(if supported) and DCI format 1\_X simultaneously for the same reference cell is an optional feature for mc-scheduling.**Regarding HARQ-ACK for mc-scheduling, as all co-scheduled cells have the same SCS and the same PUCCH resource, the generation procedure of Type-1 HARQ-ACK codebook for mc-scheduling is almost identical to that of for sc-scheduling, which is mandatorily supported with capability signalling reporting in R15. Thus, the support of Type-1 HARQ-ACK generation for mc-scheduling can be considered a basic capability. But for Type-2 HARQ-ACK codebook for mc-scheduling, as several changes, including changes on DAI counting, and the number of HARQ-ACK bits per DCI are introduced, Type-2 HARQ-ACK codebook for mc-scheduling should be an optional feature. **Proposal 3. Support of Type-1 HARQ-ACK codebook is a basic feature for mc-scheduling.****Proposal 4. Support of Type-2 HARQ-ACK codebook is an optional feature for mc-scheduling.**Regarding whether/how to support existing optional features of other WIs in earlier releases or future releases, some issues need to be discussed.Firstly, in R15-17, 3GPP introduced a series of capability signaling to indicate the support for some specific features in sc-DCI. When it comes to mc-DCI, an issue that needs to be resolved is how to determine which of these features/DCI fields the UE mandatorily supports for the mc-scheduling. Should RAN1 introduce a new R18 capability for each of the features/DCI fields that have introduced UE capability signaling, or should RAN1 simply reuse the existing capabilities defined for a legacy DCI format (e.g., DCI format 0-1/1-1) and extend the corresponding features to mc-DCI? An example is DCI-based BWP switching. In R15, NW can include a BWP indicator in a sc-DCI and trigger BWP switching via a sc-DCI only if the UE reported a per Band capability ***bwp-SameNumerology*** or ***bwp-DiffNumerology*** for DCI-based BWP switching. For mc-scheduling, whether new mc-DCI-based BWP switching capabilities, e.g., ***bwp-SameNumerology-DCI-0-X-And-DCI-1-X***, ***bwp-DiffNumerology-DCI-0-X-And-DCI-1-X*** are needed? Or, legacy capability can be directly reused, and NW assumes that mc-DCI-based BWP switching capability is supported by UE if the UE reported ***bwp-SameNumerology*** or ***bwp-DiffNumerology*** for at least one of the co-scheduled cells? Another example is Type-3 HARQ-ACK codebook, which is an optional feature with capability signalling in NRU, it seems that the legacy capability signalling can be reused in this case.In most cases, reusing the existing capabilities could be feasible. But for dormancy/deactivation, one question that needs clarification is whether the dormancy/deactivation of the reference cell needs additional capability indication. Similar discussions had occurred in R17 DSS regarding the dormancy/deactivation of sScell. In R17 DSS, scheduling from Pcell falls back to self-scheduling only, and the BD/CCE budget for Pcell self-scheduling changes after the sScell becomes dormant or deactivated. As this dormancy/deactivation procedure results in the redistribution of BD/CCE counting, new UE capabilities were introduced for dormancy/deactivation of the sScell. Similarly, if the reference cell becomes dormant or deactivated, the mc-DCI scheduling function should be disabled. As discussed earlier, when the UE monitors both mc-DCI and sc-DCI for a reference cell, the monitoring of mc-DCI and sc-DCI shares the legacy R17 BD/CCE limit dynamically. If mc-scheduling is disabled, the reference cell falls back to sc-DCI-based scheduling only, and the single-cell scheduling for the reference cell is subject to the R17 BD/CCE limit. On the other hand, since PDCCH monitoring for sc-DCI scheduling the reference cell is not performed when the reference cell is dormant or deactivated, the dormancy/deactivation procedure of the reference cell may not cause a BD/CCE budget re-allocation. Therefore, reusing existing capability is also feasible for this case.**Proposal 5. For each existing optional NR UE feature that corresponds to a field agreed to be included in mc-DCI, consider one of the following:- Alt1. Existing UE capabilities for the feature can be directly reused to indicate the support of this feature and the corresponding DCI field for mc-DCI when the UE capabilities are reported together with the basic capability of mc-DCI monitoring.- Alt2. Introduce new UE capabilities for supporting the feature for mc-scheduling.**Secondly, in addition to the existing fields, mc-DCI also introduces some new fields and functions. It should be noted that although ‘Antenna port(s)’, ‘Precoding information and number of layers’ and ‘SRS resource indicator’ are existing fields, they are different from the legacy sc-scheduling in that the types of these fields are configurable between Type-1A and Type2. Since Type-1A and Type-2 lead to different field structures and interpretations, it is unreasonable to force basic UEs to support both types for a single field. The support of type configurability should be an optional feature. For simplicity, basic UE may only support these three fields as Type-2. If UE is not informed by NW of the field type for these fields, Type-2 is assumed by default.**Proposal 6. Support of configurability between Type 1A and Type-2 is an optional feature. If UE does not report the support of configurability between Type 1A and Type-2 for ‘Antenna port(s)’, ‘Precoding information and number of layers’ or ‘SRS resource indicator’, it means that UE only supports these fields as Type-2.**The indicator of cell sets and the indicator of co-scheduled cells are new fields introduced in R18. Regarding the ‘cell set indication’, support of one cell set should be a basic capability, and advanced UEs can further report the number of supported cell sets. Regarding indicating cell combinations, two solutions are agreed: 1) indication based on cell combination indicator; 2) indication based on FDRA. The two solutions would result in different DCI structures and interpretations. Both solutions work. But it is not necessary to force basic UEs to support both solutions. If each cell combination in a cell set only contains a subset of the cell set, the solution 1) is favorable as it makes the DCI decoding easier to UE (as the cell indication is a standalone dedicated field), and it has better flexibility and a smaller DCI size. If there is a cell combination containing all the cells in the cell set, these two solutions are almost the same in terms of DCI structures and interpretations. Whether to support a cell combination that includes all cells in a cell set can be considered a prerequisite for supporting the FDRA-based solution. In other words, the cell combination indicator-based solution, which is always applicable, should be a mandatory capability, while the support of a cell combination that includes all cells in a cell set can be an optional capability.**Proposal 7. The cell combination indicator-based solution should be a basic feature, while the support of a cell combination that includes all cells in a cell set and FDRA-based cell combination indication can be an optional capability.****Proposal 8. Regarding the cell set indication, the support of one cell set should be a basic feature, and advanced UEs can further report the support of more cell sets.**In 38.306, the number of unicast DCIs that can be processed per scheduled cell per scheduling CC slot has been specified. With mc-DCI introduced in R18, it should be clarified whether these restrictions are applicable to mc-DCI. For simplicity, a mc-DCI should be considered as a unicast DCI from the perspective of the reference cell, and the total number of unicast sc-DCIs and mc-DCIs that can be proceeded simultaneously in a scheduling CC slot should not exceed the maximum number specified in the 38.306:

| ***crossCarrierSchedulingProcessing-DiffSCS-r16***Indicates the UE cross carrier scheduling processing capability for DL carrier aggregation processing up to X unicast DCI scheduling for DL per scheduled CC. X is based on pair of (scheduling CC SCS, scheduled CC SCS) where a pair of (15,120), (15,60), (30,120) kHz SCS can have X = {1,2,4} while a pair of (15,30), (30,60), (60,120) kHz SCS can have X = {2}, and X applies per slot of scheduling CC. | FS | No | N/A | N/A |
| --- | --- | --- | --- | --- |
| ***crossCarrierSchedulingProcessing-DiffSCS-r16***Indicates the UE cross carrier scheduling processing capability for UL carrier aggregation processing up to X unicast DCI scheduling for UL per scheduled CC. X is based on pair of (scheduling CC SCS, scheduled CC SCS) where a pair of (15,120), (15,60), (30,120) kHz SCS can have X = {1,2,4} while a pair of (15,30), (30,60), (60,120) kHz SCS can have X = {2}, and X applies per slot of scheduling CC. | FS | No | N/A | N/A |

Proposal 9. From the perspective of the reference cell counting toward the BD/CCE/DCI size of mc-DCI, a mc-DCI is considered as a unicast DCI, and the total number of mc-DCI and sc-DCI for the reference cell should not exceed the legacy restriction of the maximum number of unicast DCI specified in 38.306.With the above logic, an example of the corresponding UE feature for DCI monitoring in R18 mc-scheduling is as below. The previous agreements on the restrictions for mc-scheduling are also reflected in the table.Proposal 10. For mc-scheduling, consider the FGs in Table 1.Table 1. Example of UE feature for mc-scheduling

|  |  |  |  |
| --- | --- | --- | --- |
| Index | Feature group | Components | note |
| XX-1Basic(mandatory with signalling) | Monitoring DCI format 0\_X and DCI format 1\_X | 1. Support monitoring DCI format 0\_X for UL scheduling a)The maximum number of co-scheduled UL CCs supported by the UE2, Support monitoring DCI format 1\_X for DL schedulinga)The maximum number of co-scheduled DL CCs supported by the UE3. UE is not expected to monitor both DCI format 0\_0/0\_1/0\_2(if supported) and DCI format 0\_X simultaneously for the same reference cell4. UE is not expected to monitor both DCI format 1\_0/1\_1/1\_2(if supported) and DCI format 1\_X simultaneously for the same reference cell5. Number of cell set N6. Support HARQ enhancements for Type 1 HARQ codebook for multi-cell PDSCH scheduling with same SCS/carrier type/duplex mode among the co-scheduled cells7. DCI format 0\_X/1\_X includes an indicator to indicate the co-scheduled cells | Component 1-a), the candidate value are {2,3,4}Component 2-a) , the candidate values are {2,3,4}Component 5, the candidate values are {1,2}Note:UE supports that a DCI format 0-X/1-X on a scheduling cell can schedule multiple cells including the scheduling cell and same SCS is used among all the co-scheduled cells including the scheduling cell.UE supports that a DCI format 0-X/1-X on a scheduling cell can schedule multiple cells not including the scheduling cell and same SCS is used among all the co-scheduled cells which may be same or different to the SCS of the scheduling cell.UE does not support that a DCI format 0-X/1-X on a scheduling cell can schedule multiple cells and different SCS are used among all the co-scheduled cells.UE only supports that a DCI format 0-X/1-X on a scheduling cell can schedule multiple cells and the same carrier type (licensed or unlicensed, FR1 or FR2-1 or FR2-2) is used among all the co-scheduled cells.UE does not support both CBG-based PDSCH/PUSCH transmission and the multi-cell PDSCH/PUSCH scheduling on the same or different cells within a same PUCCH groupUE does not support both multi-PDSCH scheduling and multi-cell PDSCH scheduling on the same or different cells within a same PUCCH group.UE does not support enhanced Type-2 HARQ-ACK codebook for the multi-cell PUSCH/PDSCH scheduling by a DCI format 0-X/1-X.UE supports Type-1 HARQ-ACK codebook only for the case where co-scheduled cells by a DCI format 1\_X have same SCS/carrier type/duplex mode.UE does not support that more than one scheduling cells are configured for DCI format 0\_X/1\_X for each scheduled cell.UE does not support PUSCH repetition Type B operation with DCI format 0\_X (i.e. UE cannot be configured with PUSCH repetition Type B applicable for DCI format 0\_1)UE does not support that SCell schedules multiple cells including P(S)Cell.UE does not support that both multi-cell PDSCH/PUSCH scheduling and multi-TRP are configured for a scheduled cell.UE does not support that PCell schedules multiple cells by DCI format 0\_X/1\_X when a sSCell is configured to schedule PCell |
| XX-1aoptional | Monitoring both DCI format 0\_1/0\_0/0\_2(if supported) and DCI format 0\_X simultaneously | Support monitoring of both DCI format 0\_0/0\_1/0\_2(if supported) and DCI format 0\_X simultaneously for the same reference cell |  |
| XX-1boptional | Monitoring both DCI format 1\_1/1\_0/1\_2(if supported) and DCI format 1\_X simultaneously | Support monitoring of both DCI format 1\_0/1\_1/1\_2(if supported) and DCI format 1\_X simultaneously for the same reference cell |  |
| XX-2optional | Type-2 HARQ-ACK codebook for multi-cell PDSCH scheduling | Support HARQ enhancements for type 2 HARQ codebook for multi-cell PDSCH scheduling |  |
| XX-3optional | FDRA-based cell combination indicator | Support all the cells in a cell set to be scheduled by a DCI format 0-X/1-X Support indicating a scheduled cell combination by FDRA | The UE determines the actually scheduled cell(s) based on the FDRA field of each cell of the set of cells.-For Type 0 FDRA, all 0s indicates the cell is not scheduled.-For Type 1 FDRA, all 1s indicates the cell is not scheduled. |
| XX-4optional | Configurable field Type | Support ‘Antenna port(s)’, ‘Precoding information and number of layers’ and ‘SRS resource indicator’ being configurable between Type 1A and Type-2 |  |

 |
| [3] | OPPO | ***UE feature for multi-cell scheduling with DCI 0\_X/1\_X*** In the current UE feature structure, DCI 0\_0/1\_0/0\_1/1\_1 are mandatory Rel-15 feature (in FG3-1) without capability signaling while DCI 0\_2/1\_2 is optional Rel-16 feature (FG11-1) with capability signaling. In our view, some characteristics of DCI 0\_2/1\_2 feature can apply to DCI 0\_X/1\_X. ***Proposal 1: A new FG is defined for Rel-18 support of multi-cell scheduling with DCI 0\_X/1\_X.*** * ***The new FG is optional with UE capability signaling.***
* ***The new FG does not differentiate between FR1 and FR2.***
	+ ***FFS whether/how to capture RAN1 agreement that the co-scheduled cells per single DCI 0\_X/1\_X shall have the same carrier type between FR1 and FR2.***
* ***The new FG does not differentiate between FDD and FDD.***

As for the new FG components, RAN1 agreed that, although the spec-allowed maximum number of co-scheduled cells per single DCI 0\_X/1\_X is 4, the maximum number of co-scheduled cells by a DCI format 0\_X and the maximum number of co-scheduled cells by a DCI format 1\_X for a UE can be the same or different, and can be smaller than or equal to 4. This should be reflected as a UE capability. However, according to the RAN1 agreements on DCI 0\_X/1\_X payload size determination, the “maximum number of cells in a co-scheduled cell set” can have stronger influence to the UE implementation on PDCCH processing than the “maximum number of co-scheduled cells by a single DCI 0\_X/1\_X”. The latter one may be more meaningful for UE’s capability on co-scheduled PDSCH, while the former one is more meaningful for UE’s implementation capability on PDCCH. Therefore we suggest including “maximum number of cells in a co-scheduled cell set” in the new FG components as well. Additionally, RAN1 already agreed that the number of cell sets that UE can be configured and scheduled from a same scheduling cell is reported as UE capability. ***Proposal 2: The new FG in Proposal 1 has the following FG components:*** * ***Component-1: Supports monitoring DCI format 1\_X for DL scheduling, with one DCI format 1\_X scheduling PDSCH on up to NDL,max cells in a co-scheduled cell set that can have maximum Nset\_size,max cells, where 2≤NDL,max ≤ Nset\_size,max≤4.***
* ***Component-2: Supports monitoring DCI format 0\_X for UL scheduling, with one DCI format 0\_X scheduling PUSCH on up to NUL,max cells in a co-scheduled cell set that can have maximum Nset\_size,max cells, where 2≤NUL,max ≤ Nset\_size,max≤4.***
* ***Note: NDL,max , NUL,max and Nset\_size,max above are UE capability parameters***
* ***Component-3: Maximum number of co-scheduled cell sets (Nset,max) that can be scheduled from a same scheduling cell.***
* ***FFS whether to introduce multiple combinations of values for these capability parameters.***

