**3GPP TSG RAN WG1 #104b-e R1-21xxxxx**

**e-Meeting, April 12th – 20th, 2021**

**Agenda Item:** 8.2.5

**Source:** Moderator (LG Electronics)

**Title:** Summary #1 of PDSCH/PUSCH enhancements (Scheduling/HARQ)

**Document for:** Discussion and decision

# Introduction

This is the summary document for 8.2.5 on PDSCH/PUSCH enhancements (especially for scheduling and HARQ) for NR above 52.6 GHz, based on the contributions listed in reference section.

To facilitate discussion, priorities are set for each proposal/observation/conclusion, as follows:

* High priority
  + Proposal #1 in Section 2.1 for the maximum number of scheduled PDSCHs/PUSCHs
  + Proposal #3 in Section 2.2 for TDRA field of multi-PUSCH scheduling DCI
  + Proposal #5 in Section 2.3 for details of multi-PDSCH scheduling DCI
  + Proposal #6 in Section 3.1 for semi-static HARQ-ACK codebook
  + Observations #1/2-1/2-2/3 in Section 3.2 for dynamic HARQ-ACK codebook
* Low priority
  + Proposal #2 in Section 2.1 for DCI format of multi-PDSCH/PUSCH scheduling DCI
  + Proposed conclusion #1 in Section 2.2 for CSI-request field of multi-PUSCH scheduling DCI
  + Proposal #4 in Section 2.2 for URLLC related field of multi-PUSCH scheduling DCI
  + Proposal #7 in Section 3.3 for multiple PUCCHs corresponding to multiple PDSCHs
  + Proposal #8 in Section 3.4 for the number of HARQ processed

The following email thread is assigned for discussion of this topic:

[104b-e-NR-52-71GHz-06] Email discussion/approval on scheduling particularly w.r.t. multi-PDSCH/PUSCH with a single DCI, HARQ, with checkpoints for agreements on Apr-16, Apr-20 – Seonwook (LGE)

# Multi-PDSCH/PUSCH scheduling

## General aspects

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| Company | Views |
| [1] Huawei | Proposal 5: The maximum number of PDSCHs/PUSCHs scheduled by a single DCI should be 4 and 8 for 480 kHz and 960 kHz respectively.  Proposal 6: Only support PDSCH/PUSCH mapping type A for 480 kHz SCS and 960 kHz SCS. |
| [4] vivo | Proposal 14: For scheduling DCI format, the same solution adopted in Rel-16 NR-U can be reused, i.e., the same DCI format is used for both single PUSCH scheduling and multi-PUSCH scheduling. |
| [5] Nokia | Proposal 6: Consider dynamic indication of the number of repetition also for PDSCH.  Proposal 7: For multi-PxSCH.  • Use Rel-16 solution as the baseline for both multi-PDSCH and multi-PUSCH  • Support up-to eight PxSCH by a single DCI  • No need to support multi-PDSCH for 120 kHz SCS. |
| [6] CAICT | Proposal 1: The maximum number of PDSCHs or PUSCHs that can be scheduled with a single DCI could be 8 for 480kHz and 960kHz.  Proposal 2: Multiple PDSCH scheduling could apply to 120 kHz. |
| [7] CATT | Proposal 5：When the actual number of scheduled PDSCH/PUSCH is less than maximum number of PDSCH/PUSCH scheduling by RRC configuration, RAN1 can further study how to utilize the unused bits to improve transmission efficiency.  Proposal 6: Fall back DCI (e.g format 1\_0/0\_0) does not support multi-PDSCH/PUSH transmission. |
| [10] Ericsson | Proposal 2: The maximum number of PDSCHs/PUSCHs that can be scheduled with a single DCI is 8.  Proposal 4: Support single-slot scheduling with slot-based monitoring for 480 and 960 kHz SCSs.  Proposal 5: Support multiple PDSCH scheduling for 120 kHz SCS.  Proposal 16: Do not support scheduling of multiple PDSCHs with a single DCI where the TB(s) corresponding to one or more of the PDSCHs is(are) mapped over multiple slots by legacy TB repetition (semi-statically configured by pdsch-AggregationFactor or dynamically indicated by repetitionNumber in TDRA table).  Proposal 17: As in Rel-16, do not support scheduling of multiple PUSCHs with a single DCI where one or more of the PUSCHs is(are) mapped over multiple slots by legacy TB repetition (Type A or B repetition). |
| [11] Xiaomi | Proposal 6: For 480 kHz SCS, maximum number of PDSCHs or PUSCHs that can be scheduled with a single DCI is 8, for 960 kHz SCS, maximum number is 16. |
| [14] Intel | Proposal 2: For multi-PDSCH scheduling, supported both TB and CBG based scheduling.  O Maximum number of PDSCHs for TB based scheduling is 8  O Maximum number of PDSCHs for CBG based scheduling is 2. |
| [16] Qualcomm | Proposal 7: Multi-PDSCH or multi-PUSCH scheduling with the same DCI should be applicable to 120kHz as well as 480 and 960kHz, though we don’t need to introduce multi-slot monitoring capability for 120KHz  Proposal 8: For a given SCS, if the PDCCH monitoring periodicity is N slots, then a single DCI should be able to grant at least N PDSCHs/PUSCHs. |
| [17] Samsung | Proposal 5: The maximum number of PDSCHs/PUSCHs scheduled by a single DCI can be 8.  Proposal 8: Support single DCI for single or multi-PDSCH/PUSCH scheduling as Rel-16 NR-U. |
| [18] Sony | Proposal 4: No new DCI format is needed for multi-PDSCH scheduling. |
| [19] LG Electronics | Proposal #1: The maximum number of PDSCHs or PUSCHs that can be scheduled with a single DCI in Rel-17 is no less than 8.  Proposal #2: Apply scheduling multiple PDSCHs by single DL DCI to all SCSs including 480 and 960 kHz.  Proposal #4: Do not introduce new DCI format and use DCI format 1\_1 to schedule multiple PDSCHs with a single DCI. |
| [20] CEWiT | Proposal 2: The maximum number of PDSCH/PUSCH that can be scheduled per DCI should be studied. |
| [21] Convida | Proposal 1. The maximum number of scheduled PDSCHs by a single DCI can be referred from Rel-16 single DCI scheduling multi-PUSCH as a baseline.  Proposal 2. Same DCI format can schedule either single PDSCH or multi-PDSCH to reduce BD effort and support scheduling flexibility. |
| [22] InterDigital | Proposal 3: Single-slot scheduling with slot-based monitoring is supported for all the SCS values, i.e. 120 kHz, 480 kHz, and 960 kHz.  Observation 5: The enhancement of time domain resource allocation can be a crucial part for efficient operation in higher frequencies due to use of higher SCSs (e.g. 480 kHz and 960 kHz)  Observation 6: Flexible time domain resource determination based on Rel-16 multi-slot PUSCH scheduling or slot bundling requires complex UE implementation burdens and specification impacts. However, performance benefits are not clear considering the reduced symbol/slot lengths of high SCSs.  Observation 7: Semi-statically configured scaling factor per SCS provides competitive signaling overheads and blind detections with simple UE implementation and specification impact.  Proposal 4: Support semi-static configuration of scaling factor per SCS for multiple PDSCH/PUSCH scheduling with the same DCI.  Proposal 5: Multiple PDSCH scheduling only applies to 480 kHz and 960 kHz SCS. Multiple PDSCH scheduling does not apply to 120 kHz.  Proposal 6: The maximum number of PDSCHs or PUSCHs schedule by a single DCI depends on the SCS. For 480 kHz the value is 4 and for 960 kHz the value is 8. |
| [23] Panasonic | Proposal 2: The number of PDSCHs/PUSCHs scheduled by a DCI is increased to 16 only when a UE supports 32 HARQ processes in order to prevent all HARQ processes from being used by a single DCI.  Proposal 3: FFS on increasing the number of PDSCHs/PUSCHs scheduled by a DCI to 16.  Proposal 4: Support at least 8 PDSCHs/PUSCHs scheduled by a DCI to 120 kHz SCS regardless of licensed band or unlicensed band usage. |
| [25] NEC | Proposal 1: The maximum number of PDSCHs that can be scheduled with a single DCI should be discussed and decided. |
| [26] NTT | Proposal 4: For multi-PDSCH/PUSCH scheduling,  - Multi-PDSCH scheduling can apply to 120kHz in addition to 480kHz and 960kHz SCS.  - Maximum number of PDSCHs or PUSCH scheduled by a DCI can be equal to 8 or larger than 8 (e.g. 16). The maximum number may be different for different SCSs. |

### Summary (on the maximum number of scheduled PDSCHs/PUSCHs):

Company views on the maximum number of PDSCHs or PUSCHs that can be scheduled by a single DCI:

