**3GPP TSG RAN WG1 #110bis-e R1-2210276**

**e-Meeting, October 10th – 19th, 2022**

**Agenda item:** 8.16.1

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

**Title:** Summary#1 on UE features for NR coverage enhancement

**Document for:** Discussion and Decision

# **Introduction**

This document summarizes contributions submitted to AI 8.16.1 regarding UE features for CovEnh and captures company views based on the announcement in the following email thread.

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| [110bis-e-R17-UE-features-01] Email discussion on Rel-17 UE features topics 1 by October 19 – Hiroki (NTT DOCOMO)* eIIoT & URLLC, RedCap, UE power saving, coverage enhancement, NB-IoT & eMTC, sidelink, MBS, 5G terrestrial broadcast, UL TX switching, SDT
 |

# **Discussion on UE features for NR coverage enhancement**

In [1], there are following FGs including yellow highlighted part in RAN1 UE feature list for NR\_cov\_enh.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 30. NR\_cov\_enh | 30-4a | DM-RS bundling for PUSCH repetition type A | Support DM-RS bundling for PUSCH repetition type A over consecutive symbols | 30-4 and one of {5-14, 5-16, 5-17} | Yes | N/A | UE does not Support DM-RS bundling for PUSCH repetition type A | [Per UE] | FFS | [No] | [N/A] |  | Optional with capability signalling |
|  30. NR\_cov\_enh | 30-4b | DM-RS bundling for PUSCH repetition type B | Support DM-RS bundling for PUSCH repetition type B over consecutive symbols | 30-4, 11-5 | Yes | N/A | UE does not Support DM-RS bundling for PUSCH repetition type B | [Per UE] | FFS | [No] | [N/A] |  | Optional with capability signalling |
|  30. NR\_cov\_enh | 30-4c | DM-RS bundling for TB processing over multi-slot PUSCH | Support DM-RS bundling for TB processing over multi-slot PUSCH over consecutive symbols  | 30-4, 30-3 | Yes | N/A | UE does not Support DM-RS bundling for TB processing over multi-slot PUSCH | [Per UE] | FFS | [No] | [N/A] | Note: If a UE reports support of FG 30-3a and 30-4c, the UE supports DMRS bundling for the repetitions of TBoMS | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4d | DMRS bunding for PUCCH repetitions | Support DM-RS bundling for PUCCH repetitions for PUCCH formats 1/3/4 over consecutive symbols | 30-4, 4-23 | Yes | N/A | UE does not support DMRS bunding for PUCCH repetitions | [Per UE] | FFS | [No] | [N/A] |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4e | Enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH | Support enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH | 30-4a or 30-4b or 30-4c | Yes | N/A | UE does not support enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH | [Per UE] | FFS | [No] | [N/A] |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4f | Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | 30-4d | Yes | N/A | UE does not support Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | [Per UE] | FFS | [No] | [N/A] |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4g | [Restart DM-RS bundling after the events that violate power consistency and phase continuity] | [Support restarting DM-RS bundling after the events that violate power consistency and phase continuity] | 30-4 | Yes | N/A | [UE does not support restarting DM-RS bundling after the events that violate power consistency and phase continuity] | [Per UE] | FFS | [No] | [N/A] |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4h | DM-RS bundling for non-back-to-back transmission | Support DM-RS bundling for non-back-to-back transmission for consecutive slots for PUSCH and PUCCH only for corresponding supported back-to-back transmission FGs (30-4a, 30-4b, 30-4c, or 30-4d) | 30-4a, 30-4b, 30-4c, or 30-4d | Yes | N/A | UE does not Support DM-RS bundling for non-back-to-back transmission | [Per UE] | FFS | [No] | [N/A] |  | Optional with capability signalling |

Following views are provided in contributions for the RAN1#110bis-e meeting.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| [2] | Huawei, HiSilicon | For FG 30-4g, UEs can restart a new actual TDW after a semi-static event anyway. Therefore, for UEs not capable of restarting DM-RS bundling,* If a semi-static event is triggered after one or multiple dynamic events, a new actual TDW is created after the triggered semi-static event.
* If a semi-static event overlaps with a dynamic event, a new actual TDW is created after the triggered semi-static event.