Note that the “maximum number of cells in a co-scheduled cell set” (i.e., ***Nset\_size,max*** above) can work for both table-configuration based indication and FDRA-reuse based indication for the co-scheduled cell combination. For a capability indication with more precise capability granularity, the maximum number of table rows can be considered as an alternative capability parameter for table-configuration based cell combination indication. Regarding to the FFS in Proposal 2, Proposal 2 introduces four capability parameters < ***NDL,max , NUL,max, Nset\_size,max, Nset,max*** > and gives individual maximum values, under the assumption of no dependency among these maximum values. However, it is also possible to take these four capability parameters into a multi-dimensional capability space, with multiple combinations of maximum values, where one combination of maximum values may observe a larger value for one capability parameter and a smaller value for another capability parameter comparing to another combination of maximum values. Under this scheme, a UE may report, e.g., both <3,3,4,2> and <2,2,3,4> as capability. This scheme may allow better utilization of UE implementation resources but may lead to more sophisticated RAN1 discussions. There was a brief discussion in RAN1 #112 regarding to whether/how to have UE capability indication for UE’s support of two mechanisms to indicate the co-scheduled cell combinations: table-based indication and FDRA-reuse-based indication. We certainly do not think the UE implementation should be mandated to support both. There was a proposal in RAN1 #112 to make the FDRA-reuse-based method mandatory and the table-based method optional. However, it was also commented that the DCI 0\_X/1\_X payload size derivations (3rd and 4th bullets) in the following FDRA-reuse based method are not clearly finalized and are still open to solution explore. It is premature to lock some uncertainty as mandatory at this stage.

|  |
| --- |
| * + The UE determines the actually scheduled cell(s) based on the FDRA field of each cell of the set of cells.
		- For Type 0 FDRA, all 0s indicates the cell is not scheduled.
		- For Type 1 FDRA, all 1s indicates the cell is not scheduled.
	+ The size of the Type 2 fields for each cell does not change according to actually co-scheduled cells.
	+ The payload size of DCI format 0\_X is derived by UE based on RRC configuration of the active BWP(s) of all cells within the set of cells.
	+ The payload size of DCI format 1\_X is derived by UE based on RRC configuration of the active BWP(s) of all cells within the set of cells.
 |

***Proposal 3: At least one method of co-scheduled cell combination indication, between table-based and FRDA-reuse-based, is capability optional in FG component.*** * ***RAN1 clarifies details of the DCI 0\_X/1\_X payload size derivation for the FDRA-reuse based cell combination indication, before determining which method is selected as optional.***

Given RAN1 agreement does not prevent DCI 0\_X/1\_X from being configured in the same search space with legacy DCI formats (if we correctly understood the RAN1 #112 agreement about “independent configuration of separate search space sets between DCI 0\_X/1\_X and legacy DCIs”), there should be another FG similar to FG11-1a, created for support of monitoring DCI 0\_X/1\_X and any of legacy unicast DCI in the same search space.***Proposal 4: With clarification of RAN1 #112 agreement on “independent configuration on separate search space”, a second new FG is introduced for DCI 0\_X/1\_X upon necessity to fulfill the similar purpose of FG11-1a.*** Besides the above UE features that can find logic source from existing UE feature architecture and earlier RAN1 discussion in Rel-18 WI, there are some DCI 0\_X/1\_X related features that are logically brand-new in Rel-18 and therefore may need further discussion. One example is the new configuration, Configuration 3, of nominal RBG size for RA type 0. Within Configuration 3, RBG size of 32 is a new RBG size that never appears in legacy specification, and therefore the UE implementation should be given a chance not to implement it in support of scheduling with DCI 0\_X/1\_X in RA type 0. Another example is Type-2 HARQ codebook that contains two sub-codebooks. ***Proposal 5: The following FG component is included in the new FG in Proposal 1.**** ***Support of nominal RBG size of Configuration 3.***
* ***Support of Type-2 HARQ codebook within multi-cell scheduling by DCI 0\_X/1\_X.***
 |
| [4] | ZTE | **Issue 1: The scheduling of multi-cell scheduling**Since multi-cell scheduling is a new feature in NR, whether the UE supports multi-cell scheduling or not should be reported by the UE. Since the co-scheduled cells within a set of cells can be in different bands, the report granularity should be per BC report.For multi-cell scheduling, the following agreements have been reached on the number of co-scheduled cells and the number of sets.

|  |
| --- |
| **Agreement**Confirm the following working assumption reached in RAN1#110 meeting.**Working Assumption*** The maximum number of co-scheduled cells by a DCI format 1\_X in Rel-18 is 4.
* The maximum number of co-scheduled cells by a DCI format 0\_X in Rel-18 is 4.
* FFS: The maximum number of configurable cells for co-scheduling

**Agreement**For a set of cells which is configured for multi-cell scheduling, up to 4 cells within the set of cells are supported.* A DCI format 0\_X/1\_X can schedule PUSCH(s)/PDSCH(s) on a combination of co-scheduled cells among the same set of cells.

**Agreement**Following is supported in Rel-18 multi-cell scheduling* A UE can be configured one or multiple sets of cells with each set configured for multi-cell scheduling using DCI format 0\_X/1\_X.
* Up to 4 sets of cells can be configured per PUCCH group.
* When multiple sets of cells are configured,
	+ a cell in one set of cells can’t be included in another set of cells.
	+ n\_CI value is independently configured for each set of cells.
	+ reference cell for counting DCI size and BD/CCE of DCI format 0\_X/1\_X is independently determined for each set of cells.
	+ search space configuration of DCI format 0\_X/1\_X is independently configured for each set of cells.
	+ DCI size of DCI format 0\_X is independently determined for each set of cells.
	+ DCI size of DCI format 1\_X is independently determined for each set of cells.
* The multiple sets of cells can be scheduled by DCI format 0\_X/1\_X from different scheduling cells.
* Up to N sets of cells can be configured and respectively scheduled by DCI format 0\_X/1\_X from a same scheduling cell.
	+ The value of N is reported as UE capability.
	+ An indicator is included in the DCI to indicate the scheduled set of cells,
		- The size of the indicator is equal to ceil(log2(N)), where N is the number of sets of cells.
	+ Unique n\_CI value is configured for each set of cells.
 |

It was agreed that the maximum number of co-scheduled cells by a single DCI format 0\_X/1\_X is 4 and up to 4 sets of cells can be configured for a UE. Therefore, the number of the co-scheduled cells by a single DCI format 0\_X/1\_X shall be reported by the UE. Since the number of sets of cells that can be configured with the same scheduling cell should be reported by the UE as agreed, up to 4 sets of cells per PUCCH group can be guaranteed by gNB configuration. For multi-cell scheduling for downlink, all the Type-1, Type-2, Type-3 codebook are supported. If a UE support multi-cell scheduling for downlink, the corresponding HARQ feedback should also be supported since HARQ feedback is always needed for downlink scheduling. ***Proposal 1:*** *For multi-cell scheduling cell scheduling with single DCI, it should be per BC report with the following three components.** *The support of multi-cell scheduling for the band combination.*
* *The number of co-scheduled cells by a single DCI format 0\_X/1\_X, including the candidate value 2, 3, and 4.*
* *The number of sets that can be scheduled by the same scheduling cell, including the candidate value 1, 2, 3, and 4.*

**Issue 2: RBG size for multi-cell scheduling**For FDRA indication, a larger granularity was introduced to reduce the overhead of FDRA field as shown below.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Agreement*** A new RBG size configuration “Configuration 3” is added with the following values and only used for DCI format 0\_X/1\_X for RA type 0.
* RBG size is configured per BWP per cell.
* Independent RA type configuration is applied per BWP per cell for multi-cell scheduling DCI.

 Table 5.1.2.2.1-1 / Table 6.1.2.2.1-1: Nominal RBG size *P*

|  |  |  |  |
| --- | --- | --- | --- |
| Bandwidth Part Size | Configuration 1 | Configuration 2 | Configuration 3 |
| 1 – 36  | *2* | 4 | 8 |
| 37 – 72 | 4 | 8 | 16 |
| 73 – 144 | 8 | 16 | 32 |
| 145 – 275 | 16 | 16 | 32 |

**Agreement**New RRC parameter of RBG granularity for RA type 1 can be configured per BWP per cell for DCI format 0\_X/1\_X with same value range applicable for DCI 0\_2/1\_2. |

Therefore, the UE should be report whether it supports the new configuration of the RBG size or not. It should be per UE reporting since it is not related to the band.***Proposal 2:*** *The support of new configuration of the RBG size should be reported by the UE and the type should be per UE reporting.* |
| [5] | Nokia, NSB | Based on the agreements and functionalities for multi-cell PDSCH/PUSCH scheduling, we see a need for discussions related to the following potential specific UE capabilities: * **Separate capabilities for multi-cell PDSCH and multi-cell PUSCH?**
	+ The operation for multi-cell scheduling of PUSCH & PDSCH is handled through the structure of ‘a set of cells’. As the set of cells is the same for PUSCH & PDSCH based on RAN1 agreements, separating the capabilities of multi-cell PUSCH and multi-cell PDSCH seems to be creating issues with the related UE capability of some of the aspects below. Moreover, we don’t think a separate capability for scheduling using DCI format 0\_3 and 1\_3 will be needed.
* **Supported maximum number of ‘set of cells’ within a PUCCH cell group:**
	+ We agreed to support up to a maximum of 4 set of cells from specification perspective. There could be some signaling on the maximum number of set of cells supported by the UE for multi-cell PDSCH/PUSCH scheduling if seen needed.
* **Supported maximum number of cells per set of cells**
	+ From specification perspective, up to 4 cells within a set of cells are supported. If seen needed, there could be UE capabilitiy signaling of the component.
* **Scheduling of more than one set of cells from a single scheduling cell**
	+ There is a RAN1 agreement that up to N set of cells can be scheduled from a single scheduling cell, with N being a UE capability. Therefore, such signaling would need to be defined.
* **Indication of the scheduled cell combination**
	+ Two different ways for indicating the scheduled cell combination (which also affects on the DCI content) have been agreed in RAN1.

 **Proposal 1: Take table 1 as the basis for UE capability discussion for the Multi-cell PDSCH / PUSCH scheduling using DCI format 0\_3 / 1\_3**Table 1: Starting point for Rel-18 UE capabilities for Multi-cell PDSCH / PUSCH scheduling

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| FG | FG name | Components | Value range | Note |
| X-1 | Multi-cell PDSCH/PUSCH scheduling | * Multi-cell PDSCH/ PUSCH scheduling for up to M set of cells with a PUCCH cell group from different scheduling cells
* Support for up to L cells within a set of cells
* Scheduling of PDSCH on one or more cells of a set of cells using DCI format 1\_3
* Scheduling of PDSCH on one or more cells of a set of cells using DCI format 0\_3
 | For component 1: M={1,2,3,4}For component 2: L={2,3,4} | Basic capability for this feature with potential UE signaling on the maximum number of supported set of cells and max. number of cells within a set of cells |
| X-2 | Multi-cell scheduling PDSCH / PUSCH scheduling of different sets from the same scheduling cell  | Multi-cell PDSCH/ PUSCH scheduling for up to N set of cells for a PUCCH cell group from the same scheduling cell  | For component 1: N={2,3,4} | X-1 is a pre-requisite capabilityNo separate signaling of M and L needed, can be taken from X1 with the total number of set of cells that can be scheduled given by M of X-1.  |
| X-3a | Indication of scheduled cell combination based on indicator field in DCI 0\_3 / 1\_3 | Support for using an indicator in DCI 0\_3 / 1\_3 to indicate the scheduled cell combination for PDSCH or PUSCH scheduling | {Supported} | X-1 is a pre-requisite capabilityNote: A UE supporting X-1 (or X-2) needs to support X-3a or X-3b (or both) |
| X-3b | Indication of scheduled cell combination based on FDRA field in DCI 0\_3 / 1\_3 | Support for using the FDRA field in DCI fomat 0\_3 / 1\_3 to indicate the scheduled cell combination for PDSCH or PUSCH scheduling  | {Supported} | X-1 is a pre-requisite capabilityNote: A UE supporting X-1 (or X-2) needs to support X-3a or X-3b (or both) |

 |
| [6] | Samsung | Based on the following RAN1 agreements, a UE can be configured with up to 4 sets of cells for multi-cell scheduling, with each set of cells including up to 4 cells. The up to 4 configured sets of cells for multi-cell scheduling can be associated with different scheduling cells, while only up to *N* sets of cells can be from a same scheduling cell, where *N* can be a UE capability. A DCI format 0\_X/1\_X can schedule one or more PUSCHs or PDSCHs on one or more cells in one set of cells, from the configured sets of cells. The cell combinations, in a set of cells, that a DCI format 0\_X/1\_X schedules can be configured in a table and associated with an index that is indicated in the DCI format 0\_X/1\_X, or can be arbitrary and indicated by FDRA values, where a non-reserved FDRA value for a cell indicates that the cell is scheduled, and a reserved FDRA value for a cell indicates that the cell is not scheduled. Accordingly, the following parameters can be potentially considered as UE capability:1. Maximum number of sets of cells in a PUCCH group (i.e., across all scheduling cells) 🡪 since different scheduling cells are considered, there seems little motivation to introduce a new UE capability for this parameter. The maximum value of 4 sets of cells, as already agreed, can be assumed for all Rel-18 UEs that support multi-cell scheduling;
2. Maximum number of sets of cells from a same scheduling cell 🡪 this is already agreed in RAN1 to be a UE capability. This parameter can be further considered in conjunction with parameter (5) below for a total number of configurable cells for co-scheduling from a same scheduling cell;
3. Maximum number of cells in a set of cells 🡪 since a DCI format schedules only subsets / combinations of cells from a set of cells, there seems little motivation to introduce a UE capability for this parameter. The maximum value of 4 cells in each set of cells, as already agreed, can be assumed for all Rel-18 UEs that support multi-cell scheduling;
4. Maximum number of cells in a/any configured cell combination from a set of cells 🡪 this parameter is related to a legacy UE capability for UL/DL CA. For example, if a UE reports a legacy capability for 2-cell UL CA (e.g., by FG 6-6 “Basic UL NR-NR CA operation”), the UE does not expect to be scheduled by an UL MC-DCI format 0\_X on a cell combination that includes more than 2 UL cells. Therefore, a new UE capability for MC-DCI may not be necessary.
	* When a UE determines a co-scheduled cell combination based on FDRA values, there is no pre-configured list/table of cell combinations provided to the UE. Therefore, the legacy UE capability for DL/UL CA implies a maximum number of non-reserved values for FDRA in a DCI format 0\_X/1\_X supported by the UE.
5. Maximum total number of configurable cells for co-scheduling from a same scheduling cell 🡪 Since Rel-17 supports up to 8 scheduled cells from a same scheduling cell, the UE does not expect to be configured a total number of cells across the *N* sets of cells that exceeds 8 cells. However, each set of cells can include fewer cells, such as 4 sets of cells, each including 2 cells. Therefore, it can be further discussed whether parameter (2) can be combined with or replaced by parameter (5);
6. Maximum total number of cells across cell combinations that are co-scheduled by a DCI format 0\_X/1\_X from a same scheduling cell in a PDCCH monitoring occasion (or in a same slot) 🡪 This parameter is related to a total number of DCI formats that the UE can process in a slot/MO for a same scheduling cell and prepare corresponding PUSCHs/PDSCHs. This parameter is related to FG 18-5 and 18-5b “DL/UL cross-carrier scheduling with different SCS”, and can be further discussed as potential UE capability;
7. Maximum total number of configurable cells for co-scheduling across all sets of cells / scheduling cells 🡪 Since different scheduling cells are considered, similar to parameter (1), there may be little motivation for a new UE capability. This parameter appears to be related to legacy DL/UL CA capability, such as FG 6-5 and 6-6 for “Basic DL/UL NR-NR CA operation”.