* 8 for all SCSs
  + Supported by Nokia, CAICT, Ericsson, Intel, Samsung, LG Electronics, Convida, Panasonic, NTT DOCOMO
* 4 for 480 kHz SCS and 8 for 960 kHz SCS
  + Supported by Huawei, InterDigital
* 16 for all SCSs
  + Supported by Panasonic (if 32 HARQ processes are supported)
* 8 for 480 kHz SCS and 16 for 960 kHz SCS
  + Supported by Xiaomi

### Summary (on the applicability of multi-PDSCH scheduling for 120 kHz SCS):

Company views on the applicability of multi-PDSCH scheduling for 120 kHz SCS:

* Supported by CAICT, Ericsson, Qualcomm, LG Electronics, Panasonic
* Objected by Nokia, InterDigital

### Summary (on DCI format for multi-PDSCH/PUSCH scheduling):

Company views on DCI format for multi-PDSCH/PUSCH scheduling:

* vivo, Samsung, Convida: Same principle with Rel-16 multi-PUSCH scheduling (i.e., the same DCI format is used for both single PDSCH/PUSCH scheduling and multi-PDSCH/PUSCH scheduling)
* CATT: Not for fallback DCI (e.g., DCI format 1\_0/0\_0)
* Sony: NO new DCI format
* LG Electronics: Reuse DCI format 1\_1 for multi-PDSCH scheduling

### Summary (on other aspects):

Other aspects that are suggested by a few companies are summarized as follows:

* Huawei: Only support PDSCH/PUSCH mapping type A for 480 kHz SCS and 960 kHz SCS.
* Ericsson, InterDigital: Support single-slot scheduling with slot-based monitoring for 480 and 960 kHz SCSs.

On the maximum number of scheduled PDSCHs/PUSCHs, most companies suggest up to 8 PDSCH/PUSCHs can be scheduled by a single DCI. However, there are different views on whether additional value can be introduced depending on SCSs. Therefore, the following proposal can be made:

### Proposal #1 (High priority):

* The maximum number of PDSCHs or PUSCHs that can be scheduled with a single DCI in Rel-17 is 8.
  + FFS: Additional value for the maximum number of PDSCHs or PUSCHs that can be scheduled with a single DCI, e.g., depending on SCSs

Companies are encouraged to provide views on Proposal #1.

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| Company | Views |
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On DCI format for multi-PDSCH/PUSCH scheduling, common views seem not to introduce new DCI format but to reuse legacy DCI format. Thus, the following proposal can be made:

### Proposal #2 (Low priority):

* Do not introduce new DCI format for multi-PDSCH/PUSCH scheduling.
* Use DCI format 0\_1 to schedule multiple PUSCHs with a single DCI.
* Use DCI format 1\_1 to schedule multiple PDSCHs with a single DCI.

Companies are encouraged to provide views on Proposal #2.

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| Company | Views |
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## Details on multi-PUSCH scheduling