***Proposal 1: Updating 30-4a/4b/4c/4d/4e/4f/4g/4h as follows in red:***

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 30. NR\_cov\_enh | 30-4a | DM-RS bundling for PUSCH repetition type A | Support DM-RS bundling for PUSCH repetition type A over consecutive symbols | 30-4 and one of {5-14, 5-16, 5-17} | Yes | N/A | UE does not Support DM-RS bundling for PUSCH repetition type A | ~~[Per UE]~~Per band | ~~FFS~~No | ~~[~~No~~]~~ | ~~[~~N/A~~]~~ |  | Optional with capability signalling |
|  30. NR\_cov\_enh | 30-4b | DM-RS bundling for PUSCH repetition type B | Support DM-RS bundling for PUSCH repetition type B over consecutive symbols | 30-4, 11-5 | Yes | N/A | UE does not Support DM-RS bundling for PUSCH repetition type B | ~~[Per UE]~~Per band | ~~FFS~~No | ~~[~~No~~]~~ | ~~[~~N/A~~]~~ |  | Optional with capability signalling |
|  30. NR\_cov\_enh | 30-4c | DM-RS bundling for TB processing over multi-slot PUSCH | Support DM-RS bundling for TB processing over multi-slot PUSCH over consecutive symbols  | 30-4, 30-3 | Yes | N/A | UE does not Support DM-RS bundling for TB processing over multi-slot PUSCH | ~~[Per UE]~~Per band | ~~FFS~~No | ~~[~~No~~]~~ | ~~[~~N/A~~]~~ | Note: If a UE reports support of FG 30-3a and 30-4c, the UE supports DMRS bundling for the repetitions of TBoMS | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4d | DMRS bundling for PUCCH repetitions | Support DM-RS bundling for PUCCH repetitions for PUCCH formats 1/3/4 over consecutive symbols | 30-4, 4-23 | Yes | N/A | UE does not support DMRS bunding for PUCCH repetitions | ~~[Per UE]~~Per band | ~~FFS~~No | ~~[~~No~~]~~ | ~~[~~N/A~~]~~ |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4e | Enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH | Support enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH | 30-4a or 30-4b or 30-4c | Yes | N/A | UE does not support enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH | ~~[Per UE]~~Per band | ~~FFS~~No | ~~[~~No~~]~~ | ~~[~~N/A~~]~~ |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4f | Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | 30-4d | Yes | N/A | UE does not support Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | ~~[Per UE]~~Per band | ~~FFS~~No | ~~[~~No~~]~~ | ~~[~~N/A~~]~~ |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4g | ~~[~~Restart DM-RS bundling after the events triggered by DCI other than frequency hopping or by MAC-CE that violate power consistency and phase continuity~~]~~ | ~~[~~Support restarting DM-RS bundling after the events triggered by DCI other than frequency hopping or by MAC-CE that violate power consistency and phase continuity~~]~~ | 30-4 | Yes | N/A | ~~[~~UE does not support restarting DM-RS bundling after the events triggered by DCI other than frequency hopping or by MAC-CE that violate power consistency and phase continuity~~]~~ | ~~[Per UE]~~Per band | ~~FFS~~No | ~~[~~No~~]~~ | ~~[~~N/A~~]~~ |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4h | DM-RS bundling for non-back-to-back transmission | Support DM-RS bundling for non-back-to-back transmission for consecutive slots for PUSCH and PUCCH only for corresponding supported back-to-back transmission FGs (30-4a, 30-4b, 30-4c, or 30-4d) | 30-4a, 30-4b, 30-4c, or 30-4d | Yes | N/A | UE does not Support DM-RS bundling for non-back-to-back transmission | ~~[Per UE]~~Per band | ~~FFS~~No | ~~[~~No~~]~~ | ~~[~~N/A~~]~~ |  | Optional with capability signalling |

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| [3] | ZTE | ***roposal 6:*** *For DMRS bundling related FGs, adopt the following changes.* * *Add the following note for UE FG 30-4a, 4b, 4c, and 4d (the four back-to-back cases):*

|  |
| --- |
| *Note: This capability is applicable in the following multi-carrier scenarios:** *FR1+FR2 CA/DC with one band on FR1 and another band on FR2. DMRS bundling configuration is limited to one uplink NR carrier in total on all FRs at a time.*
* *FR1 inter-band DL CA with a ‘single’ uplink band configured*
* *DL CA with ‘additional’ UL carrier configured with SRS only*
* *SUL, where UE does not expect concurrent uplink transmissions on two carriers in case of SRS on an SUL/non-SUL carrier and PUSCH/PUCCH/SRS on the other UL carrier in the same cell*
* *FR1+FR1 inter-band CA involving two or more FR1 bands, where UE does not expect concurrent uplink transmissions on two carriers*
	+ *Only configuration of a single TAG is supported.*
 |

* *Add the following note for FG 30-4h (non-back-to-back case):*

|  |
| --- |
| *Note: This capability is only applicable when UE is configured with single uplink carrier.* |

With support of DMRS bundling for multi-carrier operation, we think per band and band combination reporting as discussed in RAN1#109-e and RAN1#110 is a good compromise. ***Proposal 7:*** *Reporting type of FGs 30-4a/b/c/d/g/h is per band and per BC.*For FG 30-4e and 30-4f, we think per UE reporting is sufficient similar as Rel-15 FG 5-10 for inter-slot hopping for PUSCH. ***Proposal 8:*** *Reporting type of FGs 30-4e/f is per UE.* |
| [4] | vivo | As discussed in previous meetings, DMRS bundling should at least be a per band feature. However, for a UE supporting DMRS bunding in each of a set of bands, it may be not able to support DMRS bundling simultaneously in all combinations of bands selected from the set of bands. Furthermore, same or different RF circuits may be used for different combinations of bands in UE implementation, therefore FG 30-4a to FG 30-4h should be per band per BC.***Proposal 4: For DMRS bundling, FG 30-4a to FG 30-4h should be per band per BC.***Besides, for FG 30-4g, we do not see the need to introduce more UE capabilities on restarting TDW due to overlapping between dynamic event and semi-static event, the single UE capability below is enough for the case in which the actual TDW is created in response to an event triggered by DCI other than frequency hopping or by MAC-CE. Hence, the brackets for FG 30-4g can be removed.***Proposal 5: Remove the brackets in the table for FG 30-4g.***