**Proposal 1: Further discuss whether/how to introduce UE capability for the following parameters for multi-cell scheduling:*** **Maximum number of sets of cells for multi-cell scheduling from a same scheduling cell;**
* **Maximum total number of configurable cells for co-scheduling, across different sets of cells for multi-cell scheduling, from a same scheduling cell;**
* **Maximum total number of cells across cell combinations that are co-scheduled by a DCI format 0\_X/1\_X from a same scheduling cell in a PDCCH monitoring occasion (or in a same slot).**

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| **Agreement (RAN1#109-e)*** For a UE, the maximum number of cells scheduled by a DCI format 0\_X can be same or different to the maximum number of cells scheduled by a DCI format 1\_X.

**Agreement (RAN1#109-e)*** One value for the maximum number of co-scheduled cells by a DCI format 0\_X in Rel-18 is selected from {3, 4, 8}.
* For a UE, the maximum number of co-scheduled cells by a DCI format 0\_X can be smaller than or equal to the maximum number supported in Rel-18.

**Agreement (RAN1#109-e)*** One value for the maximum number of co-scheduled cells by a DCI format 1\_X in Rel-18 is selected from {3, 4, 8}.
* For a UE, the maximum number of co-scheduled cells by a DCI format 1\_X can be smaller than or equal to the maximum number supported in Rel-18.

**Agreement (RAN1#110bis-e)**Confirm the following working assumption reached in RAN1#110 meeting.**Working Assumption*** The maximum number of co-scheduled cells by a DCI format 1\_X in Rel-18 is 4.
* The maximum number of co-scheduled cells by a DCI format 0\_X in Rel-18 is 4.
* FFS: The maximum number of configurable cells for co-scheduling

**Agreement (RAN1#111)**For a set of cells which is configured for multi-cell scheduling, up to 4 cells within the set of cells are supported.* A DCI format 0\_X/1\_X can schedule PUSCH(s)/PDSCH(s) on a combination of co-scheduled cells among the same set of cells.

**Agreement (RAN1#112)**Following is supported in Rel-18 multi-cell scheduling* A UE can be configured one or multiple sets of cells with each set configured for multi-cell scheduling using DCI format 0\_X/1\_X.
* Up to 4 sets of cells can be configured per PUCCH group.
* When multiple sets of cells are configured,
	+ a cell in one set of cells can’t be included in another set of cells.
	+ n\_CI value is independently configured for each set of cells.
	+ reference cell for counting DCI size and BD/CCE of DCI format 0\_X/1\_X is independently determined for each set of cells.
	+ search space configuration of DCI format 0\_X/1\_X is independently configured for each set of cells.
	+ DCI size of DCI format 0\_X is independently determined for each set of cells.
	+ DCI size of DCI format 1\_X is independently determined for each set of cells.
* The multiple sets of cells can be scheduled by DCI format 0\_X/1\_X from different scheduling cells.
* Up to N sets of cells can be configured and respectively scheduled by DCI format 0\_X/1\_X from a same scheduling cell.
	+ The value of N is reported as UE capability.
	+ An indicator is included in the DCI to indicate the scheduled set of cells,
		- The size of the indicator is equal to ceil(log2(N)), where N is the number of sets of cells.
	+ Unique n\_CI value is configured for each set of cells.
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The following agreement was reached as a compromise for indication of a co-scheduled cell combination in a DCI format 0\_X/1\_X using one of two methods: table-based and FDRA-based. If selection between the two methods is to be based on a UE capability, the first method based on RRC-configured table should be considered as the baseline method and default UE capability, as it leads to more efficient DCI size. **Proposal 2: If a UE capability is to be introduced for selecting the method for indication of co-scheduled cells in a DCI format 0\_X/1\_X, adopt the “table-based” method as the default UE capability.**

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| **Agreement (RAN1#112)**For a set of cells which is configured for multi-cell scheduling using DCI format 0\_X and DCI format 1\_X, support the following: * If table defining combinations of co-scheduled cells for the set of cells is configured,
	+ an indicator in the DCI is included and points to one row of the table.
	+ The table is configured by RRC signaling for the set of cells.
		- Separate tables are configured for downlink scheduling and uplink scheduling
	+ The size of the indicator is equal to ceil(log2(N)), where N is the number of rows in the table.
	+ The max number of rows in the table is 16
	+ The size of the per-cell Type 2 fields for each co-scheduled cell does not change according to the indicated co-scheduled cell combination
	+ The payload size of DCI format 1\_X is derived by UE based on RRC configuration of the active BWP(s) of co-scheduled cell combinations within the set of cells.
		- The payload size of DCI format 1\_X is the same for the active BWP(s) of all the co-scheduled cell combinations and equal to the largest payload size among the active BWP(s) of all the co-scheduled cell combinations determined by the co-scheduled cell combination table.
	+ The payload size of DCI format 0\_X is derived by UE based on RRC configuration of the active BWP(s) of co-scheduled cell combinations within the set of cells.
		- The payload size of DCI format 0\_X is the same for the active BWP(s) of all the co-scheduled cell combinations and equal to the largest payload size among the active BWP(s) of all the co-scheduled cell combinations determined by the co-scheduled cell combination table.
* Otherwise,
	+ The UE determines the actually scheduled cell(s) based on the FDRA field of each cell of the set of cells.
		- For Type 0 FDRA, all 0s indicates the cell is not scheduled.
		- For Type 1 FDRA, all 1s indicates the cell is not scheduled.
	+ The size of the Type 2 fields for each cell does not change according to actually co-scheduled cells.
	+ The payload size of DCI format 0\_X is derived by UE based on RRC configuration of the active BWP(s) of all cells within the set of cells.
	+ The payload size of DCI format 1\_X is derived by UE based on RRC configuration of the active BWP(s) of all cells within the set of cells.
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The following RAN1 agreement describes the UE behavior for monitoring legacy single-cell scheduling DCI (SC-DCI) formats in parallel with the new DCI format 0\_X/1\_X for multi-cell scheduling for a same scheduled cell. In Rel-17, the UE can be configured to monitor different SC-DCI formats for a same scheduled cell in same or different monitoring occasions, without any restriction or UE capability. Since RAN1 has agreed to maintain the Rel-17 PDCCH monitoring limits when DCI formats 0\_X/1\_X are configured, there is no reason to make an exception or restriction for monitoring DCI formats 0\_X/1\_X, so an additional UE capability is not necessary.**Proposal 3: Do NOT introduce a UE capability for monitoring, for any scheduled cell, both DCI formats 0\_X/1\_X and DCI formats 0\_0/1\_0, 0\_1/1\_1, and/or 0\_2/1\_2 (if supported by the UE), either simultaneously or non-simultaneously, from a same scheduling cell.**

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| **Agreement (RAN1#110bis-e)**Confirm below working assumption reached in RAN1#110 meeting with revision.Working Assumption* For any cell within a set of cells which can be co-scheduled by a DCI format 0\_X/1\_X, RAN1 specification supports monitoring the DCI format 0\_X/1\_X and DCI format 0\_0/1\_0, 0\_1/1\_1, and/or 0\_2/1\_2 (if supported by the UE), if configured from a same scheduling cell.
* The DCI format 0\_X/1\_X and the DCI format 0\_0/1\_0/0\_1/1\_1/0\_2/1\_2 can be monitored simultaneously.
* Note: This does not mean a UE is required to support number of BDs/CCEs beyond the Rel-17 limits (i.e., $M\_{PDCCH}^{max,slot,μ}, C\_{PDCCH}^{max,slot,μ}, M\_{PDCCH}^{total,slot,μ}$ and $C\_{PDCCH}^{total,slot,μ}$) for PDCCH candidates for each scheduled cell.

**Agreement (RAN1#111)**Confirm the RAN1#110bis-e working assumption with the following changes:  **Working Assumption**For a set of cells which is configured for multi-cell scheduling, * Existing DCI size budget is maintained on each cell of the set of cells.
* DCI size of DCI format 0\_X/1\_X is counted on one cell among the set of cells.
	+ DCI size of the DCI format 0\_X/1\_X is counted on the reference cell.
* BD/CCE of DCI format 0\_X/1\_X is counted on one cell among the set of cells.
	+ BD/CCE of the DCI format 0\_X/1\_X is counted on the reference cell.
* Same reference cell is used for both DCI format 0\_X and DCI format 1\_X.
* The reference cell is
	+ the scheduling cell if the scheduling cell is included in the set of cells and search space of the DCI format 0\_X/1\_X is configured only on the scheduling cell;
	+ one cell of the set of cells which search space of DCI format 0\_X/1\_X is configured on and associated with the search space of the scheduling cell with the same search space ID if search space of the DCI format 0\_X/1\_X is configured on the cell in addition to the scheduling cell.
		- It is up to gNB on which cell the SS of the DCI format 0\_X/1\_X is configured on.
* To address Rel-17 BD/CCE limit for any given cell (operating the feature under Rel-17 BD/CCE limit)
	+ For the reference cell, a total number of configured BD/CCEs for both DCI formats 0\_X/1\_X and legacy DCI formats (if configured) does not exceed the Rel-17 limits.
	+ For other cells in the sets of cells, Rel-17 limits for PDCCH/DCI monitoring and BD/CCE counting rules for legacy DCI formats (not including DCI formats 0\_X/1\_X) apply
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| [7] | MediaTek | In RAN1 #110be [1], it is agreed that:Agreement:* Confirm below working assumption reached in RAN1#110 meeting.

**Working Assumption*** The maximum number of co-scheduled cells by a DCI format 1\_X in Rel-18 is 4.
* The maximum number of co-scheduled cells by a DCI format 0\_X in Rel-18 is 4.
* …

In RAN1 #111 [2], it is agreed that:Agreement:* For a set of cells which is configured for multi-cell scheduling, up to 4 cells within the set of cells are supported.
	+ A DCI format 0\_X/1\_X can schedule PUSCH(s)/PDSCH(s) on a combination of co-scheduled cells among the same set of cells.

In RAN1 #112 [3], it is agreed that:AgreementFollowing is supported in Rel-18 multi-cell scheduling* A UE can be configured one or multiple sets of cells with each set configured for multi-cell scheduling using DCI format 0\_X/1\_X.
* Up to 4 sets of cells can be configured per PUCCH group.
* …
* Up to N sets of cells can be configured and respectively scheduled by DCI format 0\_X/1\_X from a same scheduling cell.
	+ The value of N is reported as UE capability.
	+ …

We hence have the following proposals:**Proposal 1: For R18 multi-cell scheduling with a single DCI, introduce the following UE capabilities:*** **Supportable maximum number of co-scheduled cells in one set (for DL and UL separately)**
	+ **Candidate values: {2, 3, 4}**
	+ **Type: Per BC**
* **Supportable maximum number of sets in one PUCCH group (for DL and UL separately)**
	+ **Candidate values: {1, 2, 3, 4}**
	+ **Type: Per BC**
* **Supportable maximum number of sets in one cell group (for DL and UL separately)**
	+ **Candidate values: {1, 2, 3, 4}**
	+ **Type: Per BC**
* **Supportable maximum number of sets in one PUCCH group with the same scheduling cell (for DL and UL separately)**
	+ **Candidate values: {1, 2, 3, 4}**
	+ **Type: Per BC**
* **Supportable maximum number of sets in one cell group with the same scheduling cell (for DL and UL separately)**
	+ **Candidate values: {1, 2, 3, 4}**
	+ **Type: Per BC**
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| [8] | Apple | For Rel-18 multi-cell scheduling with a single DCI for PDSCH/PUSCH, in our view, a new UE capability framework to indicate the support of scheduling more than 1 cell should be introduced. As a candidate values under this UE capability, UE can report the maximum number of cells that can be scheduled by a single scheduling cell from {2,3,4}. Maximum value of 1 should not be considered for this UE capability. For up to 1 cell, legacy framework can be used. Furthermore, it can be considered whether a separate capability can be indicated for multiple PUSCH scheduling and multiple PDSCH scheduling from multiple cells.