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| Company | Views |
| [1] Huawei | Observation 1: Further enhancements of FDRA and frequency hopping for multi slot scheduling are not essential.  Proposal 7: For multi-slot scheduling of 480 kHz and 960 kHz, support Alt 1 as the TDRA indication scheme, and reuse the FDRA indication including the RBG size definition in FR2.  - Alt 1: TDRA table is extended such that each row indicates up to [X, FFS for X] multiple PUSCHs (continuous in time-domain). Each PUSCH has a separate SLIV and mapping type. The number of scheduled PUSCHs is signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.  Proposal 9: CBG (re)transmission is not supported for multi-slot PDSCH/PUSCH scheduling  Proposal 10: Same multiplexing rule for aperiodic CSI report in multi PUSCH scheduling in Rel-16 should be applied at least in shared spectrum operation.  Proposal 11: URLLC related issues should be low priority in the WI. |
| [2] OPPO | Proposal 1: CBG (re)transmission is not supported when more than one PUSCHs are scheduled.  Proposal 2: A same rule should be applied for AP-CSI feedback on scheduled PUSCH.  Proposal 3: If non-contiguous PUSCH transmission is identified to be beneficial, then Alt 2 is supported, otherwise, Alt 1 is supported.  Proposal 4: There is no need to change the granularity of FDRA.  Proposal 5: Inter-PUSCH/intra-PUSCH frequency hopping for scheduled PUSCHs can be considered.  Proposal 6: Do not apply URLLC related fields for scheduling PUSCHs in Rel-17.  Proposal 7: The mechanism of resource allocation for slot aggregation should be supported for multi-PDSCH in addition to the mechanisms similar to Alt 1/Alt 2 for multi-PUSCH. |
| [3] Spreadtrum | Proposal 1: Regarding TDRA mechanism, non- continuous PUSCH assignment method (Alt 2) with X=8 should be supported.  Proposal 2: Frequency hopping should be supported for scheduled PUSCH.  Proposal 3:  • CBG (re)transmission should not be supported when more than one PUSCHs are scheduled.  • apply same rule compared to Rel-16 NR-U for CSI request.  • apply same method rule compared to Rel-16 NR-U for FDRA. |
| [4] vivo | Proposal 7: The Alt 2 for time domain scheduling is supported as the baseline, where the TDRA table is extended such that each row indicates up to X multiple PUSCHs that can be non-continuous in time domain.  Proposal 8: The Alt 3 for time domain scheduling can also be considered if the maximum number of PUSCHs scheduled by a single DCI is larger than a threshold, where the TDRA table is extended such that each row indicates up to 8 multiple PUSCH groups that can be non-continuous in time domain among them.  Proposal 9: It is not needed to enhance frequency domain scheduling for multi-PUSCH scheduling.  Proposal 10: It can be clarified that the URLLC related fields in the DCI scheduling multiple PUSCHs are applied equally to each scheduled PUSCH, including priority indicator and open-loop power control parameter set indication.  Proposal 12: For CBG based scheduling, the same solution adopted in Rel-16 NR-U multi-PUSCH scheduling can be reused, i.e., CBG based scheduling is supported only when a UL DCI schedules a single PUSCH.  Proposal 13: For A-CSI reporting, the same solution adopted in Rel-16 NR-U multi-PUSCH scheduling can be reused, i.e. A-CSI is multiplexed in the M-th or (M-1)-th scheduled PUSCH based on the value of M. |
| [5] Nokia | Proposal 8: For TDRA, support Alt 1 for both multi-PDSCH and multi-PUSCH  • Introduce slot dropping by a separate mechanism.  Proposal 9: The following enhancements are considered as secondary topics which are considered only if time allows: FDRA enhancements, frequency hopping enhancements, URLLC enhancements, and CBGTI enhancements. |
| [6] CAICT | Proposal 4: Alt.2 is proposed for multi-PUSCH TDRA.  Proposal 5: Multi-PDSCH scheduling could also use the TDRA scheme for Multi-PUSCH scheduling under the condition of non-continues transmission is supported. |
| [7] CATT | Proposal 7：For TDRA configuration, Alt 2 is preferred since it provides more flexibility in scheduling.  Proposal 8：Whether the HARQ process ID is still consecutive when one or more SLIVs value is invalid shall be further discussed. |
| [8] Fujitsu | Proposal 1: Support Alt 2 for TDRA of multi-PUSCH scheduling.  • Alt 2: TDRA table is extended such that each row indicates up to [X, FFS for X] multiple PUSCHs (that can be non-continuous in time-domain). Each PUSCH has a separate SLIV and mapping type. The number of scheduled PUSCHs is signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI. |
| [10] Ericsson | Proposal 6: Support Alt-2 with separate SLIV, mapping type, and scheduling offset K2 for each scheduled PUSCH. Support similar TDRA table with separate SLIV, mapping type and scheduling offset K0 for each scheduled PDSCH.  Proposal 7: Introduce new RBG configuration for PDSCH/PUSCH frequency resource allocation Type 0 to reduce FDRA granularity and DCI size.  Proposal 8: Support configurable Resource Allocation Granularity (P) up to 32 for DCI Format 0\_1 and 1\_1 with PUSCH/PDSCH frequency resource allocation Type 1 to reduce FDRA granularity and DCI size.  Proposal 9: Support intra- and inter-slot frequency hopping for multi-PUSCH scheduling with a single DCI. For inter-slot hopping, consider modifying the hopping counter such that it increments across the scheduled PUSCHs rather than being tied to the slot number within the radio frame.  Proposal 10: When DCI Format 0\_1 is used for scheduling multiple PUSCHs, priority indicator and open-loop power control parameter set indication fields in the DCI should apply to all PUSCHs being scheduled.  Proposal 11: The multi-PUSCH scheduling defined in Rel-16 NR-U is used as the baseline for designing multi-PDSCH scheduling in Rel-17.  Proposal 21: Do not support CBG based HARQ feedback for multi-PDSCH/PUSCH scheduling |
| [11] Xiaomi | Proposal 12: Not support CBG (re)transmission when more than one PUSCHs are scheduled especially when the total HARQ processes is extended to 64/128.  Observation 1: The current DCI 0-2/1-2 can be reused to allow frequency domain resource by multi-PRB granularity.  Proposal 13: Support dynamic indication by DCI to determine the number of scheduled TTIs.  Proposal 14: Support to study intra-TTI frequency hopping and its enabling mechanism for multi-TTI scheduling. |
| [12] Lenovo | Proposal 1: For NR operation between 52.6 GHz and 71 GHz with high subcarrier spacing values such as 480kHz and 960kHz, specify enhancements to support multiple beams (multiple TCI states with QCL type-D assumption) indication via single DCI and corresponding duration of each beam within the scheduled duration:  • FFS the number of TCI states (beams) that can be indicated for multiple PDSCH (or PUSCH) across multiple slots by single TCI codepoint in DCI  Proposal 3: For NR operation between 52.6 GHz and 71 GHz with high subcarrier spacing values such as 480kHz and 960kHz, for TDRA for multiple PUSCH across multiple slots, support the extension of TDRA table such that:  • Each row indicates multiple SLIVs for multiple PUSCHs  • Each PUSCH is associated separate mapping type  • Maximum number of PUSCHs that is indicated by number of SLIVs is depending upon the SCS value i.e. 120kHz, 480kHz or 960kHz |
| [14] Intel | Proposal 1: For multi-PUSCH scheduling,  O Support Alt. 2 for TDRA, i.e., non-continuous resource in time for scheduled PUSCHs.  O Support CBG based scheduling when 2 PUSCHs are scheduled.  O Support intra-slot frequency hopping for scheduled PUSCHs.  O Do not support enhancement on CSI request.  O Do not support enhancement on FDRA. |
| [15] Apple | Proposal 2: For Rel-17 multi-PUSCH transmission  • A clear use case should be made for CBG support for multi-PUSCH transmission.  • Re-use the CSI-request mechanism in Rel-16 NR-U  • Specify non-continuous transmission of PDSCH/PUSCH with a maximum of 8 transmissions  • The FDRA size should be optimized to reduce the FDRA overhead.  • Specify inter-slot frequency hopping but not intra-slot frequency hopping for 480 kHz and 960 kHz  • a single URLLC priority should be assigned to a single DCI |
| [16] Qualcomm | Proposal 11: For multi-PUSCH DCI fields enhancements:  • CBGTI: Not to be supported for more than one PUSCH  • TDRA field: We support Alt 2  • URLLC fields: To be applied for all granted PUSCHs/PDSCHs with the same DCI  • FDRA: No changes are needed  • Frequency hopping: Not to be supported for multi-PUSCH grant |
| [17] Samsung | Proposal 6: Rel-16 NR-U multi-PUSCH scheduling DCI can be reused for multi-PUSCH in 52.6~71GHz with at least the following enhancement:  - A-CSI feedback: A-CSI in first PUSCH that satisfies the multiplexing timeline for licensed band, and A-CSI in last or penult PUSCH for unlicensed band.  - PUSCH TDRA: non-continuous PUSCH transmissions (Alt-2).  - PUSCH FDRA: larger RRC configured range for RBG.  - Frequency hopping: intra-PUSCH hopping.  - URLLC related field: same priority for all PUSCHs scheduled by a single DCI |
| [18] Sony | Proposal 2: Support Alt2: TDRA table is extended such that each row indicates up to [X, FFS for X] multiple PUSCHs (that can be non-continuous in time-domain). Each PUSCH has a separate SLIV and mapping type. The number of scheduled PUSCHs is signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI  Proposal 3: Support URLLC related fields  • Further study whether single or multiple fields related to URLLC are applied to multiple PUSCH scheduled by single DCI. |
| [19] LG Electronics | Proposal #3: For the multi-PUSCH scheduling in Rel-17, at least consider the following enhancements.  • TDRA: Alt 2 (as per the previous agreement made in RAN1#104-e). In detail, a row index of TDRA table is signalled with {K2, SLIV, mapping type} for the first PUSCH and {D, SLIV, mapping type} for each of next PUSCH(s) where D corresponds to slot level gap between adjacent PUSCHs.  • URLLC related fields such as priority indicator and/or open loop power control parameter set indication: Apply indicated value(s) only to the first PUSCH and apply pre-defined value (e.g., low priority) to the remaining PUSCH(s), if any. |
| [20] CEWiT | Proposal 1: Scheduling of multi PDSCHs/PUSCHs in non-contiguous time resources should be supported in NR above 52.6GHz |
| [22] InterDigital | Observation 8: It is observed that required payloads of DCI for frequency domain resource allocation do not increase as maximum number of RBs does not increase.  Observation 9: Larger RB size reduces frequency domain resource allocation flexibility, and this may be a crucial disadvantage as higher SCSs occupies larger bandwidths than lower SCSs within the same RBG size.  Proposal 7: The benefits from frequency domain resource allocation enhancements should be carefully evaluated.  Proposal 8: When multiple PUSCHs are scheduled using the same DCI, support only intra-PUSCH frequency hopping. |
| [23] Panasonic | Proposal 5: Not support CBG-based (re)transmission for multi-PDSCH/PUSCH scheduling by a DCI.  Proposal 6: Support to reuse the existing rule for CSI-request specified in Rel. 16 for multi-PDSCH/PUSCH scheduling by a DCI.  Proposal 7: Support to select Alt. 2 for enhancing TDRA table.  Proposal 8: No need to have the optimization of FDRA size except the consideration to change the minimum resource granularity for frequency resource allocation type 1.  Proposal 9: Support multi-beam indications for multi-PDSCH/PUSCH scheduling by a DCI and discuss it in AI 8.2.4. |
| [24] ZTE | Proposal 1: The CBG (re)transmission should be supported when more than one PUSCHs are scheduled and the CBGTI field should be per re-transmitted PUSCH in the multiple PUSCHs scheduling DCI.  Proposal 2: For CSI request, the same design as in Rel-16 NRU can be considered for above 52.6GHz at least for unlicensed band.  Proposal 3: The TDRA design can follow the principle of R16 NRU multi-PUSCH scheduling, that is Alt1 multiple consecutive PDSCHs/PUSCHs scheduling should be adopted. |
| [26] NTT DOCOMO | Proposal 5: For multi-PUSCH scheduled by single DCI,  • Support Alt 2 (non-contiguous scheduling enhancement) TDRA design for multi-PUSCH scheduling.  • Discuss whether/how a DCI format supporting multi-PUSCH scheduling can support scheduling single PUSCH with repetition.  • CBG based scheduling is not supported when multiple PUSCHs are scheduled by one DCI.  • A-CSI reporting on PUSCH rule in Rel-16 should be reused.  • Support FDRA enhancement to reduce DCI overhead.  • Support frequency hopping for multi-PUSCH scheduling. Newly introduced frequency hopping scheme for multi-PUSCH scheduling can be considered.  • For URLLC related fields, one value of each related field is applied for all scheduled PUSCHs. |

### Summary (on CBGTI enhancement):

Company views on CBGTI enhancement:

* CBG (re)transmission is NOT supported for multi-PUSCH scheduling DCI
  + Supported by Huawei, Ericsson, Apple?, Panasonic
* CBGTI field is not present when more than one PUSCHs are scheduled, i.e., same as Rel-16
  + Supported by OPPO, Spreadtrum, vivo, Xiaomi, Qualcomm, NTT DOCOMO
* CBGTI field is present when TWO PUSCHs are scheduled
  + Supported by Intel
* CBGTI field is always present
  + Supported by ZTE

### Summary (on CSI-request enhancement):

Company views on CSI-request enhancement:

* Same as in Rel-16 NR-U
  + Supported by Huawei (at least in shared spectrum operation), OPPO, Spreadtrum, vivo, Intel, Apple, Samsung (for unlicensed band), Panasonic, ZTE, NTT DOCOMO
* In the first PUSCH that satisfies the multiplexing timeline
  + Supported by Samsung (for licensed band)

### Summary (on TDRA enhancement):

Company views on TDRA enhancement:

* Alt 1 (only continuous allocation, same as in Rel-16)
  + Supported by Huawei, OPPO?, Nokia (with slot dropping), ZTE
* Alt 2 (allowing discontinuous allocation)
  + Supported by OPPO, Spreadtrum, vivo, CAICT, Fujitsu, Ericsson, Lenovo?, Intel, Apple, Qualcomm, Samsung, Sony, LG Electronics, CEWiT, Panasonic, NTT DOCOMO
* Alt 3 (same allocation for PUSCHs in a group)
  + Supported by vivo (if the maximum number of PUSCHs scheduled by a single DCI is larger than a threshold)

### Summary (on FDRA enhancement):

Company views on FDRA enhancement:

* Same as in Rel-16 (i.e., no enhancement): OPPO, Spreadtrum, vivo, Intel, Qualcomm, InterDigital?, Panasonic
* FDRA field enhancement to reduce DCI overhead
  + Supported by Ericsson (introducing new RBG configuration or supporting configurable granularity for RA type 1, for DCI format 0\_1/1\_1), Apple, Samsung (introducing new RBG configuration), NTT DOCOMO

### Summary (on frequency hopping enhancement):

Company views on frequency hopping enhancement:

* Intra-PUSCH hopping: OPPO, Xiaomi?, Samsung, InterDigital
* Inter-PUSCH hopping: OPPO, Spreadtrum?
* Intra-slot hopping: Ericsson
* Inter-slot hopping: Ericsson, Apple
* NO frequency hopping: Qualcomm

### Summary (on URLLC related field enhancement):

Company views on CBGTI enhancement:

* Apple commonly to all PUSCHs
  + Supported by vivo, Ericsson, Apple?, Qualcomm, Samsung, Sony?, NTT DOCOMO
* Apply indicated value(s) only to the first PUSCH and apply pre-defined value (e.g., low priority) to the remaining PUSCH(s), if any
  + Supported by LG Electronics
* Low priority or objection to handling of URLLC related feature in this WI
  + Huawei, OPPO, Nokia

Among above issues, we may reach the consensus on CSI-request, TDRA, and URLLC related fields.

