**3GPP TSG RAN WG1 #104b-e R1-210xxxx**

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

**Agenda Item:** 8.2.5

**Source:** Moderator (LG Electronics)

**Title:** Summary #2 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
    - Agreed in 4/15 GTW session
  + 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
    - Agreed in 4/15 GTW session
  + 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 |
| Qualcomm | The maximum number of scheduled PDSCHs or PUSCHs should be at least equal to PDCCH monitoring periodicity to ensure that all the resources between two PDCCH monitoring occasions can be scheduled by a single DCI.  The maximum number of granted allocations to defined in the specs. can be independent from SCS, i.e., be applied to 120kHz, 480kHz and 960kHz, while the UE capability for number of supported PDSCHs/PUSCHs per grant can SCS based. |
| Huawei, HiSilicon | The proposal is in principle fine but it may imply the same maximum number for 480 kHz and 960 kHz SCS, although the maximum values could be different. We would support maximum 8 for 960 kHz SCS, and maximum 4 for 480 kHz SCS to match the scheduled PDSCH duration with one slot of 120 kHz. |
| Intel | We share similar view as Huawei. We prefer maximum 8 for 960kHz SCS and 4 for 480kHz SCS. |
| Panasonic | We agree the proposal. |
| Lenovo, Motorola Mobility | We are generally fine with the proposal and agree with other companies that maximum of 8 for 960kHz and 4 for 480kHz. |
| WILUS | We support the proposal. |
| OPPO | The maximum number of PDSCHs should cover the span of two neighbor PDCCH monitoring occasions. |
| vivo | Agree with Qualcomm. |
| DOCOMO | We are supportive of the proposal in principle but the wording can be refined a little bit. In the main proposal, it claims the maximum number is 8 which looks like to us it is a fixed value. But the FFS looks like the value is still open and intending to discuss additional values. We propose the following update:   * Support 8 as t~~T~~he 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 |
| Fujitsu | We support Proposal #1 in principle. Regarding the FFS points, we share similar view as Qualcomm. We think it is unnecessary to have different values for SCSs. That is, for all SCSs, the maximum number is 8. |
| NEC | We support the proposal. |
| ZTE, Sanechips | We support the proposal. |
| Spreadtrum | We support the proposal. |
| Futurewei | Support the number 8 as the maximum number of PDSCH/PUSCH with a single DCI for any SCS.  One concern is that whether the maximum number is SCS dependent. For 960kHz, for many cases the channel variation is limited across 8 slots, such that channel estimation overhead may be reduced by only allocating DMRS to a subset of these slot. While not sure if this is also the case for 480kHz. Besides this point, we might need to clarify the motivation of making the max number dependent/independent of SCS. |
| Nokia/NSB | Support the proposal. |
| InterDigital | We share similar view as Huawei and Intel. We prefer maximum 8 for 960kHz SCS and 4 for 480kHz SCS. |
| Convida Wireless | We are fine with the proposal. |
| Ericsson | Support the proposal. We agree with Qualcomm that we don't see a need to introduce an SCS dependence on the maximum. |
| Apple | We are fine with the proposal. |
| CATT | We support the proposal. We prefer an uniform design, not depending on SCS. It is also noted the max number of PDSCH/PUSCH support does not have to same as the PDCCH monitoring duration. |
| Sony | We support the proposal. We agree with Qualcomm. The maximum number of PDSCHs/PUSCH can be independent for SCS. |
| CEWiT | We support the proposal. |
| Samsung | We’re fine with proposal #1. |

**Summary on comments for Proposal #1:**

It seems that Proposal #1 is acceptable to most companies. One remaining issue is whether the maximum number of PDSCHs or PUSCHs depends on SCS or not.

* SCS-agnostic design
  + Supported by Qualcomm, vivo, NTT DOCOMO, Fujitsu, Futurewei, Ericsson, CATT, Sony
* 4 for 480 kHz and 8 for 960 kHz
  + Supported by Huawei, Intel, Lenovo, InterDigital

Moderator’s note #1: Proponents supporting SCS-dependent design should justify its motivation. One more question for multi-PUSCH scheduling DCI is, do proponents supporting SCS-dependent design suggest 8 / 4 / 8 maximum number of PXSCHs for 120 / 480 / 960 kHz SCS, respectively?

Moderator’s note #2: In order to reflect the views on SCS-dependent design more clearly, FFS is refined as follows.