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| Features | Index | Feature group | Components |
| XX. NR\_MC\_enh-Core | XX-1 | Indicating supported option for scheduling more can one cell with single DCI | Indicating supported option for scheduling more can one cell with single DCI Candidate values set is {2,3,4} |

***Proposal 1: For Rel-18 multi-cell scheduling, a new capability (new FG) should be introduced to indicate the support of multi-cell scheduling using single DCI format**** ***It can be further discussed on whether to support separate capability for multiple PUSCH and multiple PDSCH scheduling***

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| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-1* | *Indicating supported option for scheduling more can one cell with single DCI* | *Indicating supported option for scheduling more can one cell with single DCI* *Candidate values set is {2,3,4}* |

Another aspect related to UE capability is whether the same scheduling cell can be used for scheduling more than 1 set of cells or not. Based on the RAN1 agreement, UE can report the maximum number of sets of cells that can be scheduled by same scheduling cell. For this UE capability indication, a candidate set of values {1,2} can be reported. Furthermore, this can be an optional capability and if not reported, the default capability is that only 1 set of cells can be scheduled by a given scheduling cell.***Proposal 2: For Rel-18 multi-cell scheduling, a new capability should be introduced to indicate the support of number of sets of cells that can be scheduled by the same scheduling cell**** ***This is an optional capability and if not reported, the default value is 1***

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| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-1a* | *Indicating supported number of sets of cells that can be scheduled by same scheduling cell* | *Indicating supported number of sets of cells that can be scheduled by same scheduling cell Candidate values set is {1,2}* |

Furthermore, based on RAN1 agreement, for determining the actually scheduled cells from the set of cells, two options have been agreed. In our view, mandating UE to support both options is not reasonable and it should be a UE capability to report the support for either one or both the options. The candidate values set will include { table-based, FDRA-based}. Furthermore, it can be discussed, if this capability can be optional and if one of the two options can be a default option

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| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-1b* | *Indicating supported option for indication of co-scheduled cells within a set of cells* | *Indicating supported option for indication of co-scheduled cells within a set of cells* *Candidate values set is {table-based,FDRA-based}* |

***Proposal 3: For Rel-18 multi-cell scheduling, a new capability should be introduced to indicate the supported option for indicating the co-scheduled cells within a set of cells.**** ***It can be further discussed whether this is an optional capability and what is the default option***

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| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-1b* | *Indicating supported option for indication of co-scheduled cells within a set of cells* | *Indicating supported option for indication of co-scheduled cells within a set of cells* *Candidate values set is {table-based,FDRA-based}* |

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| [9] | Qualcomm | First of all, multi-cell PDSCH scheduling and multi-cell PUSCH scheduling should be separate features, same as for Rel-16 DL/UL cross-carrier scheduling (FG18-5, FG18-5b). In addition, multi-cell scheduling should not prerequisite cross-carrier scheduling since multi-cell scheduling works even without cross-carrier scheduling.**Proposal 1:*** Introduce separate capabilities for multi-cell PDSCH scheduling and multi-cell PUSCH scheduling
* Capabilities for multi-cell PDSCH scheduling and multi-cell PUSCH scheduling do not prerequisite UE capabilies for R15/16 cross-carrier scheduling (FG6-10, 18-5, 18-5b)

There are various DL/UL-CA configurations including intra/inter-bands, FDD/TDD, multiple SCSs, inter/intra-FR, etc. It should be possible to support multi-cell scheduling for a limited set of bands in a DL/UL-CA configurations. Three options can be considered:* Option 1: a UE reports support for one or multiple combinations of {a band for scheduling cell, a set of band(s) for scheduled cells} for multi-cell scheduling
* Option 2: a UE reports support for one or multiple combinations of {a carrier type for scheduling cell, a carrier type for scheduled cells} for multi-cell scheduling
	+ Carrier type: one from {FDD, TDD, Unlicensed, FR2}
* Option 3: a UE reports support for one or multiple combinations of {a SCS for scheduling cell, a SCS for scheduled cells} for multi-cell scheduling

Example is illustrated in Fig. 1.Fig. 1 Example of multi-cell scheduling for a subset of cells/bands in a CA band combinationIt is essential to incorporate one of the above options. Among the three, considering the fact that UE features for legacy cross-carrier scheduling were based on SCS, Option 3 could be straightforward. Within each combination, the UE should be able to report the max number of cells that can be in the set of cells for multi-cell scheduling by a DCI format. In addition, RAN1 agreed to support UE capability indicating the number of sets of cells for multi-cell scheduling by respective DCI formats from the same scheduling cell. This should also be part of the UE capability for basic multi-cell scheduling.**Proposal 2:** For multi-cell PDSCH or PUSCH scheduling:* For a given DL-CA or UL-CA band combination, the UE reports support for:
	+ Opt. 1: one or multiple combinations of {a band for scheduling cell, a set of band(s) for scheduled cells} for multi-cell scheduling by a single DCI format
	+ Opt. 2: one or multiple combinations of {a carrier type for scheduling cell, a carrier type for scheduled cells} for multi-cell scheduling by a single DCI format
		- Carrier type: one from {FDD, TDD, Unlicensed, FR2}
	+ Opt.3: one or more combination(s) of {a SCS for scheduling cell, a SCS for scheduled cells} for multi-cell scheduling by a single DCI format
* For each combination in either of Options, the UE also reports:
	+ Max number of cells in a set of cells configured for multi-cell scheduling by a DCI format
		- Candidate values: {2, 3, 4}
	+ Max number of sets of cells configured for multi-cell scheduling a same scheduling cell
		- Candidate values: {1, 2, 3, 4}

In the following, we assume Option 3 is adopted and a UE can report one or more combination(s) that the UE supports multi-cell scheduling per CA band combination.RAN1 agreed two options for identifying actually co-scheduled cell(s) by a single DCI format. Since the options are quite different, the UE should be able to indicate support of either or both of them. To make the multi-cell scheduling work, the indication should be part of basic UE capability for multi-cell scheduling.It was agreed that Antenna port(s) for DCI format 1\_X and Antenna port(s), TPMI, and SRI for DCI format 0\_X are configurable fields between Type-1A and Type-2. Because of potential IODT problem, it is not always true that this configurability is available. Therefore, UE should be able to indicate support either or both of Type-1A mode and Type-2 mode. If a UE indicate support of both, the network can configure either of the modes.Support of Type-1/2/3 HARQ-ACK codebook was agreed. To make the multi-cell scheduling work, at least one type of HARQ-ACK codebook construction is necessary. A UE should be able to indicate support either or both of Type-1 and Type-2 HARQ-ACK codebook constructions. Type-3 HARQ-ACK codebook should be based on a separate optional UE capability.**Proposal 3:** For a given combination of {a SCS for scheduling cell, a SCS for scheduled cells} in a CA band combination that the UE indicates support of multi-cell PDSCH scheduling by a single DCI format 1\_X: * + For co-scheduled cell(s) identification, the UE reports support for either or both of:
		- Based on the co-scheduled indicator field
		- Based on FDRA fields
	+ For HARQ-ACK codebook, the UE reports support for either or both of:
		- Type-1 HARQ-ACK codebook
		- Type-2 HARQ-ACK codebook based on a concatenation of two sub-codebooks
	+ For Antenna port(s) field, the UE reports support for either or both of:
		- Type-1A (common field for all the scheduled cells)
		- Type-2 (per scheduled cell field)

**Proposal 4:** For a given combination of {a SCS for scheduling cell, a SCS for scheduled cells} in a CA band combination that the UE indicates support of multi-cell PUSCH scheduling by a single DCI format 0\_X: * + For co-scheduled cell(s) identification, the UE reports support for either or both of:
		- Based on the co-scheduled indicator field
		- Based on FDRA fields
	+ For Antenna port(s) field, Precoder and Number of Layers, and SRS resource indicator, the UE reports support for either or both of:
		- Type-1A (common field for all the scheduled cells)
		- Type-2 (per scheduled cell field)

RAN1 agreed that specification supports simultaneous monitoring of DCI format 0\_X/1\_X as well as legacy DCI formats 0\_0/1\_0, 0\_1/1\_1, and/or 0\_2/1\_2 (if supported by the UE), if configured from a same scheduling cell, simultaneously. However, this is quite unrealistic scenario while requires extra complexity on PDCCH monitoring. Our view of the basic operation of multi-cell scheduling is following:* Case 1: When a scheduling cell for multi-cell scheduling for a set of cells is part of the cells in the set (i.e., when the scheduling cell is the reference cell that counts BD/CCE/DCI-size of the DCI format 0\_X/1\_X), the UE should be able to monitor DCI format 0\_0/1\_0 on the scheduling cell for self-scheduling, as well as DCI format 0\_X/1\_X for the set of cells
* Case 2: When a schedulin cell for multi-cell scheduling for a set of cells is NOT part of the cells in the set (i.e., when the scheduling cell is NOT the reference cell that counts BD/CCE/DCI-size of the DCI format 0\_X/1\_X), the UE does not need to monitor any other DCI formats for the set of cells

In other words, we consider monitoring PDCCH for non-fallback legacy DCI formats for a cell in the set of cells configured for multi-cell scheduling by a DCI format 0\_X/1\_X is not part of the basic operation. Monitoring legacy non-fallback DCI formats, as well as DCI format 0\_X/1\_X, should be optionally supported.Case 1 exampleCase 2 exampleFig. 2 Case 1 and Case 2 of basic PDCCH monitoring framework for multi-cell schedulingMonitoring legacy non-fallback DCI formats should be split into two cases: * (i) monitoring legacy non-fallback DCI formats for the reference cell
	+ i.e., only for the cell where BD/CCE/DCI-size of DCI format 0\_X/1\_X is counted
* (ii) monitoring legacy non-fallback DCI formats for any cell of the set of cells

The reason is that (ii) effectively increases the number of BDs/CCEs/DCI-sizes that a UE has to support for a cell in the set as we have explained in Section 5.1 of R1-2301429. Having said that, we consider the UE should be able to indicate optional support of non-fallback DCI formats for the reference cell or for any cell in the set.**Proposal 5:** For a given combination of {a SCS for scheduling cell, a SCS for scheduled cells} in a CA band combination that the UE indicates support of multi-cell scheduling:* The UE indicates support for:
	+ Monitoring DCI formats 1\_1/1\_2 for a cell, as well as DCI format 1\_X for a set of cells:
		- Candidate values: {no, for the reference cell, for any cell}
* The UE indicates support for:
	+ Monitoring DCI formats 0\_1/0\_2 for a cell, as well as DCI format 0\_X for a set of cells:
		- Candidate values: {no, for the reference cell, for any cell}

Regarding the number of unicast DCI to process, legacy FGs (FG3-1/18-5/5b/5c/5d) counts the number of unicast DCI per scheduled cell per scheduling cell span/slot. Now for multi-cell scheduling, each DCI can schedule one or multiple cell(s) in each set of cells where actual co-scheduled cell(s) by each DCI is up to the network. Therefore, for multi-cell scheduling, the number of unicast DCI to process should be defined per set of cells for multi-cell scheduling per scheduling cell span/slot. Otherwise, the number of unicast DCIs per scheduling cell per scheduling cell span/slot varies depending on the number of cells each DCI schedules, making the UE to identify the maximum possible number of unicast DCIs at a span/slot unpredictable.At least as for basic framework, following should be feasible.**Proposal 6:** For multi-cell scheduling, * Number of unicast DCI to process for a set of cells for multi-cell PDSCH scheduling
	+ From lower SCS to higher SCS, or same SCS
		- One unicast DCI per slot of scheduling cell for a set of cells configured for multi-cell PDSCH scheduling for FDD/TDD scheduling cell
	+ From higher SCS to lower SCS
		- One unicast DCI per N consecutive slots of scheduling cell for a set of cells configured for multi-cell PDSCH scheduling for FDD/TDD scheduling cell, where:
			* N = 2 for (30, 15)
			* N = 4 for (60, 15), (120, 30)
			* N = 8 for (120, 15)
* Number of unicast DCI to process for a set of cells for multi-cell PUSCH scheduling
	+ From lower SCS to higher SCS, or same SCS
		- One unicast DCI per slot of scheduling cell for a set of cells configured for multi-cell PUSCH scheduling for FDD scheduling cell
		- Two unicast DCIs per slot of scheduling cell for a set of cells configured for multi-cell PUSCH scheduling for TDD scheduling cell
	+ From higher SCS to lower SCS
		- One unicast DCI per N consecutive slots of scheduling cell for a set of cells configured for multi-cell PUSCH scheduling for FDD scheduling cell, and
		- Two unicast DCIs per N consecutive slots of scheduling cell for a set of cells configured for multi-cell PUSCH scheduling for TDD scheduling cell, where:
			* N = 2 for (30, 15)
			* N = 4 for (60, 15), (120, 30)
			* N = 8 for (120, 15)

Similar clarifications are necessary for span-based PDCCH monitoring (FG3-5b, 11-2, 22-8c, 22-8d) and slot-group-based PDCCH monitoring (FG24-4, 24-5). Whether/what new FGs to introduce should be discussed once we have clear understanding on the basic feature as above.For multi-cell scheduling, both FDRA Type-0 and Type-1 introduce new mechanisms. These should be separate UE features.**Proposal 7:*** New FDRA features are introduced for multi-cell PDSCH scheduling and multi-cell PUSCH scheduling:
	+ 1) FDRA Type-0 configuration 3 (larger RBG size)
	+ 2) FDRA Type-1 granularity of 2, 4, 8, or 16 consecutive RBs based RIV

Note: these are only for PDSCH(s) scheduled by DCI format 1\_X and only for PUSCH(s) scheduled by DCI format 0\_XRAN1 agreed to support priority indicator for DCI format 0\_X and 1\_X. There are UE features for priority indicator in a DL DCI and in a UL DCI as FG11-4, 11-4a, 11-4b, 12-1, and 12-1a. However, these are not applicable to DCI format 1\_X and DCI format 0\_X.* FG11-4/11-4a are for the case where only DCI format 0\_1/1\_1 or only DCI format 0\_2/1\_2 is configured.
* FG11-4b indicates support of operation with mixed DCI formats (1\_1 and 1\_2) with priority indication field.
* FG12-1 is for the case where dynamic indication of priority level of dynamic PUSCH with a single DCI format. Although there is no specific description of which DCI format this applies, it is clear from FG12-1a that this single DCI format is either DCI format 0\_1 or DCI format 0\_2.
* FG12-1a indicates support of operation with mixed DCI formats (0\_1 and 0\_2) with priority indication field.