### Proposed conclusion #1 (Low priority):

* For a DCI that can schedule multiple PDSCHs,
  + CSI-request: When a DCI schedules M PUSCHs, the PUSCH that carries the aperiodic CSI feedback is M-th scheduled PUSCH for M <= 2, or (M-1)-th scheduled PUSCH for M > 2.

Companies are encouraged to provide views on Proposed conclusion #1.

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| Company | Views |
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### Proposal #3 (High priority):

* For a DCI that can schedule multiple PDSCHs,
  + TDRA: Alt 2 (TDRA table is extended such that each row indicates up to [X, FFS for X] multiple PUSCHs (that can be non-continuous in time-domain). Each PUSCH has a separate SLIV and mapping type. The number of scheduled PUSCHs is signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.)
    - FFS: details

Companies are encouraged to provide views on Proposal #3.

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| Company | Views |
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### Proposal #4 (Low priority):

* For a DCI that can schedule multiple PDSCHs,
  + URLLC related fields such as priority indicator and open-loop power control parameter set indication: This applies to all of scheduled PUSCHs

Companies are encouraged to provide views on Proposal #4.

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## Details on multi-PDSCH scheduling

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| Company | Views |
| [1] Huawei | Proposal 9: CBG (re)transmission is not supported for multi-slot PDSCH/PUSCH scheduling  Proposal 11: URLLC related issues should be low priority in the WI. |
| [4] vivo | Proposal 11: The multi-PUSCH scheduling defined in Rel-16 NR-U can also be the baseline for multi-PDSCH scheduling in Rel-17, at least for the same or similar set of operations applicable to both DL and UL scheduling. |
| [5] Nokia | Proposal 10: Enhance DCI Format 1\_1 to support triggering multiple PDSCH TBs over multiple slots. Use multi-TB signaling defined for DCI format 0\_1 as the starting point. |
| [8] Fujitsu | Proposal 2: At least TDRA, HARQ process ID indication, RV indication and NDI indication for multi-PUSCH scheduling are applicable for multi-PDSCH scheduling. |
| [10] Ericsson | Proposal 7: Introduce new RBG configuration for PDSCH/PUSCH frequency resource allocation Type 0 to reduce FDRA granularity and DCI size.  Proposal 8: Support configurable Resource Allocation Granularity (P) up to 32 for DCI Format 0\_1 and 1\_1 with PUSCH/PDSCH frequency resource allocation Type 1 to reduce FDRA granularity and DCI size.  Proposal 11: The multi-PUSCH scheduling defined in Rel-16 NR-U is used as the baseline for designing multi-PDSCH scheduling in Rel-17.  Proposal 12: Introduce a new RRC TDRA table (pdsch-TimeAllocationListForMultiPDSCH) for multi-PDSCH scheduling in Rel-17.  Proposal 13: Similar enhancements on HARQ process ID, MCS, RV and NDI fields in DCI Format 0\_1 for multi-PUSCH scheduling in Rel-16 are leveraged to DCI Format 1\_1 to support multi-PDSCH scheduling in Rel-17.  Proposal 14: When multiple PDSCHs are scheduled by a single DCI with DCI Format 1\_1, the triggered ZP CSI-RS is applied to all the PDSCHs scheduled by the DCI.  Proposal 18: Support multi-PDSCH scheduling with a single DCI for multi-TRP transmission in Rel-17 except for the case where the TB(s) corresponding to one or more of the scheduled PDSCHs is(are) mapped over multiple slots by legacy TB repetition.  Proposal 21: Do not support CBG based HARQ feedback for multi-PDSCH/PUSCH scheduling |
| [11] Xiaomi | Observation 1: The current DCI 0-2/1-2 can be reused to allow frequency domain resource by multi-PRB granularity.  Proposal 13: Support dynamic indication by DCI to determine the number of scheduled TTIs. |
| [12] Lenovo | Proposal 2: For NR operation between 52.6 GHz and 71 GHz with high subcarrier spacing values such as 480kHz and 960kHz, specify enhancements to support multiple default beam association for multiple PDSCH scheduled by single DCI:  • PDCCH CORESET can be associated with multiple QCL assumptions (beams) that can be used to determine multiple default beams based on lowest CORESET ID  • Duration/applicability for each of the default beam can also be associated to allow UE to determine when to switch from one default beam to another during the duration of multiple PDSCH transmission  Proposal 4: For NR operation between 52.6 GHz and 71 GHz with high subcarrier spacing values such as 480kHz and 960kHz, for TDRA for multiple PDSCH across multiple slots, support the extension of TDRA table such that:  • Each row indicates multiple SLIVs for multiple PDSCHs  • Each PDSCH is associated separate mapping type  • Maximum number of PDSCHs that is indicated by number of SLIVs is depending upon the SCS value i.e. 120kHz, 480kHz or 960kHz |
| [14] Intel | Proposal 3: For multi-PDSCH scheduling  O Separate SLIVs are configured for each PDSCH as part of TDRA configuration. Number of PDSCHs is determined based on the number of SLIVs.  O Carrier indicator, BWP indicator, frequency domain resource allocation, MCS, DMRS configuration including antenna port, DMRS sequence initialization, etc., can be applied for all the scheduled PDSCHs.  O HARQ process ID for each PDSCH is based on the indicated HARQ process ID in the DCI and increased by 1 for subsequent PDSCHs.  O NDI and RV bitmap for each scheduled PDSCH is included in the DCI. |
| [15] Apple | Proposal 3: For multi-PDSCH transmission  • additional signaling is needed for the second codeword compared with multi-PUSCH transmission.  • New signaling may be needed for PRI, K1, priority, DAI, CBGTI and CBGFI to support HARQ compared with multi-PUSCH transmission. |
| [17] Samsung | Proposal 7: For multi-PDSCH scheduling, the bit field common for DL and UL grant use the same design as multi-PUSCH scheduling, and at least following DL-specific bit field should be specified,  - MCS/RV/NDI for 2nd TB is not applicable to multi-PDSCH scheduling (only support single TB case)  - CBG-based transmission is not applicable to multi-PDSCH scheduling, including CBGTI/CBGFI  - HARQ-ACK relevant bit field is applicable to all PDSCHs and single PUCCH |
| [18] Sony | Proposal 5: For multi-PDSCH scheduling, TDRA table should be extended.  • Multiple PDSCHs scheduled by one DCI can be non-continuous allocation in time-domain. |
| [19] LG Electronics | Proposal #5: For multi-PDSCH scheduling with a single DCI,  • TDRA: (Similar to multi-PUSCH scheduling) A row index of TDRA table is signalled with {K0, SLIV, mapping type} for the first PDSCH and {D, SLIV, mapping type} for each of next PDSCH(s) where D corresponds to slot level gap between adjacent PDSCHs.  • NDI and RV: For 1-TB case, separate indication per PDSCH, but 1 bit RV per PDSCH if multiple PDSCHs are scheduled   * FFS for 2-TB case   • HARQ process number: HARQ process ID is incremented by 1 (staring from the HARQ ID value indicated in DCI) for subsequent PDSCHs in the scheduled order (with modulo operation, if needed).  • CBGTI: CBGTI field is not present when more than one PDSCHs are scheduled, but present when a single PDSCH is scheduled.  • FFS on the following fields   * Rate matching indicator * ZP-CSI-RS trigger * CBGFI * Priority indicator |
| [20] CEWiT | Proposal 1: Scheduling of multi PDSCHs/PUSCHs in non-contiguous time resources should be supported in NR above 52.6GHz |
| [23] Panasonic | Proposal 5: Not support CBG-based (re)transmission for multi-PDSCH/PUSCH scheduling by a DCI.  Proposal 6: Support to reuse the existing rule for CSI-request specified in Rel. 16 for multi-PDSCH/PUSCH scheduling by a DCI.  Proposal 7: Support to select Alt. 2 for enhancing TDRA table.  Proposal 8: No need to have the optimization of FDRA size except the consideration to change the minimum resource granularity for frequency resource allocation type 1.  Proposal 9: Support multi-beam indications for multi-PDSCH/PUSCH scheduling by a DCI and discuss it in AI 8.2.4. |
| [26] NTT DOCOMO | Proposal 5: For multi-PDSCH scheduled by single DCI,  • Similar consideration on CBG based transmission, TDRA, and FDRA as multi-PUSCH scheduling can be applied to multi-PDSCH scheduling.  • For multi-PDSCH scheduling, if only supporting HARQ-ACK for PDSCHs scheduled by one DCI on one PUCCH, it is natural only one priority indicator field and open-loop power control field is needed. |

### Summary (on multi-PDSCH scheduling):

Most companies seem to suggest that the design of a multi-PUSCH scheduling DCI can be the basis for a multi-PDSCH scheduling DCI, at least for the following fields:

* MCS
* NDI
* RV
* HARQ process number

For the following DCI fields, common design between multi-PDSCH and multi-PUSCH scheduling should be pursued, but enhancements on them are being discussed.