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 30. NR\_cov\_enh | 30-4g | ~~[~~Restart DM-RS bundling after the events that violate power consistency and phase continuity~~]~~ | ~~[~~Support restarting DM-RS bundling after the events that violate power consistency and phase continuity~~]~~ | 30-4 | Yes | N/A | ~~[~~UE does not support restarting DM-RS bundling after the events that violate power consistency and phase continuity~~]~~ |

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| [5] | China Telecom | * **Proposal: FGs for DMRS bundling for PUSCH/PUCCH.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Features** | Index | Feature group | Components | Prerequisite feature groups | **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)** | Note | Mandatory/Optional |
| 30. NR\_cov\_enh | 30-4 | The maximum duration for DM-RS bundling | The maximum duration during which UE is able to maintain power consistency and phase continuity to support DM-RS bundling for PUSCH/PUCCH |  | UE does not support DM-RS bundling for PUSCH/PUCCH | Per band | Candidate values for the maximum duration for FDD are {4, 8, 16, 32}Candidate values for the maximum duration for TDD are {2, 4, 8, 16}NOTE: DM-RS bundling is only applicable for UL transmissions with pi/2 BPSK, BPSK, and QPSK modulation orders for the corresponding physical channels. | Optional with capability signalling |
|  30. NR\_cov\_enh | 30-4a | DM-RS bundling for PUSCH repetition type A | Support DM-RS bundling for PUSCH repetition type A over consecutive symbols | 30-4 and one of {5-14, 5-16, 5-17} | UE does not Support DM-RS bundling for PUSCH repetition type A | ~~[Per UE]~~Per band per BC or Per band and per BC |  | Optional with capability signalling |
|  30. NR\_cov\_enh | 30-4b | DM-RS bundling for PUSCH repetition type B | Support DM-RS bundling for PUSCH repetition type B over consecutive symbols | 30-4, 11-5 | UE does not Support DM-RS bundling for PUSCH repetition type B | ~~[Per UE]~~Per band per BC or Per band and per BC |  | Optional with capability signalling |
|  30. NR\_cov\_enh | 30-4c | DM-RS bundling for TB processing over multi-slot PUSCH | Support DM-RS bundling for TB processing over multi-slot PUSCH over consecutive symbols  | 30-4, 30-3 | UE does not Support DM-RS bundling for TB processing over multi-slot PUSCH | ~~[Per UE]~~Per band per BC or Per band and per BC | Note: If a UE reports support of FG 30-3a and 30-4c, the UE supports DMRS bundling for the repetitions of TBoMS | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4d | DMRS bundling for PUCCH repetitions | Support DM-RS bundling for PUCCH repetitions for PUCCH formats 1/3/4 over consecutive symbols | 30-4, 4-23 | UE does not support DMRS bundling for PUCCH repetitions | ~~[Per UE]~~Per band per BC or Per band and per BC |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4e | Enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH | Support enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH | 30-4a or 30-4b or 30-4c | UE does not support enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH | ~~[Per UE]~~Per band per BC or Per band and per BC |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4f | Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | 30-4d | UE does not support Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | ~~[Per UE]~~Per band per BC or Per band and per BC |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4g | ~~[~~Restart DM-RS bundling after the events that violate power consistency and phase continuity~~]~~ | ~~[~~Support restarting DM-RS bundling after the events triggered by DCI or MAC-CE that violate power consistency and phase continuity~~]~~Note: Events which are triggered by DCI or MAC CE, but regarded as semi-static events, e.g. frequency hopping, UL beam switching for multi-TRP operation, or other if defined, are excluded. | 30-4 | ~~[~~UE does not support restarting DM-RS bundling after the events that violate power consistency and phase continuity~~]~~ | ~~[Per UE]~~Per band per BC or Per band and per BC |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4h | DM-RS bundling for non-back-to-back transmission | Support DM-RS bundling for non-back-to-back transmission for consecutive slots for PUSCH and PUCCH only for corresponding supported back-to-back transmission FGs (30-4a, 30-4b, 30-4c, or 30-4d) | 30-4a, 30-4b, 30-4c, or 30-4d | UE does not Support DM-RS bundling for non-back-to-back transmission | ~~[Per UE]~~Per band per BC or Per band and per BC |  | Optional with capability signalling |