With the understanding, we need new FGs to accommodate DCI format 1\_X and DCI format 0\_X with priority indication field.For mixed DCI formats with priority indication field with DCI format 1\_X or 0\_X, we do not think it is necessary to support three DCI formats with priority indication fields (1\_X + 1\_1 + 1\_2, or 0\_X + 0\_1 + 0\_2). The mixed DCI formats with priority indication field for Rel-18 multi-cell scheduling can be 1\_X + (1\_1 or 1\_2), and 0\_X + (0\_1 or 0\_2).**Proposal 8:*** UE features for DL priority indicator in a DCI format 1\_X should be introduced:
	+ 1) Two HARQ-ACK codebooks with different priorities with up to one sub-slot based HARQ-ACK codebook enabled for DCI format 1\_X
	+ 2) Two HARQ-ACK codebooks with different priorities with two sub-slot based HARQ-ACK codebooks enabled for DCI format 1\_X:
	+ 3) Mixed DCI formats including DCI format 1\_X for DL priority indication in a BWP
		- Support of priority indication field in DCI formats (1\_1 or 1\_2) and 1\_X

**Proposal 9:*** UE features for UL priority indicator in a DCI format 0\_X should be introduced:
	+ 1) UL priority indication in DCI with DCI format 0\_X
		- Support of priority indicator field configured in DCI format 0\_X
	+ 2) Mixed DCI formats including DCI format 0\_X for UL priority indication
		- Support priority indication field in DCI formats (0\_1 or 0\_2) and 0\_X

One shot HARQ-ACK feedback (Type-3 HARQ-ACK codebook) can be triggered by DCI format 1\_1 with FG10-16 and by DCI format 1\_2 with FG25-4. There should be aonther FG for triggering by DCI format 1\_X. Relevant to this, phy priority handling (same as FG25-5) and enhanced Type-3 HARQ-ACK feedback (same as FG25-6) by a DCI format 1\_X should be enabled by another set of FGs.**Proposal 10:*** UE features for Type-3 HARQ-ACK feedback triggered by DCI 1\_X should be introduced:
	+ 1) One-shot HARQ-ACK feedback by DCI 1\_X:
		- Type-3 HARQ-ACK feedback triggered by a DCI format 1\_X scheduling one or more PDSCHs
		- Type-3 HARQ-ACK feedback triggered by a DCI format 1\_X without scheduling a PDSCH using reserved FDRA values
	+ 2) PHY priority handling for one-shot HARQ-ACK feedback by DCI 1\_X:
		- Support transmission of Type-3 HARQ-ACK codebook using the first or second PUCCH configuration based on PHY priority indication in the triggering DCI format 1\_X
	+ 3) Enhanced Type-3 HARQ-ACK codebook feedback triggered by a DCI format 1\_X

FG25-7 specifies that HARQ-ACK re-transmission can be triggered by DCI format 1\_1 and DCI format 1\_2. To enable this by using DCI format 1\_X, corresponding new FG is necessary.**Proposal 11:*** UE feature for HARQ-ACK re-transmission triggered by DCI format 1\_X should be introduced

FG18-5 indicates support of SCell dormancy indication by DCI format 0\_1/1\_1. There must be a corresponding FG for SCell dormancy indication by DCI format 0\_X/1\_X. Since now we are willing to enable multi-cell scheduling for DL and UL separately, it is preferred to have the feature for DL and UL separately.**Proposal 12:*** UE features for SCell dormancy indication within active time by DCI format 1\_X and DCI format 0\_X should be introduced
	+ 1) SCell dormancy indication within active time by DCI 1\_X:
	+ 2) SCell dormancy indication within active time by DCI 0\_X:

FG19-2 indicates support of cross slot scheduling with minimum scheduling offset K0/K2 by DCI format 0\_1/1\_1. It is necessary to have another FG indicating support of dynamic indication of applicable minimum scheduling restriction by DCI format 0\_X and 1\_X.**Proposal 13:*** UE features for cross-slot scheduling by DCI format 1\_X and DCI format 0\_X should be introduced
	+ 1) Dynamic indication of applicable minimum scheduling restriction by DCI format 1\_X
	+ 2) Dynamic indication of applicable minimum scheduling restriction by DCI format 0\_X

FG23-1-1b and FG23-10-1b specify the UE capabilieis for unified TCI with joint and separate DL/UL TCI updates by a DCI format. According to their description, the FGs are limited to DCI format 1\_1. In order to support the features by DCI format 1\_X, it is necessary to introduce the FGs for joint DL/UL TCI update and for separate DL/UL TCI update, respectively.**Proposal 14:*** UE features for Unified-TCI indication by DCI format 1\_X should be introduced
	+ 1) Unified TCI with joint DL/UL TCI update with DCI-based TCI state indication for DCI format 1\_X:
		- TCI state indication for update and activation
			* b) MAC-CE + DCI-based TCI state indication (use of DCI format 1\_X with DL assignment(s)),
			* c) MAC-CE + DCI-based TCI state indication (use of DCI format 1\_X without DL assignment)
		- The min beam application time in Y symbols per SCS
		- The max number of MAC-CE activated joint TCI states per CC in a band
	+ 2) Unified TCI with separate DL/UL TCI update with DCI-based TCI state indication for DCI format 1\_X:
		- TCI state indication for update and activation
			* b) MAC-CE + DCI-based TCI state indication (use of DCI format 1\_X with DL assignment(s)),
			* c) MAC-CE + DCI-based TCI state indication (use of DCI format 1\_X without DL assignment)
		- The min beam application time in Y symbols per SCS
		- The max number of MAC-CE activated DL TCI states per CC in a band
		- The max number of MAC-CE activated UL TCI states per CC in a band
 |
| [10] | DOCOMO | **Co-scheduled cell indication as basic feature**Regarding co-scheduled cell indication in DCI format 0\_X/1\_X, the following agreements were made at the RAN1#112 meeting.

|  |
| --- |
| **Agreement**For a set of cells which is configured for multi-cell scheduling using DCI format 0\_X and DCI format 1\_X, support the following: * If table defining combinations of co-scheduled cells for the set of cells is configured,
	+ an indicator in the DCI is included and points to one row of the table.
	+ The table is configured by RRC signaling for the set of cells.
		- Separate tables are configured for downlink scheduling and uplink scheduling
	+ The size of the indicator is equal to ceil(log2(N)), where N is the number of rows in the table.
	+ The max number of rows in the table is 16
	+ The size of the per-cell Type 2 fields for each co-scheduled cell does not change according to the indicated co-scheduled cell combination
	+ The payload size of DCI format 1\_X is derived by UE based on RRC configuration of the active BWP(s) of co-scheduled cell combinations within the set of cells.
		- The payload size of DCI format 1\_X is the same for the active BWP(s) of all the co-scheduled cell combinations and equal to the largest payload size among the active BWP(s) of all the co-scheduled cell combinations determined by the co-scheduled cell combination table.
	+ The payload size of DCI format 0\_X is derived by UE based on RRC configuration of the active BWP(s) of co-scheduled cell combinations within the set of cells.
		- The payload size of DCI format 0\_X is the same for the active BWP(s) of all the co-scheduled cell combinations and equal to the largest payload size among the active BWP(s) of all the co-scheduled cell combinations determined by the co-scheduled cell combination table.
* Otherwise,
	+ The UE determines the actually scheduled cell(s) based on the FDRA field of each cell of the set of cells.
		- For Type 0 FDRA, all 0s indicates the cell is not scheduled.
		- For Type 1 FDRA, all 1s indicates the cell is not scheduled.
	+ The size of the Type 2 fields for each cell does not change according to actually co-scheduled cells.
	+ The payload size of DCI format 0\_X is derived by UE based on RRC configuration of the active BWP(s) of all cells within the set of cells.
	+ The payload size of DCI format 1\_X is derived by UE based on RRC configuration of the active BWP(s) of all cells within the set of cells.
 |

Based on the agreement, two methods are supported for co-scheduled cell indication in DCI format 0\_X/1\_X; one is co-scheduled cell indicator field-based indication, and another is FDRA field-based indication. Which indication method to apply can be configured by NW, i.e., if combinations table of co-scheduled cells for the set of cells is configured by RRC, co-scheduled cell indicator field-based indication is applied, otherwise FDRA field-based indication is applied. Of course, UE should support at least one of them for multi-cell scheduling feature, however, it is unclear whether UE should support both co-scheduled cell indicator and FDRA field-based indication. Co-scheduled cell indicator-based indication can optimize the field sizes of Type 2 fields by repurposing the field for each cell when the maximum number of co-scheduled cells for the set of cells is smaller than the number of cells included in the set of cells. On the other hand, it was concerned that such repurposing operation may increase the complexity at UE, and hence FDRA-based indication which does not require such repurposing of DCI fields was also supported. In that sense, at least UE supporting multi-cell scheduling feature should support FDRA-based indication.It should be noted that if it is up to UE to support which co-scheduled cell indicator-based and/or FDRA-based indication, it may result in the fragmentation. This implies that NW has to configure/schedule based on the reported capability which indication method is supported by a UE and it would increase the complexity at NW. Therefore, it is preferable to define at least one of them as the basic feature for multi-cell scheduling.**Proposal 1:****For co-scheduled cell indication in DCI format 0\_X/1\_X, at least one of co-scheduled cell indicator-based indication or FDRA field-based indication should be supported as basic feature.*** **FDRA-based indication can be the basic feature for multi-cell scheduling.**

**Relation between scheduling cell and set of calls/UL and DL**Given that the UE capability for CA can be different between UL and DL, it should be considered that the support of multi-cell scheduling by DCI format 0\_X and 1\_X can be reported separately. Furthermore, similar to the UE features for legacy cross-carrier scheduling, support of multi-cell scheduling can be reported separately depending on whether scheduling cell is included in the set of cells or whether scheduling cell and co-scheduled cells are configured with the same SCS/carrier type.Then, based on the agreements so far, it is unclear whether UE can report different maximum number of co-scheduled cells and set of cells between UL and DL. As stated above, the maximum number of CCs UE supports can be different between UL and DL, it seems reasonable to allow UE reporting different maximum number of co-scheduled cells for UL and DL. On the other hand, for the maximum number of set of cells, the total number of supporting sets for UL and DL should be reported by a UE while the set(s) of cells (number of sets and the cells included in the set(s) of cells) can be appropriately configured for UL and DL separately by NW based on the reported capability for supporting number of CCs and co-scheduled cells for UL and DL.**Proposal 2:****For a UE supporting multi-cell scheduling,** * + **support of multi cell scheduling can be reported separately depending on whether scheduling cell is included in co-scheduled cells.**
	+ **support of multi cell scheduling can be reported separately depending on whether SCS/carrier type of scheduling cell and co-scheduled cells are the same.**
	+ **supporting maximum number of set of cells should be the unified value for UL and DL.**
	+ **supporting maximum number of co-scheduled cells can be separately reported between UL and DL.**

**HARQ-ACK codebook type as basic feature**

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| **Agreement**Confirm below working assumption:**Working Assumption**HARQ-ACK codebook types (Type-1, Rel-15 Type-2, Rel-16 Type-3, Rel-17 Type-3) are applicable when multi-cell PDSCH scheduling is configured. |

Similar to the discussion above for co-scheduled cell indication, at least one type of HARQ-ACK codebook generation for multi-cell PDSCH scheduling needs to be supported by a UE which supports multi-cell scheduling feature, however, it is unclear whether the UE should support all types of codebook for multi-cell scheduling. Accordingly, similar to co-scheduled cell indication, we should clarify the basic feature on HARQ-ACK codebook type.Considering that Type-1 and Type-2 codebooks are supported as mandatory feature for Rel-15 UEs, both of them can be the basic feature for multi-cell PDSCH scheduling while the support of Type-3 and enhanced Type-3 codebook for multi-cell scheduling can be reported with other UE feature than basic features for multi-cell scheduling as anyway support of Type-3 and enhanced Type-3 HARQ-ACK codebook are optional. Given the enhancements from previous releases, no/little enhancements are specified for Type-1 codebook while some enhancements are specified for Type-2 codebook, e.g., sub-codebook generation, HARQ-ACK information bits for each DCI and DAI counting, etc. Therefore, it can be discussed whether the support of Type-2 HARQ-ACK codebook for multi-cell scheduling is part of basic feature or optional.**Proposal 3:****For multi-cell PDSCH scheduling with DCI format 1\_X, at least one type of HARQ-ACK codebook generation should be supported as basic feature.*** **Type-1 HARQ-ACK codebook can be the basic feature for multi-cell scheduling, and whether Type-2 HARQ-ACK codebook can also be the basic feature for multi-cell scheduling or not can be discussed.**
 |
| [11] | Ericsson | Below we provide a few initial comments. 1. RAN1 agreed to following two types of indication of co-scheduled cells via DCI 1\_X/0\_X.
	* Alt 1: Explicit field for indication of co-scheduled cells
	* Alt 2: Indication Via FDRA field

As discussed during WI discussions, either all UEs supporting DCI 1\_X/0\_X based scheduling should support both indication mechanisms or at least one common mechanism to avoid unnecessary implementation complexity (e.g. at the gNB). Considering this and UE impact, we think Alt 2 should be considered for support in the basic functionality. For Indication of co-scheduled cells via DCI 1\_X/0\_X, at least ‘Indication via FDRA’ is supported in the basic functionality. 1. RAN1 also agreed to support multiple sets of serving cells that can be scheduled using DCI 1\_X/0\_X from a same scheduling cell. The basic functionality would support one set per scheduling cell for downlink/uplink and additional values can be reported using additional capability signaling.

Maximum number of sets that can be supported per scheduling cell is included in the FG. 1. Regarding pre-requisites (especially legacy cross-carrier scheduling), it is preferable to discuss on a case-by-case basis. For example, a UE may support DCI 1\_X to support up to four cells while the UE may or may not have the capability (e.g. due to BDs) to support cross-carrier scheduling using legacy CIF for the same case. If UE indicates support for both multi-cell scheduling via DCI 1\_X/0\_X and cross-carrier scheduling, the UE should support DL/UL reception on a cell in the set also using legacy DCI formats with CIF.

Support of DL (UL) reception on a cell within the set of cells via cross-carrier scheduling with DCI 1\_1/1\_2 (0\_1/0\_2) with CIF from the scheduling cell, if UE indicates support for cross-carrier scheduling.1. At least slot-based monitoring for DCI 1\_X/0\_X should be in the basic functionality.

Slot-based PDCCH monitoring on the scheduling cell on which DCI 1\_X/0\_X is monitored should be assumed in basic functionality. |
| [12] | Huawei, HiSilicon | Monitoring DCI format 0\_X/1\_X and legacy DCI formats (DCI format 0\_0/1\_0/0\_1/1\_1/0\_2/1\_2) from a same scheduling cell has been agreed to be supported in previous meetings, as shown in the following.

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| **Agreement**Confirm below working assumption reached in RAN1#110 meeting with revision.**Working Assumption*** For any cell within a set of cells which can be co-scheduled by a DCI format 0\_X/1\_X, RAN1 specification supports monitoring the DCI format 0\_X/1\_X and DCI format 0\_0/1\_0, 0\_1/1\_1, and/or 0\_2/1\_2 (if supported by the UE), if configured from a same scheduling cell.
* The DCI format 0\_X/1\_X and the DCI format 0\_0/1\_0/0\_1/1\_1/0\_2/1\_2 can be monitored simultaneously.
* Note: This does not mean a UE is required to support number of BDs/CCEs beyond the Rel-17 limits (i.e., $M\_{PDCCH}^{max,slot,μ}, C\_{PDCCH}^{max,slot,μ}, M\_{PDCCH}^{total,slot,μ}$ and $C\_{PDCCH}^{total,slot,μ}$) for PDCCH candidates for each scheduled cell.
 |

This feature is useful to enable different traffic/services at the same time for a same UE without always relying on a DCI format with relatively large DCI size.On the other hand, there are difference between the potential legacy DCI formats that are to be simultaneously used with the new DCI format, in terms of UE implementations. For a same legacy DCI format, it may be or even required to be able to be used for self-scheduling. For example, considering single DCI is a non-fallback DCI, it is necessary to monitor legacy DCI formats such as DCI format 0\_0/1\_0 for self-scheduling and DCI format 0\_X/1\_X to maintain transmission reliability, which can be served as a basic UE capability.While it is also possible for a legacy DCI format to be used for cross-carrier scheduling, since the PDCCH capacity in scheduling cell is expected to be larger than other scheduled cells and data part can be conveyed on scheduled cell(s). In this case, compared to multi-cell scheduling together with a legacy DCI for self-scheduling especially fall-back DCI formats, more cross-carrier configuration and UE processing are required, including separate BD/CCE and DCI size budget counting per scheduled cell etc.As multi-carrier scheduling with a single DCI is not a simple extension of cross-carrier scheduling, support of multi-carrier scheduling does not mean that the UE directly supports cross-carrier scheduling, which has adds-on UE implementation thus as well as complexity. Cross-carrier scheduling is also a later feature introduced than self-carrier scheduling, when different SCS scheduling is considered. Thus, the simultaneous use of cross-carrier scheduling by legacy DCI format with multi-carrier scheduling can have different implementations, UE complexity and commercial support compared to multi-cell scheduling together with a legacy DCI for self-scheduling.***Proposal 1:*** *Support of the following as separate UE capabilities:** *Simultaneously monitoring DCI format 0\_X/1\_X and legacy DCI format(s) where the legacy DCI format(s) is for self-carrier scheduling*
* *Simultaneously monitoring DCI format 0\_X/1\_X and legacy DCI format(s) where the legacy DCI format(s) is for cross-carrier scheduling.*
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## **Discussion**