* FDRA
* TDRA
* CBGTI
* Priority indicator

In addition, some rules for the following DL-specific fields need to be determined.

* MCS/NDI/RV for the 2nd TB
* Resource allocation related fields such as VRB-to-PRB mapping, PRB bundling size indicator, rate matching indicator, and ZP CSI-RS trigger
* CBGFI

It is noted that HARQ related fields (e.g., DAI, PRI, K1) can be discussed together under Section 3.

Based on the above summary, the following proposal can be made:

### Proposal #5 (High priority):

* For a DCI that can schedule multiple PDSCHs,
  + MCS for the 1st TB: This appears only once in the DCI and applies commonly to all scheduled PDSCHs
  + NDI for the 1st TB: This is signaled per PDSCH
  + RV for the 1st TB: This is signaled per PDSCH, with 2 bits if only a single PDSCH is scheduled or 1 bit for each PDSCH otherwise
  + HARQ process number: This applies to the first scheduled PDSCH and is incremented by 1 for subsequent PDSCHs (with modulo operation, if needed)
  + FFS
    - MCS/NDI/RV for the 2nd TB, including whether the 2nd TB can be scheduled or not
    - Resource allocation related fields such as VRB-to-PRB mapping, PRB bundling size indicator, rate matching indicator, and ZP CSI-RS trigger
    - CBGFI
    - Fields that can apply the common design with multi-PUSCH scheduling, e.g., TDRA, FDRA, CBGTI, priority indicator

Companies are encouraged to provide views on Proposal #5.

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# HARQ

## Type-1 (semi-static) HARQ-ACK codebook

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| Company | Views |
| [2] OPPO | Proposal 9: The definition of PDSCH reception candidates for Type-1 HARQ-ACK codebook needs to be enhanced. |
| [4] vivo | Proposal 17: For multi-PDSCH scheduling, semi-static HARQ-ACK codebook should be enhanced to guarantee that for any PDSCH potentially scheduled for which the corresponding HARQ-ACK feedback is reported in a semi-static codebook, there is a corresponding HARQ-ACK bit(s) in the codebook.  Proposal 18: Study semi-static HARQ-ACK codebook combined with time domain bunding for multi-PDSCH scheduling. |
| [5] Nokia | Proposal 15: For Type-1 codebook, the set of slot timing values K1 is extended with the values corresponding to multi-PDSCH scheduled slots for each K1 value.  Proposal 16: For Type-1 codebook, the occasions for multiple candidate PDSCH reception per slot are determined based on TDRA rows scheduling single PDSCH only. |
| [10] Ericsson | The semi-static codebook determination procedure as defined in the current specification can be extended to support multiple PDSCH scheduling. More specifically, a semi-static HARQ ACK codebook in multiple PDSCH scheduling can be determined according to the following procedure:   * Step 1: For each K1 value in the configured set of K1 values, determine the candidate PDSCH reception occasions for every row r in the TDRA table. Each row r in the TDRA table schedules one or multiple PDSCHs. The corresponding set of candidate PDSCH reception occasions are identified by placing the last PDSCH in slot (nU - K1), where nU is the slot number for the HARQ ACK codebook transmission, so that the HARQ ACK bits for the PDSCH(s) scheduled by row r can be multiplexed in the HARQ ACK codebook transmitted in slot nU. For each K1, create a set from the union of candidate PDSCH reception occasions over all rows of the TDRA table. * Step 2: Merge all sets corresponding to the different K1 values together, keeping only unique candidate PDSCH reception occasions. * Step 3: Generate HARQ ACK bits for the set of unique (pruned) candidate PDSCH reception occasions generated in Step 2. The HARQ-ACK information bits in response to the candidate PDSCH reception occasions are ordered in according to ascending slot indices.   Proposal 20: The current semi-static codebook determination procedure can be extended to support multiple PDSCH scheduling with the procedure summarized in the text above. |
| [11] Xiaomi | Proposal 9: Some restrictions on the configured K1 set, or other solutions should be further studied to guarantee the Type 1 HARQ-ACK codebook of all the PDSCHs scheduled by single DCI can be feedback in one PUCCH resource. |
| [15] Apple | Proposal 5: Extend support of Type-1 Codebook to slot-groups for multi-PDSCH transmission |
| [17] Samsung | Proposal 10: For Type-1 HARQ-ACK codebook, the following enhancement should be studied:  - Whether a PDSCH candidate occasion is determined according to last SLIV of a TDRA row, or according to all SLIVs of a TDRA row, and the number of HARQ-ACK bits PDSCH candidate occasion.  - How to reduce redundant HARQ-ACK bit location with joint consideration of multiple PDSCHs in multiple slots. |
| [19] LG Electronics | Proposal #6: It should be discussed how to construct type-1 (i.e., semi-static) HARQ-ACK codebook, in term of including/generating HARQ-ACK bits corresponding to multiple SLIVs over multiple slots configured in a row index of TDRA table. |
| [25] NEC | Proposal 3: Consider optimization for type-1 HARQ-ACK codebook overlapping issue when higher SCS is used |
| [27] WILUS | Proposal 2: For Type-1 HARQ-ACK codebook construction for multi-PDSCH scheduling by a single DCI, reuse Rel-15/16 pseudo-code in the Clause 9.1.2 of TS38.213 with the following change:  - the set K1 including the configured K1 values to the set K1 including the effective K1 values and  - the set R including all SLIVs in a TDRA table to the set R including SLIVs corresponding to the effective K1 value. |

### Summary (on Type-1 HARQ-ACK codebook generation):

In Rel-15/16, the procedure for semi-static HARQ-ACK codebook generation can be briefly summarized as below:

* Step 1: The candidate slot for PDSCH reception is determined by UL slot n (where HARQ-ACK codebook is transmitted) and K1 set, and the candidate PDSCH reception occasions are pruned based on TDD configuration and every row *r* in the TDRA table.
* Step 2: HARQ-ACK bits are generated for each candidate PDSCH reception occasion determined in Step 1.

Several companies pointed out that semi-static HARQ-ACK codebook needs to be enhanced considering that a row *r* in the TDRA table can correspond to multiple SLIVs in the multi-PDSCH scheduling DCI. For simple example shown in Figure 1, it is assumed that row 0 in the TDRA table corresponds to two SLIVs each of which would be mapped in different slots, and K1 set = {2}. Following above Step 1, the candidate PDSCH occasion will be determined in slot N-2, not in slot N-3. Therefore, HARQ-ACK bit for PDSCH#1 cannot be included in semi-static HARQ-ACK codebook.



**Figure 1. Example of type-1 HARQ-ACK codebook construction**

At least 5 companies (Nokia, Ericsson, Apple, Samsung, and WILUS) proposed some approaches to resolve the problem. From the moderator’s understanding, those can be categorized into two as follows:

* Approach 1: For Step 1, a candidate PDSCH reception occasion is determined according to each SLIV of a row in the TDRA table and/or extension of K1 set considering multiple SLIVs for the row.
  + Supported by Nokia, Ericsson, Apple, Samsung, and WILUS
* Approach 2: For Step 1, a candidate PDSCH reception occasion is determined according to the last SLIV of a row in the TDRA table, and for Step 2, the number of HARQ-ACK bits corresponding to the candidate PDSCH reception occasion is determined according to the number of SLIVs of rows in the TDRA table.
  + Supported by Samsung

Based on the above summary, the following proposal for semi-static HARQ-ACK codebook enhancement can be made, as the starting point of the discussion.

### Proposal #6 (High priority):

* For enhancements of generating type-1 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs, the following options can be considered,
  + Option 1: The set of candidate PDSCH reception occasion is determined according to each SLIV of each row in the TDRA table and/or based on extension of K1 set considering multiple SLIVs in a row
  + Option 2: The set of candidate PDSCH reception occasion is determined according to the last SLIV of each row in the TDRA table
  + FFS: Codebook generation details

Companies are encouraged to provide views on Proposal #6.