 |
| [6] | Intel Corporation | According to the agreement, it is evident that subject to UE capability, UE restarts DMRS bundling within a nominal TDW only for the dynamic events that violate power consistency and phase continuity. For semi-static events that not triggered by DCI or MAC-CE, UE is mandatory to restart the DMRS bundling within a normal TDW. Hence, the description on FG30-4g needs to be updated. Further, for DMRS bundling, UE is required to maintain power consistency and phase continuity during an actual TDW. In order to meet the requirement, UE may need to consider or implement different RF components for different bands or in FR1 and FR2, especially when considering that residual absolute frequency offset may have different characteristics in low band and mmWave band. Based on reply LS [4], RAN4 has not concluded on whether the UE capability signalling to support each of these configurations should be defined per-band, or per-band per band combination. For DMRS bundling, UE is required to maintain power consistency and phase continuity during an actual TDW. In order to meet the requirement, UE may need to consider or implement different RF components for different bands or in FR1 and FR2, especially when considering that residual absolute frequency offset may have different characteristics in low band and mmWave band. Hence, it may be more appropriate to define UE feature groups for DMRS bundling per band.Based on the discussions above, Table 1 illustrates suggested updates for UE feature groups for DMRS bundling. Table 1. UE feature groups for DMRS bundling

|  |  |  |  |
| --- | --- | --- | --- |
| **Index** | **Feature group** | **Components** | **Consequence if the feature is not supported by the UE** |
| 30-4g | ~~[~~Restart DM-RS bundling after the events triggered by DCI or MAC-CE that violate power consistency and phase continuity~~]~~ | ~~[~~Support restarting DM-RS bundling after the events triggered by DCI or MAC-CE that violate power consistency and phase continuity~~]~~ | ~~[~~UE does not support restarting DM-RS bundling after the events triggered by DCI or MAC-CE that violate power consistency and phase continuity~~]~~ |

**Proposal 1*** For UE feature groups of DMRS bundling for PUSCH and PUCCH
	+ UE features for DMRS bundling are defined per band.
	+ Consider Table 1 for UE feature groups of DMRS bundling.
 |
| [7] | CMCC | In the RAN4 LS R1-2205715(R4-2211225), RAN4 informed that in FR1+FR2 UL CA, FR1+FR2 DC, and EN-DC with NR on FR2, DMRS bundling configuration is limited to one uplink NR carrier in total on all FRs at a time. Based on the above information, per band report should be enough, because the UL/CA and DMRS bundling is independent.And it was concluded that the FG 30-4 is per band reported. Then the FGs based on FG 30-4 should be also per band reported, such as FG 30-4a 30-4b. And consequently, for those per band reported FGs, FR1 and FR2 differentiation is needed. **Proposal 1:** **FG 30-4a to 30-4h should be per band reported and differentiated between FR1 and FR2.** Considering the behavior of the DMRS bundling within the nominal and actual TDWs are the same for both TDD and FDD. There is no need to differentiate TDD and FDD for those features.**Proposal 2：** **No need to differentiate TDD and FDD for FG 30-4a to FG 30-4h.**RAN 1 still have different understanding about the UE behavior when a dynamic event happened before or overlap with a semi-static event that violate power consistency and phase continuity. The FG 30-4g should be suspended until the discussion about restarting DMRS bundling ended in AI 8.8.**Proposal 3:****The FG 30-4g should be suspended until the discussion about restarting DMRS bundling ended in AI 8.8.** |
| [8] | Ericsson | Since uplink carrier aggregation can require sharing Tx chains or power among carriers, extra UE capability may be needed to operate DMRS bundling when the UE is configured for UL CA. As such, we can understand the motivation of the proposal to have more than per band capability for many of the DMRS bundling sub-features.A capability of per band and per BC could be defined in various ways. One way could be to indicate per band capability, and if the UE does not support a particular band combination, to indicate a lack of support for that band combination. This seems inconsistent with the guidance from RAN2 that says that defining “incapability” bits should be avoided [2].An alternative approach could be based on the definition of powerClass in 38.306, which has both per band and per band combination capabilities. Here we illustrate using 30-4, but this should be applied to the DMRS bundling sub-features.Table 2a: Example Per Band + Per Band Capability Definition

| **Definitions for parameters** | **Per** |
| --- | --- |
| ***maxDMRS-BundlingDurationBand-r17***Indicates the maximum number of consecutive slots during which the UE is able to maintain power consistency and phase continuity to support DM-RS bundling for a PUSCH or PUCCH when UE is configured with a single UL serving cell. | Band |
| ***DMRS-BundlingBC-r17***Indicates that the UE supports DM-RS bundling for a PUSCH or PUCCH also when UE is configured with more than one UL serving cell. The capability per band of the band combination is then given by *maxDMRS-BundlingDurationBand-r17.* | BC |