**Proposal #1a (High priority):**

* The maximum number of PDSCHs or PUSCHs that can be scheduled with a single DCI in Rel-17 is 8.
  + FFS: Whether to restrict the maximum number of PDSCHs or PUSCHs for 480 kHz as 4

On 4/15 GTW session, the following agreement was made:

### Agreement:

* The maximum number of PDSCHs that can be scheduled with a single DCI in Rel-17 is 8 for SCS of 480 and 960 kHz.
  + FFS: Further restrictions for 480 kHz to 4
  + FFS: A UE capability to select between 4 and 8 for 480 kHz SCS
  + Note: Multi-PDSCH scheduling for the case of 120 kHz SCS is still FFS as per prior agreement. This case can be addressed after this FFS has been decided.
* The maximum number of PUSCHs that can be scheduled with a single DCI in Rel-17 is 8.
  + FFS: Further restrictions for 120 kHz and 480 kHz SCS
  + FFS: A UE capability to select between different values for 120 kHz and 480 kHz SCS

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 |
| Qualcomm | We agree with the moderator’s proposal |
| Huawei, HiSilicon | We suggest to first progress on the DCI field before diving into the discussion of DCI formats. We would suggest leaving an FFS for DCI format 1\_0 in case of fallback. |
| Panasonic | DCI format 0\_2 and 1\_2 should be supported. If DCI format 0\_2 and 1\_2 are supported, it is not required to support DCI format 0\_1 and 1\_1 as the functionality of DCI format 0\_2 and 1\_2 is super set compared to DCI format 0\_1 and 1\_1. |
| Lenovo, Motorola Mobility | We agree with Huawei and think that discussion should come in later. |
| OPPO | We are fine with the proposal. |
| vivo | Support this proposal. |
| DOCOMO | Support the proposal. |
| ZTE, Sanechips | We support the proposal. |
| Spreadtrum | We support the proposal. |
| Futurewei | Agree with Lenovo regarding study this issue later. |
| Nokia/NSB | Support the proposal. |
| InterDigital | Support this proposal. |
| Convida Wireless | We prefer to discuss this proposal later. |
| Ericsson | Support the proposal |
| Apple | We support this proposal |
| CATT | This can be discussed later. |
| Sony | We support the proposal. |
| Samsung | We support proposal #2. |
| Xiaomi | We support proposal #2 |
| Intel | We support the proposal. |
| Futurewei | Suggest to postpone this issue. The prospective changes for multi-PDSCH/PUSCH are unclear now, so it is not easy to rule out whether new field is needed or not for the one DCI scheduling multi-PDSCH. |

## 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 URLLC related field 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 PUSCHs,
  + 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.

|  |  |
| --- | --- |
| Company | Views |
| Qualcomm | We agree with the proposal |
| Huawei, HiSilicon | We are fine with the proposal. |
| Panasonic | Support the proposal. |
| Lenovo, Motorola Mobility | We support the proposal |
| OPPO | We are fine with the proposal with the typo corrected:   * For a DCI that can schedule multiple ~~PDSCHs~~ PUSCHs, |
| Vivo | We support the proposal |
| ZTE, Sanechips | We support the proposal and OPPO’s correction. |
| Spreadtrum | We support the proposal and OPPO’s correction. |
| Futurewei | Support the proposal |
| Nokia/NSB | Support the proposal. |
| Apple | We support this proposal |
| CATT | Support |
| Sony | We support the proposal |
| Samsung | We do not support the proposal.  I understand companies supporting proposed conclusion #1 want to have unified solution for both licensed and unlicensed band, but I’m wondering why we can have different solution for licensed band unlicensed band in Rel-16, with the assumption of targeting different scenarios, but not ok for 52.6~71GHz ? |
| Xiaomi | We support proposed conclusion #1 |
| Intel | We support the proposal |

### Proposal #3 (High priority):

* For a DCI that can schedule multiple PUSCHs,
  + 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.