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## Type-2 (dynamic) HARQ-ACK codebook

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| Company | Views |
| [2] OPPO | Proposal 10: For Type-2/eType-2 HARQ-ACK codebook for multi-PDSCH scheduling with different TBs with a single DCI, C-DAI/T-DAI is counted per PDSCH. |
| [3] Spreadtrum | Proposal 4: Regarding the generation of type 2 codebook, C-DAI/T-DAI should be counted per PDSCH. |
| [4] vivo | Proposal 19: For dynamic HARQ-ACK codebook for multi-PDSCH scheduling, support Alt 2, i.e. C-DAI/T-DAI is counted per PDSCH.  Proposal 20: The DAI bits may be increased based on the maximum number of PDSCHs that can be scheduled by a single DCI.  Proposal 21: Study dynamic HARQ-ACK codebook combined with time domain bunding for multi-PDSCH scheduling. |
| [5] Nokia | Proposal 12: C-DAI/T-DAI is counted per M scheduled PDSCH(s), where M is configurable.  Proposal 13: Number of DAI bits is determined based on the configured M value and the maximum number of schedulable PDSCHs.  • Number of DAI bits is determined so that UE can detect failed detection of up to [2] consecutive DL assignments.  Proposal 14: Configurable time domain bundling of HARQ-ACK feedback over M consecutive PDSCHs scheduled by the same DCI can be supported. |
| [8] Fujitsu | Proposal 3: To generate type-2 HARQ-ACK codebook for DCI scheduling multiple PDSCHs, it should be supported that C-DAI/T-DAI is counted per DCI. |
| [9] Futurewei | Observation 8: The dynamic HARQ-ACK codebook design proposed during RAN1#104e can be simplified to achieve a tradeoff between efficiency and reliability, e.g., by fixing the size of multi-PDSCH corresponding to SCS and fixing the bundling size for multi-PDSCH. To improve detection performance of a codebook with increased payload, multi-PUCCH may be considered instead of single PUCCH for multi-PDSCH. |
| [10] Ericsson | Proposal 19: Support DAI counting Alt-1a (Alt-1 in combination with configurable HARQ ACK time domain bundling) for dynamic HARQ codebook for multi-PDSCH scheduling. |
| [11] Xiaomi | Proposal 7: Support Alt.1 for Type 2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs.  Proposal 8: To eliminate Type 2 HARQ-ACK codebook misalignment, for each DCI contained in the Type 2 HARQ-ACK codebook, a fixed size of HARQ-ACK information is generated. |
| [14] Intel | Proposal 4  • For type-2 HARQ-ACK codebook generation, Alt. 1 is supported. |
| [15] Apple | Proposal 6: Reusing the existing C-DAI and T-DAI definition in Rel-15/6, i.e., counting per DCI.  Proposal 7: Introduce signaling mechanism to enable generating a HARQ-ACK bit per ‘M’ scheduled PDSCHs in a multi-PDSCH scheduling by performing HARQ-ACK bundling to compress the HARQ-ACK bits overhead. |
| [16] Qualcomm | Proposal 9: Regarding the DAI counting, we support Alt 2, i.e., C-DAI/T-DAI is counted per PDSCH and we support increasing the field size of the DAI. |
| [17] Samsung | Proposal 11: For Type-2/enhanced type-2 HARQ-ACK codebook, single and multi-PDSCHs scheduled by a DCI are associated with different sub-codebook, and DAI is counted per DCI within each sub-codebook (Alt-1). |
| [18] Sony | Proposal 7: C-DAI/T-DAI for multi-PDSCH scheduling should be counted per PDSCH. |
| [19] LG Electronics | Observation #1: For generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs, if single codebook is constructed and DAI is counted per DCI (i.e., Alt 1 with single codebook), DCI overhead can be kept as before but UCI overhead can be highly increased.  Observation #2: For generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs, if single codebook is constructed and DAI is counted per PDSCH (i.e., Alt 2 with single codebook), UCI overhead can be kept as before but DCI overhead can be highly increased. It should be noted that bit-width of C/T-DAI in DL fallback DCI (i.e., DCI format 1\_0) should be also increased.  Observation #3: Large amount of specification impact can be anticipated for Alt 3, compared to Alts 1 and 2.  Proposal #7: For (enhanced) type-2 HARQ-ACK codebook,  • Alt 1: C-DAI/T-DAI is counted per DCI  • Alt 2: C-DAI/T-DAI is counted per PDSCH. Increased bit-width of each DAI field can be equal to 2 + log2(ceiling of max. configured number of PDSCHs across carriers)  • Introduce independent sub-codebooks where one is for single PDSCH scheduling case and the other is for multi-PDSCH scheduling case  • Perform C-DAI and T-DAI counting per each sub-codebook  • Include individual UL DAI for each sub-codebook in UL grant  • FFS: If CBG is configured |
| [22] InterDigital | Proposal 10: For counting C-DAI/T-DAI for generating type-2 HARQ-ACK codebook, at least support Alt2: C-DAI/T-DAI is counted per PDSCH and Alt 3: C-DAI/T-DAI is counted per M scheduled PDSCH(s), where M is configurable (e.g., 1, 2, 4, …).  Proposal 11: Support time domain bundling of HARQ-ACK feedback with configurable bundle sizes. |
| [23] Panasonic | Proposal 11: For generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs, C-DAI/T-DAI is counted per PDSCH. |
| [24] ZTE | Observation 1:  • Time domain bundling of HARQ-ACK feedback can be used in Alt1 and Alt3 for HARQ-ACK feedback overhead reduction, but it may lead to more PDSCH re-transmission.  • Alt2 needs to increase DAI bits in the DCI, but the HARQ-ACK codebook generation process can be consistent with that of one PDCCH scheduling one PDSCH.  Proposal 4: Considering the effect on the HARQ-ACK codebook generation process, Alt 2: C-DAI/T-DAI is counted per PDSCH can be selected. |
| [25] NEC | Proposal 4: Consider increasing the bit length of c-DAI and t-DAI for type-2 HARQ-ACK codebook determination. |
| [26] NTT DOCOMO | Proposal 7: For HARQ-ACK feedback for multiple PDSCHs scheduled by one DCI,  - Support HARQ-ACK bundling among PDSCHs scheduled by single DCI.  - Support Alt. 2 (C-DAI/T-DAI is counted per PDSCH) for type 2 HARQ-ACK CB construction. FFS DAI field enhancement required for Alt 2.  - Alt. 1 and Alt. 3 may also be supported if HARQ-ACK bundling is enabled. |
| [27] WILUS | Proposal 1: We propose to support Alt 1 as DAI counting for Type-2 HARQ-ACK CB when scheduling multiple PDSCHs in single DCI.  - Alt 1: C-DAI/T-DAI is counted per DCI. |

### Summary (on DAI counting of Type-2 HARQ-ACK codebook):

Company views on alternatives for DAI counting of Type-2 HARQ-ACK codebook:

* Alt 1 (C-DAI/T-DAI is counted per DCI)
  + Supported by Fujitsu, Xiaomi, Intel, Samsung, LG Electronics, WILUS
* Alt 2 (C-DAI/T-DAI is counted per PDSCH)
  + Huawei, OPPO, Spreadtrum, vivo, Qualcomm, Sony, InterDigital, Panasonic, ZTE, NEC, NTT DOCOMO
* Alt 3 (C-DAI/T-DAI is counted per M scheduled PDSCH(s), where M is configurable)
  + Supported by vivo, Nokia, InterDigital

Before narrowing-down, it was realized that companies have different understandings of each alternative. To align understandings between companies, the following observation for each alternative is prepared.

For Alt 1, it seems that proponents supporting Alt 1 are assuming two sub-codebooks in which the first (or second) sub-codebook is for single PDSCH scheduling case and the second (or first) sub-codebook is for multi-PDSCH scheduling case, similar to the case where CBG is configured.

### Observation #1 (High priority):

* For Alt 1 (C-DAI/T-DAI is counted per DCI) of generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs,
  + C-DAI/T-DAI in DL DCI: Same DCI overhead with legacy single-PDSCH DCI
  + T-DAI in UL DCI: Need additional UL DAI field (with same bit-width of legacy UL DAI) for multi-PDSCH DCI, for all serving cells including one not configured with multi-PDSCH DCI
  + HARQ-ACK codebook generation:
    - Two sub-codebooks in which one is for single PDSCH scheduling case and the other is for multi-PDSCH scheduling case, exactly same handling with CBG configured
    - HARQ-ACK payload size is increased compared to single PDSCH scheduling only, since the number of HARQ-ACK bits corresponding to each DAI of the sub-codebook for multi-PDSCH scheduling DCI equals to the maximum configured number of PDSCHs for multi-PDSCH scheduling DCI
    - The number of HARQ-ACK bits corresponding to each DAI of the sub-codebook for multi-PDSCH scheduling DCI does not depend on the number of actually scheduled PDSCHs, rather, it is fixed as the maximum configured number of PDSCHs.

Do you agree with Observation #1? If not, please provide the reason and how to modify it, if possible.