**Question 2-1:**

* **Regarding the component 1 in FGs 49-1/1a/1b and 49-2/2a/2b, companies are encouraged to provide views on whether to separate FG for DCI format 0\_3 and 1\_3**
	+ Yes: vivo, OPPO, ZTE, Nokia/NSB
	+ No: QC

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| Company | Comment |
| Qualcomm | It is true that single FG11-1 indicates support for DCI format 0\_2 and 1\_2 for the same cell. It was because URLLC DCI formats can be used for primary cell scheduling. For CA, by default, UE capabilities are separate for DL CA and UL CA. Therefore, it does not make sense to combine DCI formats for DL and UL multi-cell scheduling. Support of UL CA so far is not as wide as DL CA in the market. If we combine 0\_3 and 1\_3, there will be less chances to enable multi-cell scheduling for DL due to the limitation of UL CA. In future, support of UL CA maybe wider, but it would still be subset of DL CA configuration. Even for this case, there is no benefit to couple support of 0\_3 and 1\_3. |
| MTK | We support to have separate FG for DCI format 0\_3 and 1\_3. |
| Apple | We tend to share similar views as QC and would prefer to have separate FG for DCI format 0\_3 and DCI format 1\_3 |
| LGE | We also have similar view with other companies that it is reasonable to have separate FG for DCI format 0\_3 and 1\_3. |
| Nokia/NSB | We think there should be separate indication for 0\_3 and 1\_3, but we don’t necessarily think there needs to be a separate capability. It may be easer to have more candidate values provided for the number of set of cells for 0\_3 & 1\_3, with having overall also the number of set of cells in the primary and secondary PUCCH cell group (this seems to be currently missing here). Why we think it would be better to have this couple in a single capability (but with independent UE capability indication on the number of sets etc. for UL & DL) is the relation to (a) different SCS for the scheduling cell and (b) number of sets scheduled from a single scheduling cell. When having this combined, it will be easier to note what the UE actually supports.  |

**Question 2-2a:**

* **Regarding the components 2/3 in FGs 49-1/1a and 49-2/2a, companies are encouraged to provide views on whether to separate FG for the case when a scheduling cell is not included in a set of cells with same SCS/carrier type between scheduling cell and cells in the set (i.e., whether to support separate FGs 49-1a/2a)**
	+ Yes: Rapporteur

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| Company | Comment |
| Qualcomm | We would like to understand the intention of the question – is the proposal to have a separate FGs for (1) scheduling cell included in a set of cells, and (2) scheduling cell not included in the set of cells? This depends on some other aspects, e.g., whether to prerequisite FG6-10 (CCS with same SCS).From our point of view, in any FG49-x, FG6-10 should not be prerequisite. The reason is that multi-cell scheduling can work with DCI format 0\_3 or 1\_3 without using DCI format 0\_1/0\_2/1\_1/1\_2 with CIF for cross-carrier scheduling. It is possible for a UE to indicate support of both CCS and multi-cell scheduling. But it should not be prerequisite.If FG6-10 is not prerequisite, we are OK to have a single FG indicating support for multi-cell PDSCH or PUSCH scheduling on a scheduling cell included/not-included in the set of cells with same SCS/carrier-type between scheduling cell and cells in the set. If FG6-10 is prerequisite, then we need separation of FG49-1 and FG49-1a, or FG49-2 and FG49-2a. |
| MTK | Yes (support to have separate FGs 49-1a/2a) |
| Apple | Yes, agree to have separate FGs for the case when a scheduling cell is not included in a set of cells with same SCS/carrier type between scheduling cell and cells in the set |
| LGE | Yes, (to have separate FG for the case when scheduling cell is not in the set of cells) considering the aspect of (reference cell for) SS linking, BD/CCE counting, and DCI size counting. |
| Nokia/NSB | No. We don’t think this is needed, as the issue in the scheduling is the same SCS and not necessarily if the scheduled cell is included in the scheduled cell group or not.  |

**Question 2-2b:**

* **Regarding the components 2/3 in FGs 49-1/1a/1b and 49-2/2a/2b, companies are encouraged to provide views on whether to separate FG for the case when a scheduling cell is not included in a set of cells with different SCS/carrier type between scheduling cell and cells in the set (i.e., whether to support separate FGs 49-1b/2b)**
	+ Yes: QC, DCM

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| --- | --- |
| Company | Comment |
| Qualcomm | Agree in principle, but the proposal is not sufficient.A UE should be able to indicate which SCS can be used for scheduling cell and which SCS can be used for the set of scheduled cells. Low-to-high and high-to-low are quite different. In addition, there are many SCSs now – including 480kHz and 960kHz. Just low-to-high or high-to-low is insufficient.Same as our answer to Question 2-2a, we think FG18-5 should not be prerequisite.  |
| MTK | Yes (support to have separate FGs 49-1b/2b). Open to have more SCS combination indications as mentioned by QC. |
| Apple | Yes, agree to have separate FG for the case when a scheduling cell is not included in a set of cells with different SCS/carrier type between scheduling cell and cells in the set |
| LGE | Yes, (to have separate FG for the case when scheduling cell is with different SCS/carrier type) as for CCS with same/different SCS between scheduling cell and scheduled cell. |
| Nokia/NSB | May not be needed, but could be directly deduced from the UE capability of cross-carrier scheduling of different SCS. But if we have a capability, then such capability should not be separate for UL & DL (i.e. 0\_3 and 1\_3) but a generic scheduling capability, such as:

|  |  |  |
| --- | --- | --- |
| 49-1a | Multi-cell PDSCH and/or PUSCH scheduling for the same and different SCS of scheduling and scheduled cells  | UE supporting the Multi-cell PDSCH and/or PUSCH scheduling of 49-1 also for the case of different SCS between scheduling cell and scheduled cells* + Note: this does not include a set of cells including the PCell.
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**Question 2-3:**

* **Regarding the component 4 in FGs 49-1/1a/1b and 49-2/2a/2b, companies are encouraged to provide views on whether to report following for DL and UL separately (i.e., whether to report the number as a component in FGs 49-1/1a/1b and 49-2/2a/2b or as a unified FG similar to FG 49-4)**
	+ **Max number of co-scheduled cells supported by UE:** **Candidate value set of {[2, 3, 4]}**

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | Yes, should be separated.One comment: we think the component should be “Max number of co-scheduled cells supported by a DCI format for the UE”. |
| MTK | Yes, should be separated. |
| Apple | Yes, agree to report separately  |
| LGE | Yes, (to be separated)  |
| Nokia/NSB | Support |

**Question 2-4:**

* **Regarding the component 5 in FGs 49-1/1a/1b and 49-2/2a/2b and FG 49-4, companies are encouraged to provide views on whether to report followings for DL and UL separately (i.e., whether to report the numbers as components in FGs 49-1/1a/1b and 49-2/2a/2b or as a unified FG 49-4)**
	+ **Max number of sets of cells supported by UE in total: Candidate value set of {[2, 3, 4]}**
	+ **Max number of sets of cells supported by UE for a same scheduling cell: Candidate value set of {[1, 2, 3, 4]}**

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | We think FG49-4 should be reported in each FGs 49-1/1a/1b/2/2a/2b. These aspects cannot be decoupled from the support of same/different SCSs for scheduling/scheduled cells.  |
| MTK | Yes, report for DL and UL separately. |
| Apple | Yes, agree to report separately. Regarding, the candidate value set for max number of sets of cells supported by UE in total, just to clarify, these are optional/additional values. If not reported, by default, 1 set of cells is supported |
| LGE | Yes, (to be separated)  |
| Nokia/NSB | See our comments to the split of UL & DL above. We think we need slightly more differentiation including: * + Max number of sets (a) per PUCCH cell and (b) in total (or [1...4] for the primary group, [0...4] for the secondary PUCCH group and [1...8] in total for the UE. 1..4 is only for the PUCCH group limit – but not the limit in total
	+ We agree with 1...4 for the maximum number of cells scheduled by a single scheduling cell

It is not clear yet whether separate capabilities are the right direction, instead of combining most functionality in a single capability and differentiating by means of its components.  |

**Question 2-5:**

* **Regarding the component 6 in FGs 49-1/1a/1b and FG 49-5, companies are encouraged to provide views on which HARQ-ACK CB(s) should be included as a component of FGs 49-1/1a/1b**
	+ Type 1 CB
		- As a component of FG49-1/1a/1b: vivo, DOCOMO
		- Report either or both: QC
	+ Type 2 CB
		- As separate FG: vivo
		- As a component of FG49-1/1a/1b: OPPO
		- Report either or both: QC
		- FFS: DOCOMO

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | Our first preference is to let UE to report either or both. We are also fine to have a separate FG for Type-2 HARQ-ACK codebook. |
| MTK | Same view as Qualcomm. |
| Apple | Prefer to have separate FG for type 1 CB and type 2 CB |
| LGE | Both type 1 and type 2 are as component of FG49-1/1a/1b or separate FG. |
| Nokia/NSB | We think that a UE supporting the PDSCH multi-cell scheduling (i.e. 1\_3) should support Type 1 and Type 2 HARQ-ACK codebook. Limiting the baseline support to Type 1 HARQ-ACK codebook only seems to be unnecessarily restrictive (and limiting the feature introduction) |

**Question 2-6:**

* **Regarding the component 7 in FGs 49-1/1a/1b and 49-2/2a/2b and FG 49-6, companies are encouraged to provide views on which co-scheduled cell indication scheme(s) should be included as a component of FGs 49-1/1a/1b and 49-2/2a/2b.**
	+ Based on FDRA field
		- As a component of FGs 49-1/1a/1b and 49-2/2a/2b: DOCOMO, E///,
		- As separate FG: vivo, Nokia/NSB, Samsung, Apple
		- Report either or both: QC
	+ based on co-scheduled cell indicator field
		- As a component of FGs 49-1/1a/1b and 49-2/2a/2b: vivo, Samsung
		- As separate FG: Apple, DOCOMO
		- Report either or both: QC

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | Our first preference is to let UE to report either or both. However, if we have to select one as a default component, we believe it should be FDRA field based. The reason is that we consider the primary usecase of multi-cell scheduling is to schedule up to all the cells in a set of cells. For this case, the option based on the co-scheduled cell indicator field rather increases the overhead and hence there is no benefit compared to FDRA based. In addition, the option for co-scheduled cell indicator field requires handling of floating Type-2 fields in a DCI payload, which may cause IOT issues. Therefore, we do not agree to include co-scheduled cell indicator field as a component of FGs 49-1/1a/1b and 49-2/2a/2b. |
| MTK | Same view as QC. **Using co-scheduled cell indicator field** may **require UE to do dynamic DCI parsing in one set**, as shown below (figure courtesy of Qualcomm), which increase UE computation complexity; hence, “based on co-scheduled cell indicator field” should be optional and not a default component. |
| Apple | We are also fine to have FDRA as a component of FGs 49-1/1a/1b and 49-2/2a/2b and co-scheduled cell indicator field as separate FG |
| LGE | We are fine with separate FG (although our preference is to have co-scheduled cell indicator field as a component of FGs 49-1/1a/1b and 49-2/2a/2b). |
| Nokia/NSB | If we need a separate UE capability, then there should be separate UE capabilities for both. And a UE supporting the 0\_3 and/or 1\_3 operation should indicate at least one of them.  |

**Question 2-7:**

* **Regarding FGs 49-1/1a/1b and 49-2/2a/2b, companies are encouraged to provide views on whether to add following restrictions.**
	+ Number of unicast DCI to process for a set of cells for multi-cell PDSCH scheduling
		- From lower SCS to higher SCS, or same SCS
			* One unicast DCI per slot of scheduling cell for a set of cells configured for multi-cell PDSCH scheduling for FDD/TDD scheduling cell
		- From higher SCS to lower SCS
			* One unicast DCI per N consecutive slots of scheduling cell for a set of cells configured for multi-cell PDSCH scheduling for FDD/TDD scheduling cell, where:
				+ N = 2 for (30, 15)
				+ N = 4 for (60, 15), (120, 30)
				+ N = 8 for (120, 15)
	+ Number of unicast DCI to process for a set of cells for multi-cell PUSCH scheduling
		- From lower SCS to higher SCS, or same SCS
			* One unicast DCI per slot of scheduling cell for a set of cells configured for multi-cell PUSCH scheduling for FDD scheduling cell
			* Two unicast DCIs per slot of scheduling cell for a set of cells configured for multi-cell PUSCH scheduling for TDD scheduling cell
		- From higher SCS to lower SCS
			* One unicast DCI per N consecutive slots of scheduling cell for a set of cells configured for multi-cell PUSCH scheduling for FDD scheduling cell, and
			* Two unicast DCIs per N consecutive slots of scheduling cell for a set of cells configured for multi-cell PUSCH scheduling for TDD scheduling cell, where:
				+ N = 2 for (30, 15)
				+ N = 4 for (60, 15), (120, 30)
				+ N = 8 for (120, 15)

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | Yes, this is an important clarification. Without this, it is unclear how many unicast DCIs a UE may need to process per PDCCH monitoring. The number should not be dependent on the number of scheduled cells, since DCI 0\_3/1\_3 can schedule arbitral number of cells in a set (up to the max number). Therefore, we think it should be “per set of cells”. |
| MTK | Yes, same view as Qualcomm. |
| Apple | Yes, we support the addition of such restrictions i.e., to limit the number of unicast DCI for a set of cells.  |
| LGE | Yes, we are open to consider such restrictions. |
| Nokia/NSB | The same limitations as for the related cross-carrier scheduling could be applied (as we agreed to use the cross-carrier scheduling framework). But we are not sure if we need to spell all of those out specifically (could be sufficient in 38.213).  |

**Question 2-8:**

* **Regarding FGs 49-1/1a/1b and 49-2/2a/2b, companies are encouraged to provide views on whether/how to report the support of configurability between Type 1A and Type-2.**
	+ Type-2 as a component in FGs 49-1/1a/1b and 49-2/2a/2b: vivo
	+ Report either or both: QC

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | Our first preference is to let UE to report either or both. We are open to fix one of them as a default. |
| MTK | Same view as Qualcomm. |
| Apple | We are fine to report then separately  |
| LGE | We are open to either way. |
| Nokia/NSB | We don’t see a need for any separate capability here.  |

**Question 2-9:**

* **Regarding FGs 49-1/1a/1b and 49-2/2a/2b, companies are encouraged to provide views on whether/how to report the support of nominal RBG size of Configuration 3.**
	+ As a component of FGs 49-1/1a/1b and 49-2/2a/2b: OPPO
	+ As separate FG: ZTE, QC