The per band + BC capability seems appropriate for 30-4a,b,c,d and 30-4g,h since these features in our view are ‘DMRS bundling’ features. However, frequency hopping is not affected by CA configurations, and indeed Rel-15 inter-slot hopping for PUSCH (UE feature 5-10) has per UE granularity. Given that 5-10 is per UE, we think that is a reasonable granularity for Rel-17 for UE features 30-4e and 30-4f. Per-band capability can also be considered if sufficiently motivated, e.g. to address IoDT test issues.Table 2b: Capabilities for PUSCH and PUCCH Joint Channel Estimation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Index | Feature group | Components | Prerequisite feature groups | 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) | Note |
| 30-4 | The maximum duration for DM-RS bundling | The maximum duration during which UE is able to maintain power consistency and phase continuity to support DM-RS bundling for PUSCH/PUCCH |  | Per Band | Candidate values for the maximum duration for FDD are {4, 8, 16, 32}Candidate values for the maximum duration for TDD are {2, 4, 8, 16}NOTE: DM-RS bundling is only applicable for UL transmissions with pi/2 BPSK, BPSK, and QPSK modulation orders for the corresponding physical channels. |
| 30-4a | DM-RS bundling for PUSCH repetition type A | Support DM-RS bundling for PUSCH repetition type A over consecutive symbols | 30-4 and one of {5-14, 5-16, 5-17} | ~~[Per UE]~~Per Band and Per BC, according to the approach above. |  |
| 30-4b | DM-RS bundling for PUSCH repetition type B | Support DM-RS bundling for PUSCH repetition type B over consecutive symbols | 30-4, 11-5 | ~~[Per UE]~~Per Band and Per BC, according to the approach above. |  |
| 30-4c | DM-RS bundling for TB processing over multi-slot PUSCH | Support DM-RS bundling for TB processing over multi-slot PUSCH over consecutive symbols | 30-4, 30-3 | ~~[Per UE]~~Per Band and Per BC, according to the approach above. | Note: If a UE reports support of FG 30-3a and 30-4c, the UE supports DMRS bundling for the repetitions of TBoMS |
| 30-4d | DMRS bunding for PUCCH repetitions | Support DM-RS bundling for PUCCH repetitions for PUCCH formats 1/3/4 over consecutive symbols | 30-4, 4-23 | ~~[Per UE]~~Per Band and Per BC, according to the approach above. |  |
| 30-4e | Enhanced Inter-slot frequency hopping with inter-slot bundling for PUSCH  | Support enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH  | 30-4a or 30-4b or 30-4c | ~~[~~Per UE~~]~~ |  |
| 30-4f | Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | Enhanced inter-slot frequency hopping for PUCCH repetitions with DMRS bundling | 30-4d | ~~[~~Per UE~~]~~ |  |
| 30-4g | [Restart DM-RS bundling after the events that violate power consistency and phase continuity] | ~~[Support restarting DM-RS bundling after the events that violate power consistency and phase continuity]~~ Support power consistency and phase continuity over an actual TDW created in response to events identified in 38.214 subclause 6.1.7, where such support of consistency/continuity for the event requires UE capability. | ~~[~~30-4~~]~~, and {30-4a, 30-4b, or 30-4c} | ~~[Per UE]~~Per Band and Per BC, according to the approach above. |  |
| 30-4h | DM-RS bundling for non-back-to-back transmission | Support DM-RS bundling for non-back-to-back transmission for consecutive slots for PUSCH and PUCCH only for corresponding supported back-to-back transmission FGs (30-4a, 30-4b, 30-4c, or 30-4d) | 30-4a, 30-4b, 30-4c, or 30-4d | ~~[Per UE]~~Per Band and Per BC, according to the approach above. |  |

1. UE features for PUSCH and PUCCH joint channel estimation are defined according to Tables 2a and 2b
 |
| [9] | Samsung | In summary, UL CA is not a proper operation for coverage limited scenario. However, RAN1 has not come to any agreements on UL CA whether it is ‘supported’ or ‘not supported’. In addition, RAN4 has informed RAN1 that they agreed to define requirements for FR1+FR2 UL CA/DC/EN-DC where DM-RS bundling configuration is limited to one uplink NR carrier in total on all FRs at any given time. Therefore, in order to move forward and in light of no RAN1 specification change, we propose to take a similar approach as RAN4 and introduce a limitation on the number of uplink carriers where DM-RS bundling can be configured at any given time. Such limitation can be captured in corresponding RRC parameters. Thus, we have the following proposal (same proposal as in our companion contribution in AI 8.8 [4])**Proposal 1: Only one band can be configured with DM-RS bundling at a time for the following cases:*** **DL CA with “additional” UL carrier configured with SRS only (i.e. no PUCCH/PUSCH configured)**
* **FR1 inter-band UL CA with DM-RS bundling**
* **SUL with DM-RS bundling**

Regarding signaling granularity of UE capabilities (30-4a, 30-4b, 30-4c, 30-4d, 30-4e, 30-4f, 30-4g, 30-4h), we support ‘per band’. **Proposal 2: The signaling granularity of FGs 30-4a, 30-4b, 30-4c, 30-4d, 30-4e, 30-4f, 30-4g and 30-4h is ‘per band’.**In case when UE is not capable of restarting DMRS bundling, a question was raised how to address the scenario where semi-static events occur after dynamic events in one nominal TDW. In addition, a new UE capability of restarting DMRS bundling subject to semi-static events was proposed (either new FG or new component in the existing FG). While we understand the proponent’s motivation to maximize DMRS bundling functionality, it is not desirable to introduce additional specification change at this late stage. **Observation: Introducing new UE capability of restarting DMRS bundling subject to semi-static events is not justified.**we propose to take the same approach for FG 30-4g.**Proposal 3: Update 30-4g as following in alignment with the corresponding RRC parameter description.**

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| 30-4g | ~~[~~Restart DM-RS bundling ~~after the events that violate power consistency and phase continuity]~~ | ~~[~~Support restarting DM-RS bundling after the events triggered by DCI or MAC-CE that violate power consistency and phase continuity~~]~~Note: Events which are triggered by DCI or MAC CE, but regarded as semi-static events, e.g. frequency hopping, UL beam switching for multi-TRP operation, or other if defined, are excluded. |