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For Alt 2, it seems unclear that proponents supporting Alt 2 are assuming a single codebook or two sub-codebooks in which the first (or second) sub-codebook is for single PDSCH scheduling case and the second (or first) sub-codebook is for multi-PDSCH scheduling case. Therefore, two observations can be made for Alt 2: one is for single codebook and the other is for two sub-codebooks.

### Observation #2-1 (High priority):

* For Alt 2 (C-DAI/T-DAI is counted per PDSCH) of generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs, if a single codebook is generated,
  + C-DAI/T-DAI in DL DCI: Bit-width is increased, not only for multi-PDSCH DCI but also for single-PDSCH DCI for all serving cells including one not configured with multi-PDSCH DCI
  + T-DAI in UL DCI: Bit-width is increased, for all serving cells including one not configured with multi-PDSCH DCI
  + HARQ-ACK codebook generation:
    - HARQ-ACK payload size is the same with legacy case of single-PDSCH DCI
    - The number of HARQ-ACK bits corresponding to each DAI depends on the number of actually transmitted PDSCHs but DAI is counted per PDSCH.

Do you agree with Observation #2-1? If not, please provide the reason and how to modify it, if possible.

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### Observation #2-2 (High priority):

* For Alt 2 (C-DAI/T-DAI is counted per PDSCH) of generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs, if two sub-codebooks are generated,
  + C-DAI/T-DAI in DL DCI: Bit-width is increased, for multi-PDSCH DCI but not for single-PDSCH DCI
  + T-DAI in UL DCI: Need additional UL DAI field (with increased bit-width compared to legacy UL DAI), for all serving cells including one not configured with multi-PDSCH DCI
  + HARQ-ACK codebook generation:
    - Two sub-codebooks in which one is for single PDSCH scheduling case and the other is for multi-PDSCH scheduling case
    - HARQ-ACK payload size is the same with legacy case of single-PDSCH DCI
    - The number of HARQ-ACK bits corresponding to each DAI depends on the number of actually transmitted PDSCHs but DAI is counted per PDSCH.

Do you agree with Observation #2-2? If not, please provide the reason and how to modify it, if possible.

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For Alt 3, the following observation can be made.

### Observation #3 (High priority):

* For Alt 3 (C-DAI/T-DAI is counted per M scheduled PDSCH(s), where M is configurable) of generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs,
  + If M equals to the number of maximum configured number of PDSCHs, Alt 3 is the same with Alt 1.
  + Else if M equals to 1, Alt 3 is the same with Alt 2.
  + Otherwise (i.e., 1<M<the number of maximum configured number of PDSCHs), Alt 3 is similar to Alt 2, except that
    - The increment of DCI fields reduces as M increases.
    - The number of HARQ-ACK bits corresponding to each DAI increases by M times.
  + In addition, new RRC parameter to configure M needs to be introduced.

Do you agree with Observation #3? If not, please provide the reason and how to modify it, if possible.

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## HARQ timing

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| Company | Views |
| [2] OPPO | Proposal 8: Separate the scheduled Consider two PUCCH resources allocated for two PDSCH groups, an earlier PUCCH is used to report HARQ-ACK information of the earlier PDSCH group. |
| [4] vivo | Proposal 15: For multi-PDSCH scheduling, support reporting HARQ-ACK information corresponding to different PDSCHs scheduled by a DCI on different PUCCH(s).  Proposal 16: For reporting HARQ-ACK feedback on different PUCCHs, further study how to divide the PDSCHs scheduled by a single DL DCI, as well as indicate or determine more than one PUCCH carrying HARQ-ACK feedback. |
| [5] Nokia | Observation 4: If up to 32 DL HARQ processes are supported for 960 kHz SCSs, HARQ information for PDSCHs scheduled by single DCI can be carried by single PUCCH without HARQ starvation.  Proposal 11: If only 16 DL HARQ processes are supported for 960 kHz SCS, HARQ information for PDSCHs scheduled by single DCI can be carried by up to two PUCCHs to reduce HARQ process starvation  • When DCI schedules more than N PDSCHs, where N is configurable, the HARQ-ACK feedback for the scheduled PDSCHs is transmitted over two slots. |
| [6] CAICT | Proposal 3: HARQ-ACK information corresponding to different PDSCHs scheduled by the DCI can be carried by different PUCCH(s). |
| [10] Ericsson | Proposal 22: Do not support HARQ-ACK information corresponding to different PDSCHs scheduled by the DCI to be carried by different PUCCH occasions. |
| [11] Xiaomi | Proposal 10: For latency sensitive service, separate HARQ-ACK PUCCH resources for multiple PDSCHs scheduled by single DCI can be considered. |
| [12] Lenovo | Proposal 5: For NR operation between 52.6 GHz and 71 GHz with high subcarrier spacing values such as 480kHz and 960kHz, for HARQ-ACK information correspond to PDSCHs scheduled by the DCI, different PUCCH(s) can be used where the PUCCH carrying the HARQ-ACK can be transmitted in the middle of non-contiguous PDSCHs transmissions to allow earlier/faster transmission of HARQ-ACK associated with earlier PDSCHs |
| [15] Apple | Proposal 4: RAN1 should not support HARQ-ACK information corresponding to different PDSCHs scheduled by the DCI being carried by different PUCCH(s). |
| [16] Qualcomm | Proposal 10: All HARQ-ACK information corresponding to different PDSCHs scheduled by the same DCI to be carried by the same PUCCH. |
| [17] Samsung | Proposal 9: HARQ-ACK information corresponding to different PDSCHs scheduled by the DCI carried by different PUCCH(s) should be deprioritized. |
| [18] Sony | Proposal 6: If PDSCH processing time is long, at least one of the following solutions should be considered  1. Multiple HARQ feedback timing indication by one DCI  2. Multiple DCI in a slot  3. Increasing the number of HARQ process |
| [20] CEWiT | Proposal 3: Flexibility to transmit HARQ for the processed PDSCHs among the transmitted multi-PDSCHs, without waiting till the final PDSCH, should be supported in NR above 52.6GHz |
| [22] InterDigital | Observation 10: Configuring one PUCCH transmission with HARQ-ACK for all the PDSCHs scheduled by one DCI can introduce excessive HARQ-ACK round trip delay and negatively impact on the expected performance gains.  Proposal 9: When multiple PDSCH are scheduled using single DCI, support multiple PUCCHs each carrying HARQ-ACK information of a group of PDSCHs.  Proposal 12: Further study type-2 HARQ-ACK codebook generation details focusing on requirements for scheduling multiple PUCCHs with HARQ-ACK. |
| [23] Panasonic | Proposal 10: Support HARQ-ACK information corresponding to different PDSCHs scheduled by the DCI can be carried by different PUCCH(s). |
| [24] ZTE | Observation 2: HARQ-ACK information corresponding to different PDSCHs scheduled by the DCI can be carried by different PUCCH(s) considering HARQ-ACK feedback delay.  Proposal 5: Further enhancement on enhanced dynamic HARQ-ACK codebook construction should be considered. |
| [25] NEC | Proposal 2: HARQ-ACK information corresponding to the PDSCHs scheduled by a single DCI can be carried in an uplink slot or at most 2 uplink slots. |
| [26] NTT | Proposal 6: Further study transmitting HARQ-ACKs for multiple PDSCHs scheduled by one DCI on different PUCCHs. |

### Summary (on whether or not HARQ-ACK information corresponding to different PDSCHs scheduled by the DCI can be carried by different PUCCH(s)):

Company views on whether or not HARQ-ACK information corresponding to different PDSCHs scheduled by the DCI can be carried by different PUCCH(s):

* Supported by OPPO, vivo, Nokia, CAICT, Xiaomi, Lenovo, Sony, CEWiT, InterDigital, Panasonic, ZTE, NEC, NTT DOCOMO?
* Objected by Ericsson, Apple, Qualcomm, Samsung

Even though majority companies suggest to allow that HARQ-ACK information corresponding to different PDSCHs scheduled by a single DCI can be carried by different PUCCHs, it should be discussed with more details on e.g., how to indicate different PUCCHs and DAI, and the relationship with increased HARQ process number.

### Proposal #7 (Low priority):

* Further discuss the necessity and related impacts of allowing that HARQ-ACK information corresponding to different PDSCHs scheduled by a single DCI can be carried by different PUCCHs.

Companies are encouraged to provide views on Proposal #7.

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| Company | Views |
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## HARQ process

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| Company | Views |
| [10] Ericsson | Proposal 3: Increase maximum number of DL and UL HARQ processes in Rel-17 from 16 to 32. |
| [11] Xiaomi | Proposal 11: Tx/Rx HARQ buffer capacity will need to be enhanced if HARQ process number increases for SCS 480/960 kHz. |
| [20] CEWiT | Proposal 4: Support for increment in the maximum number of HARQ processes from 16 to 32 in UL and DL. |
| [21] Convida | Proposal 3. Multi-TB transmitted on a single HARQ process can be considered for single DCI scheduling multi-PDSCH. |
| [23] Panasonic | Proposal 1: The number of HARQ processes for a UE is increased to at least 32 for 480 or 960 kHz in order to maintain the scheduling framework same as for 120 kHz SCS. |

### Proposal #8 (Low priority):

* Increase the maximum number of DL and UL HARQ processes in Rel-17 from 16 to 32 for 480 and 960 kHz.
  + Note that it was already agreed to increase the maximum number of HARQ processes from 16 to 32 in Rel-17 NTN WI.