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | This is quite new feature and hence requires a separate indication of the support in either case.  |
| MTK | Yes (report the support of nominal RBG size of Configuration 3). |
| Apple | Support as separate FG |
| LGE | Fine with separate FG |
| Nokia/NSB | No separate capability needed – UE supporting 0\_3/1\_3 needs to support smaller RBG.  |

**Question 2-10:**

* **Regarding FGs 49-1/1a/1b and 49-2/2a/2b, companies are encouraged to provide views on whether/how to report the support of FDRA Type-1 granularity of 2, 4, 8, or 16 consecutive RBs based RIV.**
	+ As separate FG: QC

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | Yes, should be based on a separate FG |
| MTK | Yes (as separate FG) |
| Apple | Support as separate FG |
| LGE | Fine with separate FG |
| Nokia/NSB | No separate capability needed – UE supporting 0\_3/1\_3 needs to support smaller RBG.  |

**Question 2-11:**

* **Regarding FG 49-3, companies are encouraged to provide views on whether/how to report the support of monitoring both legacy DCI format(s) (0\_0/1\_0, 0\_1/1\_1 and/or 0\_2/1\_2) and DCI format 0\_3/1\_3 on the same scheduling cell.**
	+ Same FG for DCI format 0\_3 and 1\_3 (i.e., support FG 49-3): OPPO
	+ Separate FGs for DCI format 0\_3 and 1\_3: vivo, MTK, QC (for non-fallback DCI, separate FG for the reference cell or any cell)
	+ Separate FGs for self-carrier scheduling and cross-carrier scheduling by legacy DCI formats: HW/HiSi
	+ Not necessary (i.e., support by default): Samsung

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | Separate FGs are necessary. In addition, a UE should be able to indicate support of legacy DCI format(s) for the reference cell only, or for any cell, in the set of cells.In addition, we do not think this FG should be per UE. This causes a bar to support the FG very high and hence in reality this cannot be supported. |
| MTK | We support separate FGs for DCI format 0\_3 and 1\_3. |
| Apple | Support separate FGs for DCI format 0\_3 and 1\_3 |
| Nokia/NSB | We tend to agree with Samsung, no separate capability seems to be needed.  |

**Question 2-12:**

* **Regarding existing FG corresponding to a filed included in DCI format 0\_3/1\_3, companies are encouraged to provide views on whether/how to report the support of the FG in DCI format 0\_3/1\_3.**
	+ Alt.1: Reuse Existing FG to indicate the support for DCI format 0\_3/1\_3
	+ Alt.2: Introduce new FG to indicate the support for DCI format 0\_3/1\_3
		- UE features for DL priority indicator in a DCI format 1\_3
		- UE features for UL priority indicator in a DCI format 0\_3
		- 49-5a: Trigger Type 3 HARQ CB based feedback using DCI format 1\_3
		- 49-5b: Trigger enhanced Type 3 HARQ CB based feedback using DCI format 1\_3
		- PHY priority handling for one-shot HARQ-ACK feedback by DCI 1\_3
		- UE feature for HARQ-ACK re-transmission triggered by DCI format 1\_3
		- UE features for SCell dormancy indication within active time by DCI format 1\_X and DCI format 0\_3
		- UE features for cross-slot scheduling by DCI format 1\_X and DCI format 0\_3
		- UE features for Unified-TCI indication by DCI format 1\_3

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | It is obvious that all the legacy FGs defined for DCI format 1\_1/1\_2 or DCI format 0\_1/0\_2 are not applicable to DCI format 1\_3 or DCI format 0\_3. The only way to enable these features is to introduce the corresponding FGs. |
| MTK | We prefer Alt. 2. |
| Apple | We support Alt. 2  |
| Nokia/NSB | Alt. 1 – a UE supporting PHY priority, Type 3 or enhanced Type 3 incl. PHY priority, HARQ-ACK re-tx, SCell dormancy, ... – would also support the related features in combination with DCI format 0\_3 and 1\_3.  |

# **FGs for multi-carrier UL Tx switching scheme**

In [1], FGs for multi-carrier UL Tx switching scheme are captured as below.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Features** | **Index** | **Feature group** | **Components** | **Prerequisite feature groups** | **Need for the gNB to know if the feature is supported** | **Applicable to the capability signalling exchange between UEs (Sidelink WI only)”.** | **Consequence if the feature is not supported by the UE** | **Type****(the ‘type’ definition from UE features should be based on the granularity of 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | **Need of FDD/TDD differentiation** | **Need of FR1/FR2 differentiation** | **Capability interpretation for mixture of FDD/TDD and/or FR1/FR2** | **Note** | **Mandatory/Optional** |
| 49. NR\_MC\_enh | 49-X | Supported switching option for each band pair in the band combination for UL Tx switching across more than 2 bands | Indicate supported switching option for each band pair in the band combination for UL Tx switching across more than 2 bands* Candidate value set is {switchedUL, dualUL, both}
 |  | Yes |  | [UL Tx switching across more than 2 bands cannot be supported for the band pair in the band combination] | [Per band pair per band combination, details up to RAN2] | [N/A] | [N/A] | [N/A] | [AgreementAsk RAN2 to consider following alternatives for UE capability reporting about the supported UL Tx switching options* Alt.1: report {switchedUL, dualUL, both} for each band pair in the band combination]

[Agreement in RAN2#121For UE capability of switching options, introduce a per-band-pair UE capability to report supported switching options for Rel-18 UL Tx switching.] | Optional with capability signaling |
| 49. NR\_MC\_enh | 49-Y | Minimum separation time for two uplink switching on more than 2 bands within any two consecutive reference slots | If two uplink switchings are triggered and UL transmissions involved in the two uplink switchings are on more than 2 bands within any two consecutive reference slots, then the time duration between the start of all transmission(s) after the first uplink switching and the start of all transmission(s) after the second uplink switching within the two reference slots is expected to be not less than a minimum separation time* The minimum separation time is a maximum of X us and the switching gap required for the second uplink switching, and X us is reported with a candidate value set of {0us, 500us}
 | 49-X | Yes |  | [two uplink switching cannot be triggered in two consecutive reference slots for UL transmissions on more than 2 bands] | [Per BC] | [N/A] | [N/A] | [N/A] | [AgreementConfirm the working assumption with following updates* (working assumption) If two uplink switching are triggered and UL transmissions involved in the two uplink switching are on more than 2 bands within any two consecutive reference slots, then the time duration between the start of all transmission(s) after the first uplink switching and the start of all transmission(s) after the second uplink switching within the two reference slots is expected to be not less than a minimum separation time
	+ The minimum separation time is a maximum of X us and the switching gap required for the second uplink switching.
	+ X us is subject to UE capability with a value set of {0us, 500us}]
 | Optional with capability signaling |

Following inputs are provided in contributions for the RAN1#112bis-e meeting.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| [2] | vivo |

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| --- |
| **Agreement in RAN1 112[1]** Confirm the working assumption with following updates(working assumption) If two uplink switching are triggered and UL transmissions involved in the two uplink switching are on more than 2 bands within any two consecutive reference slots, then the time duration between the start of all transmission(s) after the first uplink switching and the start of all transmission(s) after the second uplink switching within the two reference slots is expected to be not less than a minimum separation time * The minimum separation time is a maximum of X us and the switching gap required for the second uplink switching.

X us is subject to UE capability with a value set of {0us, 500us} |

It has been agreed that the minimum separation time is a maximum of X us and the switching gap required for the second uplink switching, and the X us is subject to UE capability with a value set of {0us, 500us}. Regarding the granularity of this UE capability, it can be reported per UL Tx switching band combination for simplicity.Proposal 11. UE reports the value of X us per UL Tx switching band combination.

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| **1Tx-1Tx switching case**[2]**：**In RAN4 #106, RAN4 discussed the scenario of 1Tx-1Tx switching, i.e., the UL carriers in both bands before and after switching are capable of one transmit antenna connector, and agreed to apply the same length of switching period for 1Tx-1Tx switching and 1Tx-2Tx switching. |

It has been agreed to apply the same length of switching period for 1Tx-1Tx switching and 1Tx-2Tx switching in RAN4’s LS. However, how to report the 1Tx-1Tx switching period needs clarification. One understanding is that a single parameter is reported (e.g.: *uplinkTxSwitchingPeriod-r16*) applying for both 1Tx-1Tx switching and 1Tx-2Tx switching. Another understanding is that two parameters (e.g.: *uplinkTxSwitchingPeriod-r16, uplinkTxSwitching1T1T-r18*) are reported separately applying for 1Tx-2Tx switching and 1Tx-1Tx switching respectively, but the two parameters should have the same value. In our view, there is no additional benefit to introducing a new parameter to indicate 1Tx-1Tx switching period. For simplicity, the legacy parameter *uplinkTxSwitchingPeriod-r16* is applied for both1Tx-1Tx switching and 1Tx-2Tx switching.Proposal 12. The legacy parameter *uplinkTxSwitchingPeriod-r16* is applied for both1Tx-1Tx switching and 1Tx-2Tx switching. |
| [4] | ZTE | **Issue1: Whether a separate UE feature to indicate the support of UL Tx switching among 3/4bands is needed?**RAN2 has been agreed to reuse the Rel-16/17 band combination list for Rel-18 UL Tx switching. However, RAN2 is discussing the following two approaches regarding the feature set for UL Tx switching. If Approach 1 is adopted, then it seems a separate UE capability to indicate whether UE supports UL Tx switching among 3/4 bands is not necessary because it can be implicitly indicated by the feature set row. In other words, if 3/4 FeatureSetUplink are reported in one row in FSC for the 3/4 UL bands, then UE supports UL Tx switching among 3/4 bands. However, if Approach 2 below is adopted, then a separate UE feature to indicate the support of UL Tx switching among 3/4 bands is needed.

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| **Approach 1: the 3/4 FeatureSetUplink are reported in one row in FSC for the 3/4 UL bands involved in Rel-18 UL Tx switching;****Approach 2: the FeatureSets reported for Rel-16/17 Tx switching between 2 bands can be combined to indicate UL capabilities on the 3/4 UL bands for Rel-18 UL Tx switching;** |

Overall, we have the following proposal.***Proposal 3****: Regarding whether a separate UE feature to indicate the support of UL Tx switching among 3/4bands is needed, consider the following two alternatives.** *Alt.1: Not needed. The support of UL Tx switching among 3/4 bands is implicitly indicated by the feature sets indication for UL Tx switching.*
* *Alt.2: Needed. It is a per BC UE capability.*

**Issue2: Which band pair is switchedUL and which band pair is dualUL?**Based on the following agreements, this issue will be decided by RAN2 and RAN2 has agreed to have per band pair indication for *switchedUL* and *dualUL*.

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| Agreements (RAN1)  Ask RAN2 to consider following alternatives for UE capability reporting about the supported UL Tx switching options* o      Alt.1: report {switchedUL, dualUL, both} for each band pair in the band combination
* o      Alt.2: report {switchedUL, dualUL, both} for the band combination and report supported band pair for concurrent transmission for the band combination
* § Note：If there is no report on the supported band pair(s) for concurrent transmission while the UE reports “dualUL” or “both” for the band combination, gNB may assume that the UE supports concurrent transmission on all the band pairs within the band combination
* o      Alt.3: report {dualUL} for each band pair in the band combination
* § Note: Within the band combination, the UE shall be capable of being operated in switched UL mode for all band pairs

*Agreements (RAN2):*1. For UE capability of switching options, introduce a per-band-pair UE capability to report supported switching options for Rel-18 UL Tx switching.
2. Configure {switchedUL, dualUL} for combination(s) of serving cells (i.e., for each band pair in the band combination)
3. For RRC configuration to clarify ambiguous Tx state, RAN2 should introduce an RRC configuration that associates a band to another band which the unused Tx chain is switched to when the switch is from concurrent transmission on two bands to 1 Tx transmission on another band.
4. For UE capability of 2-port UL transmission, RAN2 reuse the per-FS UL-MIMO UE capability (no spec change).
 |

***Observation 1****: Regarding the UE feature for indication of switchedUL and dualUL for each band pair, it is introduced by RAN2.***Issue3: which band/carrier supports 2-port transmission?**RAN1 agreed that there is no restriction on number of bands supporting up to 2 ports UL transmission for both switched UL and dual UL and for both 3 bands and 4 bands. However, no new UE capability is needed since UE can already report its MIMO capability via legacy UE capabilities.

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| **Agreement**There is no restriction on number of bands supporting up to 2 ports UL transmission for both switched UL and dual UL and for both 3 bands and 4 bands.* It is up to UE capability to support 2 ports UL transmission on none/some/all of the 3 or 4 bands
* Note: UE with only 1 Tx chain is not expected to perform UL Tx switching (no spec impact)
 |

***Observation 2****: No need to introduce new UE capability to indicate the number of ports for PUSCH transmission for Rel-18 UL Tx switching.* **Issue4: Duration of the switching period**Regarding the duration of the switching period, RAN4 has agreed that for Rel-18 UE, for a band pair within a band combination supporting Tx switching among 3/4 bands, the switching period reported by UE for Rel-18 3/4-band Tx switching can be the same or different from the switching period for Rel-16/17 2-band switching operations. The UE capability can be decided by RAN2 and RAN4.

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| **Issue 1: Exact value of Tx switching period for each band pair**RAN4 discussed the exact value of Tx switching period for each band pair in the band combination, and has agreed that:* For Rel-18 UE, for a band pair within a band combination supporting Tx switching among 3/4 bands, the switching period reported by UE for Rel-18 3/4-band Tx switching can be the same or different from the switching period for Rel-16/17 2-band switching operations.
	+ Note 1: the set of candidate values is still the same, i.e., {35 us, 140 us, 210 us}, according to the agreement in RAN4 #104e.
	+ Note 2: here the band pair is a pair of bands within which there is a switching with a switching period.
 |

***Proposal 4****: Regarding the UE capability for duration of the switching period, it is to be introduced by RAN2/RAN4.***Issue5: Minimum separation time**RAN1 has agreed the following for minimum separation time. This UE capability should be discussed in RAN1. Based on the initial discussion in RAN1#112 meeting, the UE capability can be per BC type.

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| **Agreement**Confirm the working assumption with following updates(working assumption) If two uplink switching are triggered and UL transmissions involved in the two uplink switching are on more than 2 bands within any two consecutive reference slots, then the time duration between the start of all transmission(s) after the first uplink switching and the start of all transmission(s) after the second uplink switching within the two reference slots is expected to be not less than a minimum separation time * The minimum separation time is a maximum of X us and the switching gap required for the second uplink switching.
* X us is subject to UE capability with a value set of {0us, 500us}
 |

***Proposal 5****: Introduce a per BC UE capability for value X for determination the minimum separation time.* **Issue6: Advanced UE capability**RAN4 has agreed to introduce an advanced UE capability to indicate whether UE is able to transmit with the unchanged Tx chain during the switching period of another Tx chain.