**Proposal 4: Update the ‘Consequence if the feature is not supported by the UE’ for 30-4g as following.**~~[~~UE does not support restarting DM-RS bundling after the events triggered by DCI or MAC-CE that violate power consistency and phase continuity~~]~~ |
| [10] | NTT DOCOMO, INC. | **Proposal 3-1: Add notes indicating applicable multi-carrier scenarios in FGs 30-4a/b/c/d/h.** In our view, DMRS bundling should be at least supported for DL CA and SUL, since the concurrent uplink transmissions on NUL and SUL are not expected. Similarly, scenarios for UL Tx switching with switched UL can also apply DMRS bundling as there is no concurrent uplink transmissions on multiple UL carriers in case of switched UL. **Proposal 3-2: Add notes “this capability is also applicable to scenarios with multiple carriers where there is no concurrent uplink transmissions on multiple carriers” in FGs 30-4a/b/c/d/h.** Types of FGs 30-4a to 30-4h are still controversial. One of the biggest concerns in DMRS bundling with CA/DC is simultaneous DMRS bundling. It could cause the dynamic power sharing and RF complexity. However, RAN4 has agreed to define requirements for the scenarios with a single uplink NR carrier at a time, and there is less possibility to cover the scenarios with more than one uplink carrier from now. Therefore, we think per band with adding note “a single uplink carrier at a time is expected” can be supported for FGs 30-4a to 30-4h, unless the explicit technical problem is observed. **Proposal 3-3: FGs 30-4a to 30-4h can be supported as per band with adding a note “a single uplink carrier at a time is expected”.**Regarding FG30-4g, whether it is mandatory to restart DMRS bundling subject to semi-persistent events after the dynamic event within a nominal TDW is still under the discussion in AI 8.8 “Maintenance on NR coverage enhancement”. As we proposed in [8], one of solutions could be to introduce the multiple components corresponding to different implementation difficulties in FG30-4g as following.

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| 30. NR\_cov\_enh | 30-4g | [Restart DM-RS bundling after the events that violate power consistency and phase continuity] | 1. Support of restarting DMRS bundling subject to semi-static events, even when a dynamic event is precedent or overlapping with the corresponding semi-static event.
2. Support of restarting DMRS bundling subject to dynamic events.
 | 30-4 | Yes | N/A | UE has the ability to restart DMRS bundling subject to semi-static events, unless any dynamic event is overlap-ping or triggered before the corresponding semi-static event within the nominal TDW. | [Per UE] | FFS | [No] | [N/A] |  | Optional with capability signalling |

Another solution could be to introduce multiple FGs corresponding to different implementation difficulties as following.

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| 30. NR\_cov\_enh | 30-4g | Restart DM-RS bundling after the dynamic events that violate power consistency and phase continuity | Support of restarting DMRS bundling subject to dynamic events. | 30-4i | Yes | N/A | UE cannot restart DMRS bundling subject to dynamic events  | [Per UE] | FFS | [No] | [N/A] |  | Optional with capability signalling |
| 30. NR\_cov\_enh | 30-4i | Restart DM-RS bundling after the semi-static events after dynamic events. that violate power consistency and phase continuity | Support of restarting DMRS bundling subject to semi-static events, even when a dynamic event is precedent or overlapping with the corresponding semi-static event. | 30-4 | Yes | N/A | UE has the ability to restart DMRS bundling subject to semi-static events, unless any dynamic event is overlap-ping or triggered before the corresponding semi-static event within the nominal TDW. | [Per UE] | FFS | [No] | [N/A] |  | Optional with capability signalling |

Therefore, it is better to discuss such potential solutions either in AI 8.8 or in this AI. If it should be discussed in AI 8.8 first, the conclusion should be made as early as possible. **Proposal 3-4: Discuss potential capability for restarting DMRS bundling in either AI 8.8 or AI 8.16.2.****Proposal 3-5: Support either Alt1 or Alt2.****Alt1: Support the following UE capabilities related to restarting DMRS bundling.** **・Component 1: Support of restarting DMRS bundling subject to semi-static events, even when a dynamic event is precedent or overlapping with the corresponding semi-static event.****・Component 2: Support of restarting DMRS bundling subject to dynamic events.****・Consequence if the feature is not supported by the UE (which supports DMRS bundling): UE has the ability to restart DMRS bundling subject to semi-static events, unless any dynamic event is overlapping or triggered before the corresponding semi-static event within the nominal TDW.****Alt2: Support the following multiple UE capabilities related to restarting DMRS bundling.****・UE capability 1: UE has the ability to restart DMRS bundling subject to semi-static events, even when a dynamic event is precedent or overlapping with the corresponding semi-static event.****・UE capability 2: UE has the ability to restart DMRS bundling subject to semi-static events or dynamic events****・No UE capability: UE (which supports DMRS bundling) has the ability to restart DMRS bundling subject to semi-static events, unless any dynamic event is overlapping or triggered before the corresponding semi-static event within the nominal TDW.** |
| [11] | Qualcomm Incorporated | We suggest the following changes:**Proposal 2-1**: Add the following constraint to 30-4h (non-back-to-back case):“Note: This capability is only applicable when UE is configured with single uplink carrier.”**Proposal 2-2**: Add the following constraints to UE capability FGs 30-4a, 4b, 4c, and 4d (the four back-to-back cases):“Note: This capability is applicable in the following multi-carrier scenarios:* FR1+FR2 CA/DC with one band on FR1 and another band on FR2. DMRS bundling configuration is limited to one uplink NR carrier in total on all FRs at a time.
* SUL
* FR1+FR1 Inter-band CA/DC involving two or more FR1 bands where UE does not expect concurrent uplink transmissions on any two carriers