Companies are encouraged to provide views on Proposal #8.

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| Company | Views |
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## Others

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| Company | Views |
| [18] Sony | Proposal 8: Support NR-U HARQ enhancement features (Non-numerical K1, enhanced Type-2 HARQ CB, and Type-3 HARQ CB) for multi-PDSCH scheduling.  • Further study how to indicate/determine PDSCH group if multiple PUCCH for multi-PDSCH scheduling is supported. |

# Reference

1. R1-2102331 PDSCH/PUSCH enhancements for 52-71GHz spectrum Huawei, HiSilicon
2. R1-2102389 Discussion on PDSCH/PUSCH enhancements OPPO
3. R1-2102452 Discussion on PDSCH and PUSCH enhancements for above 52.6GHz Spreadtrum Communications
4. R1-2102518 Discussions on PDSCH/PUSCH enhancements for NR operation from 52.6GHz to 71GHz vivo
5. R1-2102562 PDSCH/PUSCH enhancements Nokia, Nokia Shanghai Bell
6. R1-2102569 Discussions on scheduling enhancements for PDSCH and PUSCH CAICT
7. R1-2102625 PDSCH/PUSCH enhancements for up to 71GHz operation CATT
8. R1-2102716 Considerations on multi-PDSCH/PUSCH with a single DCI and HARQ for NR from 52.6GHz to 71 GHz Fujitsu
9. R1-2102776 Considerations on PDSCH/PUSCH enhancements FUTUREWEI
10. R1-2102792 PDSCH-PUSCH Enhancements Ericsson
11. R1-2102980 PDSCH and PUSCH enhancements for NR 52.6-71GHz Xiaomi
12. R1-2103000 PDSCH/PUSCH scheduling enhancements for NR from 52.6 GHz to 71GHz Lenovo, Motorola Mobility
13. R1-2103012 PT-RS enhancements for NR from 52.6GHz to 71GHz Mitsubishi Electric RCE
14. R1-2103025 Discussion on PDSCH/PUSCH enhancements for extending NR up to 71 GHz Intel Corporation
15. R1-2103100 Discussion on PDSCH/PUSCH enhancements for above 52.6 GHz Apple
16. R1-2103161 PDSCH/PUSCH enhancements for NR in 52.6 to 71GHz band Qualcomm Incorporated
17. R1-2103233 PDSCH/PUSCH enhancements for NR from 52.6 GHz to 71 GHz Samsung
18. R1-2103298 PDSCH/PUSCH enhancements for NR from 52.6 GHz to 71 GHz Sony
19. R1-2103343 PDSCH/PUSCH enhancements to support NR above 52.6 GHz LG Electronics
20. R1-2103407 Discussion on PDSCH and PUSCH enhancements for 52.6GHz – 71GHZ band CEWiT
21. R1-2103414 PDSCH Considerations for Supporting NR from 52.6 GHz to 71 GHz Convida Wireless
22. R1-2103452 Discussions on PDSCH/PUSCH enhancements for 52.6 GHz to 71 GHz Band InterDigital, Inc.
23. R1-2103463 Discussion on multi-PDSCH/PUSCH scheduling for NR 52.6-71 GHz Panasonic Corporation
24. R1-2103491 Discussion on the data channel enhancements for 52.6 to 71GHz ZTE, Sanechips
25. R1-2103513 Discussion on PDSCH enhancements supporting NR from 52.6GHz to 71 GHz NEC
26. R1-2103571 PDSCH/PUSCH enhancements for NR from 52.6 to 71 GHz NTT DOCOMO, INC.
27. R1-2103693 Discussion on multi-PDSCH/PUSCH scheduling for NR from 52.6GHz to 71GHz WILUS Inc.
28. R1-2103726 PDSCH-PUSCH Enhancement Aspects for NR beyond 52.6 GHz Charter Communications

# Appendix: Previous agreements

Agreement: (RAN1#104-e)

* For a UE and for a serving cell, scheduling multiple PDSCHs by single DL DCI and scheduling multiple PUSCHs by single UL DCI are supported.
  + Each PDSCH or PUSCH has individual/separate TB(s) and each PDSCH/PUSCH is confined within a slot.
  + FFS: The maximum number of PDSCHs or PUSCHs that can be scheduled with a single DCI
  + FFS: Whether multiple PDSCH scheduling applies to 120 kHz in addition to 480 and 960 kHz
  + At least for 120 kHz SCS, single-slot scheduling with slot-based monitoring will still be supported as specified in Rel-15/Rel-16
* The followings will not be considered in this WI.
  + Single DCI to schedule both PDSCH(s) and PUSCH(s)
  + Single DCI to schedule one or multiple TBs where any single TB can be mapped over multiple slots, where mapping is not by repetition
  + Single DCI to schedule N TBs (N>1) where a TB can be repeated over multiple slots (or mini-slots)
* Note: This does not imply that existing slot aggregation and/or repetition for PDSCH and PUSCH by single DCI is precluded for the serving cell.

Agreement: (RAN1#104-e)

* For a DCI scheduling multiple PDSCHs, HARQ-ACK information corresponding to PDSCHs scheduled by the DCI is multiplexed with a single PUCCH in a slot that is determined based on K1,
  + where K1 (indicated by the PDSCH-to-HARQ\_feedback timing indicator field in the DCI or provided by *dl-DataToUL-ACK* if the PDSCH-to-HARQ\_feedback timing indicator field is not present in the DCI) indicates the slot offset between the slot of the last PDSCH scheduled by the DCI and the slot carrying the HARQ-ACK information corresponding to the scheduled PDSCHs.
    - It is noted that granularity of K1 can be separately discussed.
* FFS: If needed, further discuss whether or not HARQ-ACK information corresponding to different PDSCHs scheduled by the DCI can be carried by different PUCCH(s)

Agreement: (RAN1#104-e)

For generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs, the following alternatives can be considered to DAI counting and will be down-selected in RAN1#104bis-e.

* Alt 1: C-DAI/T-DAI is counted per DCI.
* Alt 2: C-DAI/T-DAI is counted per PDSCH.
* Alt 3: C-DAI/T-DAI is counted per M scheduled PDSCH(s), where M is configurable (e.g., 1, 2, 4, …).
* FFS: Codebook generation details
* FFS: How to signal DAI values (e.g., increase of DAI bits for Alt 2 and Alt 3)
* FFS: Whether to apply time domain bundling of HARQ-ACK feedback

Agreement: (RAN1#104-e)

The multi-PUSCH scheduling defined in Rel-16 NR-U is the baseline for multi-PUSCH scheduling in Rel-17.

* FFS: Applicability to multi-PDSCH scheduling.

Agreement: (RAN1#104-e)

* For the multi-PUSCH scheduling in Rel-17, study the enhancement of the following in addition to Rel-16 multi-PUSCH scheduling.
  + CBGTI: Whether or not CBG (re)transmission is supported when more than one PUSCHs are scheduled (Already supported when only one PUSCH is scheduled).
  + CSI-request: Whether to apply same or different rule compared to Rel-16 (e.g., the PUSCH that carries the AP-CSI feedback is the first PUSCH that satisfies the multiplexing timeline).
  + TDRA: Down-select among
    - Alt 1: TDRA table is extended such that each row indicates up to [X, FFS for X] multiple PUSCHs (continuous in time-domain). Each PUSCH has a separate SLIV and mapping type. The number of scheduled PUSCHs is signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.
    - Alt 2: TDRA table is extended such that each row indicates up to [X, FFS for X] multiple PUSCHs (that can be non-continuous in time-domain). Each PUSCH has a separate SLIV and mapping type. The number of scheduled PUSCHs is signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.
    - Alt 3: TDRA table is extended such that each row indicates up to 8 multiple PUSCH groups (that can be non-continuous between PUSCH groups). Each PUSCH group has a separate SLIV, mapping type and number of slots/PUSCHs N. Within each PUSCH group, N PUSCHs occupy the same OFDM symbols indicated by the SLIV and mapping type. The number of scheduled PUSCHs is the sum of number of PUSCHs in all PUSCH groups in the row of the TDRA table signalled in DCI.
  + FDRA: Whether/how to enhance FDRA e.g., by increasing RBG size or changing allocation granularity
  + Frequency hopping: Whether/how to support frequency hopping for scheduled PUSCHs, e.g., inter-PUSCH/intra-PUSCH hopping
  + URLLC related fields such as priority indicator and open-loop power control parameter set indication: Whether/how to apply URLLC related fields for scheduled PUSCHs
  + Applicability to multi-PDSCH scheduling in Rel-17.
  + Note: Other enhancements are not precluded.