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| **Issue 3: Impact from switching of one Tx chain on the other Tx chain****Scenario of one band with the number of Tx chain unchanged due to switching**When one of the two Tx chains is triggered to switch from one band (named “band A”) to another band (name “band B”), the other Tx chain is maintained on a different band (named “band C” or “band D” in the case of 4-band) and the number of Tx chain on band C or band D is unchanged due to the switching, RAN4 agreed the granularity of the optional UE capability to allow UL transmission on the band with the number of Tx chain unchanged during UL switching as follows: * Per band (only for the band(s) in the band combination but not included in the pair of bands before and after switching) for each pair of bands before and after switching in each band combination.
 |

***Proposal 6****: Regarding the UE capability to indicate whether UE is able to transmit with the unchanged Tx chain during the switching period of another Tx chain, it is to be introduced by RAN2/RAN4.* |
| [7] | MediaTek | For UE feature of multi-carrier UL Tx switching, we have the following proposal:**Proposal 2: For R18 UL Tx switching, the following UE feature need to be introduced.**

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| --- | --- | --- | --- | --- |
| **Feature group** | **Components** | **Prerequisite FG** | **Type** | **Mandatory/Optional** |
| ULTxSwitchingBandPair-r18 | * {bandIndexUL1-r18, bandIndexUL2-r18}
* Switching among bands {3bands, 4bands}
* uplinkTxSwitchingPeriod-r18 {n35us, n140us, n210us}
* uplinkTxSwitching-OptionSupport-r18{switchedUL, dualUL, both}
 | ULTxSwitchingBandPair-r16 | Per BC | Optional |

 |
| [8] | Apple | For Rel-18 UL Tx switching, extension up to 4 bands would require quite substantial updates to UE’s implementation in comparison to 2 bands in Rel-16/17. Therefore, in our view, a new UE capability framework to indicate support of Rel-18 UL Tx switching for UL CA option 1, UL CA option 2 and both UL CA option 1 and 2 should be introduced. Furthermore, based on the agreements in RAN2, such UE capability should be indicated per band pair per combination [1]. Pre-requisite/dependency on FG 22-1 for UL Tx switching in Rel-16 can be further discussed.

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| --- | --- | --- | --- |
| Features | Index | Feature group | Components |
| XX. NR\_MC\_enh-Core | XX-2 | Indicating supported option for UL Tx switching for inter-band UL CA for more than 2 bands | Indicating supported option for UL Tx switching for inter-band UL CA for more than 2 bands Candidate values set is {option1, option2, both option 1 and option 2} |

***Proposal 4: For Rel-18 UL Tx switching, a new UE capability (new FG) should be introduced to indicate the support of Rel-18 UL Tx switching for UL CA option 1, UL CA option 2 and both UL CA option 1 and 2***

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| --- | --- | --- | --- |
| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-2* | *Indicating supported option for UL Tx switching for inter-band UL CA for more than 2 bands* | *Indicating supported option for UL Tx switching for inter-band UL CA for more than 2 bands* *Candidate values set is {option1, option2, both option 1 and option 2}* |

***Proposal 5: For Rel-18 UL Tx switching, the new capability (new FG XX-2) is indicated per band pair per band combination of up to 4 bands******Proposal 6: For Rel-18 UL Tx switching, for the new capability (new FG XX-2), any pre-requisite/dependency on FG 22-1 (for UL Tx switching in Rel-16) can be further discussed***Another UE capability aspect is whether concurrent transmission is supported for a band pair for which UE indicated capability to support dualUL (UL option 2) [2]. Therefore, a UE capability for indicting support for concurrent transmission for a band pair should be reported. This UE capability will be dependent on the proposed FG XX-2. If UE indicates support of UL option 2 or both for FG XX-2 for a band pair within a band combination, then UE can indicate whether it supports concurrent transmission or not for that band pair. This should be an optional capability and in absence of this capability reporting, concurrent transmission can be assumed for the band pair for which UE indicated support of UL option 2 or both with FG XX-2.

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| --- | --- | --- | --- |
| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-2a* | *Indicating support of concurrent transmission for the band pair* | *Indication whether the band pair for which option 2 or both are supported by FG XX-2, supports concurrent transmission or not {concurrent transmission, non-concurrent transmission only}* |

***Proposal 7: For Rel-18 UL Tx switching, introduce an additional capability to indicate support of concurrent transmission per band pair per band combination**** ***This capability is subject to FG XX-2 report on whether option 2 or both is reported to be supported for the band pair within the band combination***
* ***This is an optional capability and if not reported for a band pair for which option 2 or both is reported to be supported in FG XX-2, then concurrent transmission is assumed to be supported for that band pair***

|  |  |  |  |
| --- | --- | --- | --- |
| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-2a* | *Indicating support of concurrent transmission for the band pair* | *Indication whether the band pair for which option 2 or both are supported by FG XX-2, supports concurrent transmission or not**Candidate values set is {concurrent transmission, non-concurrent transmission only}* |

Another aspect for UE capability is indication of minimum separation time between 2 switching instances within 2 reference slots. Based on the agreement in RAN1 [3], UE can report from a value set of {0us,500us}. UE capability under the proposed FG XX-2 can be reported by UE. Furthermore, since this is applicable for the case when more than 2 bands are involved in the 2 switching instances, therefore, this capability can be reported per band combination.

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| --- | --- | --- | --- |
| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-2c* | *Indicating support of minimum separation time between two switching instances with more than two bands within two reference slots* | *Indicating supported option for minimum separation time between two switching instances for more than 2 bands between two reference slots* *Candidate values set is {0us,500us}* |

***Proposal 8: For Rel-18 UL Tx switching, introduce a UE capability to indicate minimum separation time between two switching instances with more than two bands within two reference slots***

|  |  |  |  |
| --- | --- | --- | --- |
| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-2c* | *Indicating support of minimum separation time between two switching instances with more than two bands within two reference slots* | *Indicating supported option for minimum separation time between two switching instances for more than 2 bands between two reference slots* *Candidate values set is {0us,500us}* |

Another UE capability that should be introduced is related to RAN4 agreement on whether the unchanged band during a switching on two other bands can be used for UL transmission or not during the switching period. As a default capability, UE is not expected to be scheduled with UL transmission on any of the bands within a band combination during the switching period. This UE capability could be reported per band combination.

|  |  |  |  |
| --- | --- | --- | --- |
| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-2d* | *Indicating support of transmission during the switching period for the band on which UL Tx chain remains unchanged* | *Indicating support of transmission during the switching period for the band on which UL Tx chain remains unchanged* *Candidate values set is {supported, notSupported}* |

***Proposal 9: For Rel-18 UL Tx switching, introduce an optional UE capability to indicate support of transmission during the switching period for the band on which UL Tx chain remains unchanged***

|  |  |  |  |
| --- | --- | --- | --- |
| *Features* | *Index* | *Feature group* | *Components* |
| *XX. NR\_MC\_enh-Core* | *XX-2d* | *Indicating support of transmission during the switching period for the band on which UL Tx chain remains unchanged* | *Indicating support of transmission during the switching period for the band on which UL Tx chain remains unchanged* *Candidate values set is {supported, notSupported}* |

 |
| [10] | DOCOMO | **Reporting type of minimum separation time capability**At the last meeting, the working assumption regarding minimum separation time was confirmed with necessary updates. In addition, the reporting type of minimum separation time capability was discussed, but RAN1 did not make agreement due to lack of time [1].Based on the discussion at the last meeting, it seems majority supports per-BC reporting granularity. We think that potential finer granularity than it e.g., per switching band pair in the band combination seems too much. So, we propose that X us is reported per UL Tx switching band combination (such as 3 or 4 bands BC).**Proposal 4:****UE capability on the X us is reported per BC.** |
| [12] | Huawei, HiSilicon | In last RAN1 meeting, following agreement for the restriction of two UL Tx switching is achieved. In this section, the UE reporting granularity for minimum separation time is discussed.

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| --- |
| AgreementConfirm the working assumption with following updates(working assumption) If two uplink switching are triggered and UL transmissions involved in the two uplink switching are on more than 2 bands within any two consecutive reference slots, then the time duration between the start of all transmission(s) after the first uplink switching and the start of all transmission(s) after the second uplink switching within the two reference slots is expected to be not less than a minimum separation time * The minimum separation time is a maximum of X us and the switching gap required for the second uplink switching.
* X us is subject to UE capability with a value set of {0us, 500us}
 |

In Rel-17, 2T+2T band combination and 2T+ {intra band 2T+2T} band combination have been agreed to support without the restriction of minimum separation time, which can be set the capability baseline of UE memory management for Rel-18. Therefore, the restriction of minimum separation time should be only for the Rel-18 band combination where the aggregated number of supported Tx across all bands is more than 4, e.g., 2Tx-2Tx-2Tx band combination on 3 bands scenario and 1Tx-1Tx-2Tx-2Tx band combination on 4 bands. It is because additional 500us is to manage RF hardware and only high dimension of combined UL-MIMO capabilities across all bands can increase UE implementation burden to manage UE RF hardware compared to Rel-17 UL Tx switching. With this baseline, the UE reporting granularity for minimum separation time has following candidate schemes,* Option 1: UE reports X us with a value set of {0us, 500us} per FS.
* Option 2: UE reports X us with a value set of {0us, 500us} per BC.

***Observation 1:*** *The case of the configured band combination where the aggregated number of configured Tx across all bands is no more than 4 has been supported in Rel-17 UEs without the new scheduling restriction, which can be taken as the UE capability baseline of UE RF management for Rel-18.*For Option 1, UE can report different values for different FSs (feature sets). The granularity of per FS can achieve better flexibility of capability reporting because the restriction of minimum separation time can be only reported for some FS groups. For example, UE can report 500us for one band combination where UL-MIMO capability of one FS group is 2Tx-2Tx-1Tx and report 0us for the same band combination where UL-MIMO capability of another FS group is 2Tx-1Tx-1Tx. However, the signaling overhead is large because the field of X us exists in every FS. Additionally, it can allow a UE to report different values of separation time for each band, e.g. 0 us for Band A and 500 us for Band B within the same band combination, which seems too flexible and needs some clarifications.With respect to Option 2, UE can report different values for different band combinations. For example, a UE may report 500us for one band combination and report 0us for another band combination. Therefore, Option 2 has smaller signaling overhead and proper flexibility compared to Option 1. ***Proposal 2:*** *For the restriction of minimum separation time between two succeeding UL Tx switchings in Rel-18 UL Tx switching, a UE reports X us with a value set of {0us, 500us} per BC.*  |

## **Discussion**

**Question 3-1:**

* **Companies are encouraged to provide views on whether to introduce FG 49-X**
	+ Yes: [MTK], Apple
	+ Defined in RAN2: ZTE

|  |  |
| --- | --- |
| Company | Comment |
| Apple | Yes, we support to introduce new FG per BC |
| Qualcomm | We support define this new FG. However, it seems RAN2 already agree on the new signaling and we prefer not having duplicate discussion. |
| ZTE | It seems that RAN2 already defined the UE capability according to the following RAN2 agreements.*Agreements (RAN2):*1. For UE capability of switching options, introduce a per-band-pair UE capability to report supported switching options for Rel-18 UL Tx switching.
2. Configure {switchedUL, dualUL} for combination(s) of serving cells (i.e., for each band pair in the band combination)
3. For RRC configuration to clarify ambiguous Tx state, RAN2 should introduce an RRC configuration that associates a band to another band which the unused Tx chain is switched to when the switch is from concurrent transmission on two bands to 1 Tx transmission on another band.
4. For UE capability of 2-port UL transmission, RAN2 reuse the per-FS UL-MIMO UE capability (no spec change).

We need to avoid parallel and duplicated discussion. Once Ran2 has finalized the capability design, we can copy it into our RAN1 UE feature list if necessary (just for information).  |

**Question 3-2:**

* **Companies are encouraged to provide views on whether to introduce FG 49-Y**
	+ Yes: vivo, ZTE, Apple, DOCOMO, HW/HiSi

|  |  |
| --- | --- |
| Company | Comment |
| Apple | Yes, we support to introduce FG 49-Y for minimum separation time |
| Qualcomm | We support to define this new UE capability. In RAN1 #112, two related proposals received majority support as below. The current proposal already includes the per BC capability and we propose to agree on and include the second bullet as well.* UE capability on the X us is reported per BC
* For more than one TAG case, X us is subject to UE capability with a value set of {0us, 500us} as well as for one TAG case
 |
| ZTE | Yes.Regarding the “Consequence if the feature is not supported by the UE”, our understanding is that, the current 49-Y is trying to add some restriction for the scheduling. If UE doesn’t indicate 49-Y, then the UE should be advanced UE that support “two uplink switching **can** be triggered in two consecutive reference slots for UL transmissions on more than 2 bands without the minimum separation time”. |

**Question 3-3:**

* **Companies are encouraged to provide views on whether to introduce a FG for the support of transmission during the switching period for the band on which UL Tx chain remains unchanged**
	+ Yes: Apple
	+ Defined in RAN2/4: ZTE

|  |  |
| --- | --- |
| Company | Comment |
| Apple | Yes, this should be introduced as a FG. We are open to consider this in RAN2/4 as well if the majority thinks so |
| Qualcomm | It seems RAN4 already informed this new capability and we prefer not having duplicated discussion in RAN1 unless necessary. |
| ZTE | This functionality is introduced by RAN4 and has sent LS to RAN2 to introduce this UE capability (copying the previous LS content in the table below).

|  |
| --- |
| **Issue 3: Impact from switching of one Tx chain on the other Tx chain****Scenario of one band with the number of Tx chain unchanged due to switching**When one of the two Tx chains is triggered to switch from one band (named “band A”) to another band (name “band B”), the other Tx chain is maintained on a different band (named “band C” or “band D” in the case of 4-band) and the number of Tx chain on band C or band D is unchanged due to the switching, RAN4 agreed the granularity of the optional UE capability to allow UL transmission on the band with the number of Tx chain unchanged during UL switching as follows: * Per band (only for the band(s) in the band combination but not included in the pair of bands before and after switching) for each pair of bands before and after switching in each band combination.
 |

From our perspective, we should avoid parallel and duplicated discussion, thus it is proposed to define it in RAN2/4. |

# **Conclusions**

To be updated

# **References**

[1] R1-2303735 Draft RAN1 UE features list for Rel-18 Multi-carrier enhancements for NR NTT DOCOMO, INC.

[2] R1-2302515 Discussion on UE features for Multi-carrier enhancements vivo

[3] R1-2302577 Discussion on UE features for multi-carrier enhancement OPPO

[4] R1-2302763 Discussion on UE feature for MC enhancements ZTE

[5] R1-2302897 Initial views on UE features for Multi-carrier Enhancements Nokia, Nokia Shanghai Bell

[6] R1-2303159 Discussion on UE features for multi-carrier enhancements Samsung

[7] R1-2303343 On UE feature discussion for Rel-18 MC enhancements MediaTek Inc.

[8] R1-2303512 Initial views on UE features for Rel-18 multi-carrier enhancements Apple

[9] R1-2303621 UE features for MC enhancements Qualcomm Incorporated

[10] R1-2303736 Discussion on UE features for MC enhancements NTT DOCOMO, INC.

[11] R1-2303762 UE features for MCE Ericsson

[12] R1-2303863 UE features for MC enhancements Huawei, HiSilicon