All carriers must belong to a single TAG”**Proposal 2-3**: UE capability FGs 30-4a, 4b, 4c, and 4d are signaled at per band and per band combination granularity. |
| [12] | Nokia, Nokia Shanghai Bell | * **30-4a/b/c/d:**
* Per band and per BC indication, given that UL CA without simultaneous transmission is also supposed to be supported here.
* Add the following note: UE supporting this capability only supports it on transmissions with a single UL carrier, even when UE is configured with UL CA.
* **30-4e:**
* Per UE is sufficient if prerequisites are agreed per band/BC already. No differentiation needed.
* **30-4g:**
* Description of "Feature group" should be (changes are highlighted in red):
* "Restart DM-RS bundling after the dynamic events that violate power consistency and phase continuity"
* Description of "Components" should be (changes are highlighted in red):
* "Support restarting DM-RS bundling after the events triggered by DCI or MAC-CE that violate power consistency and phase continuity, except events which are triggered by DCI or MAC CE but regarded as semi-static events"
* Description of "Consequence if the feature is not supported by the UE" should be (changes are highlighted in red):
* "UE does not support restarting DM-RS bundling after the dynamic events that violate power consistency and phase continuity"
* Per UE is sufficient if prerequisites are agreed per band/BC already. No differentiation needed.
* **30-4h:**
* Per UE is sufficient if prerequisites are agreed per band/BC already.
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At the RAN#97-e, the following conclusion and moderator’s suggestion related to UE capability for coverage enhancements were made [13]

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| **Issue#1: Support of DMRS bundling in case of UL operation over multiple carriers**Conclusion:On the issue of supporting DMRS bundling in case of UL operation over multiple carriers, WGs are to continue with their work to resolve the issue (for radio configurations included in R4-2211225) before RAN#98 under the assumption of no RAN1 specification change.**Issue#3: UE behavior of restarting DMRS bundling**From moderator’s view, additional discussion does not seem helpful. Moderator will report the situation toRAN chair and suggest to stop the discussion on Issue#3 in RAN#97e. |

In this summary, solutions to the above remaining issues are discussed with companies’ feedback.

## **2.1 Restarting DMRS bundling**

**Proposal 2-1-1:**

* **Apply either one of following alternatives for restarting DMRS bundling**
	+ **Alt.1: Keep only one related to restarting DMRS bundling (FG 30-4g)**
		- **Alt.1-1: Keep one component [2,4,6,8,9]**
			* **If a semi-static event overlaps with or is triggered after one or multiple dynamic events, a new actual TDW is created after the semi-static events for UE supporting this capability [2]**
		- **Alt.1-2: Have two components for i) capability for restarting DMRS bundling subject to semi-static events after dynamic events within a nominal TDW and ii) capability for restarting DMRS bundling subject to dynamic events [10]**
	+ **Alt.2: Introduce two FGs for i) capability for restarting DMRS bundling subject to semi-static events after dynamic events within a nominal TDW and ii) capability for restarting DMRS bundling subject to dynamic events [10]**
	+ **Alt.3 Wait for the discussion in AI 8.8 [7]**

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**Proposal 2-1-2:**

* **Apply either one of following alternatives for the description of “Feature group” in FG 30-4g**
	+ **Alt.1: Add “triggered by DCI or MAC CE” after “event(s)” [2,6]**
		- **Alt.1-a: Add “triggered by DCI other than frequency hopping or by MAC CE” after “event(s)” [2]**
	+ **Alt.2: Add “dynamic” before “event(s)” [12]**
	+ **Alt.3: Remove “after the events that violate power consistency and phase continuity” [9]**
	+ **Alt.4: Remove bracket [4, 5]**

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**Proposal 2-1-3:**

* **Apply either one of following alternatives for the description of “Components” in FG 30-4g**
	+ **Alt.1: Add “triggered by DCI or MAC CE” after “event(s)” [2,5,6,9,12]**
		- **Alt.1-1: Make it aligned with RRC parameter description [5,9]**
		- **Alt.1-2: Add “triggered by DCI other than frequency hopping or by MAC CE” after “event(s)” [2]**
		- **Alt.1-3: Add “triggered by DCI or MAC-CE that violate power consistency and phase continuity, except events which are triggered by DCI or MAC CE but regarded as semi-static events” after “event(s)” [12]**
	+ **Alt.2: Remove bracket [4]**
	+ **Alt.3: Modify it into “Support power consistency and phase continuity over an actual TDW created in response to events identified in 38.214 subclause 6.1.7, where such support of consistency/continuity for the event requires UE capability” [8]**

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**Proposal 2-1-4:**

* **Apply either one of following alternatives for the description of “Consequence if the feature is not supported by the UE” in FG 30-4g**
	+ **Alt.1: Add “triggered by DCI or MAC CE” after “event(s)” in the description [2,6,9]**
		- **Alt.1-1: Add “triggered by DCI other than frequency hopping or by MAC CE” after “event(s)” [2]**
	+ **Alt.2: Add “dynamic” before “events” [12]**
	+ **Alt.3: Remove bracket [4, 5]**

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## **2.2 DMRS bundling for CA/DC/SUL**

**Proposal 2-2-1:**

* **Add the following note specifying the appliable multi-carrier scenarios for FG 30-4a, 4b, 4c, and 4d**
	+ **This capability is applicable to multiple carrier scenarios where UE is not expected to transmit concurrent uplink transmissions on multiple carriers [3,9,10,11,12]**
		- **Opt1: FR1+FR2 CA/DC with one band on FR1 and another band on FR2. DMRS bundling configuration is limited to one uplink NR carrier in total on all FRs at a time. [3,11]**
		- **Opt2: FR1 inter-band DL CA with a ‘single’ uplink band configured [3,9]**
		- **Opt3: DL CA with ‘additional’ UL carrier configured with SRS only [3,9]**
		- **Opt4: SUL [3,9,11]**
		- **Opt5: FR1+FR1 inter-band CA involving two or more FR1 bands, where UE does not expect concurrent uplink transmissions on two carriers where only configuration of a single TAG is supported [3,11]**

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**Proposal 2-2-2:**

* **Add the following note specifying the appliable multi-carrier scenarios for FG 30-4h**
	+ **“Note: This capability is only applicable when UE is configured with single uplink carrier. “[3,11]**

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**Proposal 2-2-3:**

* **Apply either one of following alternatives for the type of FGs 30-4a/b/c/d**
	+ **Alt.1: Per band [2,6,7,9]**
	+ **Alt.2: Per band and per BC [3,5,8,12]**
	+ **Alt.3: Per FS [4,5]**

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**Proposal 2-2-4:**

* **Apply either one of following alternatives for the type of FGs 30-4e**
	+ **Alt.1: Per UE [3,8,12]**
		- **Alt1-1: No differentiation for TDD/FDD and FR1/FR2 [12]**
	+ **Alt.2: Per band [2,6,7,9]**
	+ **Alt.3: Per band and per BC [5]**
	+ **Alt.4: Per FS [4,5]**

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**Proposal 2-2-5:**

* **Apply either one of following alternatives for the type of FGs 30-4f**
	+ **Alt.1: Per UE [3,8]**
	+ **Alt.2: Per band [2,6,7,9]**
	+ **Alt.3: Per band and per BC [5]**
	+ **Alt.4: Per FS [4,5]**

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**Proposal 2-2-6:**

* **Apply either one of following alternatives for the type of FGs 30-4g**
	+ **Alt.1: Per UE [12]**
		- **Alt1-1: No differentiation for TDD/FDD and FR1/FR2 [12]**
	+ **Alt.2: Per band [2,6,7,9]**
	+ **Alt.3: Per band and per BC [3,5,8]**
	+ **Alt.4: Per FS [4,5]**

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**Proposal 2-2-7:**

* **Apply either one of following alternatives for the type of FGs 30-4h**
	+ **Alt.1: Per UE [12]**
	+ **Alt.2: Per band [2,6,7,9]**
	+ **Alt.3: Per band and per BC [3,5,8,11]**
	+ **Alt.4: Per FS [4,5]**

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# **Conclusions**

TBD

# **References**

1. R1-2207923 Updated RAN1 UE features list for Rel-17 NR after RAN1 #110 Thursday Moderators (AT&T, NTT DOCOMO, INC.)
2. R1-2208461 Remaining issues for UE features set 1 topics Huawei, HiSilicon
3. R1-2208530 Discussion on UE features for topics 1 ZTE
4. R1-2208622 Remaining issues on UE features for MBS, Coverage enhancement and URLLC vivo
5. R1-2208767 Remaining issues on UE features for Rel-17 NR coverage enhancements China Telecom
6. R1-2209038 Discussion on UE features for NR coverage enhancement Intel Corporation
7. R1-2209319 Maintenance on Rel.17 UE features for NR coverage enhancement CMCC
8. R1-2209670 Rel-17 UE features topics set #1 Ericsson
9. R1-2209709 UE features for Coverage Enhacement Samsung
10. R1-2209886 Discussion on remaining issues regarding Rel-17 RAN1 UE features topics 1 NTT DOCOMO, INC.
11. R1-2209963 Discussion on Rel-17 UE features topic 1 Qualcomm Incorporated
12. R1-2210098 Remaining issues for UE features topics 1 Nokia, Nokia Shanghai Bell
13. RP-222592 Moderator's summary for discussion [97e-32-R17-CovEnh] RAN1 Chair (Samsung)