|  |  |
| --- | --- |
| Company | Views |
| Qualcomm | Generally, we agree with the moderator’s proposal, but the text needs to be updated to capture PDSCH and PUSCH allocations |
| Huawei, HiSilicon | It seems the main bullet point has a typo (it should be PUSCHs not PDSCHs?). For PUSCH, we should first clarify the scenarios where non-continuous PUSCH allocations would be needed. The additional flexibility comes with a price in DCI size, so if support for non-continuous allocations is introduced it should be configurable to operate with continuous allocations with reduced DCI size overhead when possible (e.g. as in 5 GHz when the use of LBT is configured).  We suggest a separate discussion on TDRA for multiple PDSCHs scheduled by a single DCI. |
| Intel | It seems this is for PUSCHs. If so, we are fine with the proposals. |
| Moderator | Apology for my typo in the main bullet, which should be PUSCH. Now, it’s fixed. |
| Panasonic | Support the proposal. |
| Lenovo, Motorola Mobility | We support the proposal. Also agree with Qualcomm that this can be captured for PDSCH as well |
| WILUS | We are fine with the proposal. |
| OPPO | We are fine with the proposal. |
| Vivo | Support the proposal in principle. Besides, when the maximum number of PDSCHs/PUSCHs scheduled by a DCI is larger than 8, Alt 3 may also be considered with less signaling overhead. |
| DOCOMO | We support the proposal in principle. But we suggest minor wording modification:  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 implicitly indicated ~~signalled~~ by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.) |
| Fujitsu | We support the proposal. |
| ZTE, Sanechips | We still think that non-continuous PUSCH allocation may suffer potential LBT failure in unlicensed band, the reason to introduce non-continuous PUSCH need to be clarified. |
| Spreadtrum | We support the proposal. |
| Futurewei | We support the proposal and the suggestion to update to capture PDSCH and PUSCH allocations. |
| Nokia/NSB | Agree with the Alt 2 functionality (non-continuous slots).  It should be considered reducing signalling overhead. (e.g. alt.1 with slot dropping)  Propose following modification.   * For a DCI that can schedule multiple PUSCHs,   + 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     - FFS: signaling overhead reduction |
| InterDigital | We share the same view with ZTE as non-continuous PUSCH allocation may suffer from potential LBT failures in the unlicensed band. |
| Ericsson | Support for both PDSCH and PUSCH. We agree with DOCOMO's correction. |
| Apple | We support the moderator’s proposal with update from DOCOMO. |
| CATT | We support the proposal. |
| Sony | We support the proposal and support it also for PDSCH. |
| CEWiT | We agree with the InterDigital’s view. |
| Samsung | Support proposal #3 for both PDSCH and PUSCH. DOCOMO’s update looks good to us. |
| Xiaomi | Support this proposal for both PDSCH and PUSCH. |

### Summary on comments for Proposal #3:

It seems that Proposal #3 is acceptable to most companies except 4 companies (Huawei, ZTE, InterDigital, and CEWiT). Reviewing Tdocs, the motivation to allow discontinuous resource allocation is to be able to transmit DL control channels or other UE’s UL signal/channel in-between (or potentially to make a gap for beam change). Please note that LBT failure problem can be handled by gNB (e.g., by using COT sharing) and also note that indicating continuous resource allocation is possible even though Alt 2 is adopted.

Another point to discuss is whether the same principle can be applicable to multi-PDSCH DCI or not. At least 5 companies (Qualcomm, Lenovo, Futurewei, Ericsson, and Sony) support to extend the same principle to multi-PDSCH DCI while 1 company (Huawei) suggests to have a separate discussion for multi-PDSCH DCI.

Moderator’s note #1: To Huawei, ZTE, InterDigital and CEWiT, NOTEs are added to address the concern on discontinuous allocation.

Moderator’s note #2: To Huawei, applicability to multi-PDSCH DCI was put as FFS but it would be better to elaborate the reason why we need a separate discussion for multi-PDSCH DCI.

Moderator’s note #3: To vivo and NTT DOCOMO, comments are reflected.

Moderator’s note #4: To Huawei and Nokia, FFS to discuss DCI overhead was written more specifically.

### Proposal #3a (High priority):

* For a DCI that can schedule multiple PUSCHs,
  + 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 implicitly indicated by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.), as per agreement made in RAN1#104-e
    - FFS: signaling details, e.g., considering DCI overhead
    - FFS: applicability to multi-PDSCH DCI
    - FFS: whether to support Alt 3 (as per agreement made in RAN1#104-e) if more than 8 PUSCHs can be scheduled by a single DCI
  + Note: Alt 2 does not preclude continuous resource allocation in time-domain.
  + Note: It’s up to gNB’s implementation how to overcome LBT failure in unlicensed spectrum (e.g., by using COT sharing mechanism)

Companies are encouraged to provide views on Proposal #3a, including comments on Moderator’s notes #1-4.

|  |  |
| --- | --- |
| Company | Views |
| Samsung | We’re general ok with proposal #3a.  For 2nd FFS, we’d like to know why we need further discussion for multi-PDSCH case ? It is natural to support same TDRA mechanism for both UL and DL transmission, and the benefit of non-continuous TDRA is valid for both DL and UL, e.g. to reduce latency for DL control or UL control channel. We suggest to remove 2nd FFS, and add PDSCH in the main bullet, i.e. “For a DCI that can schedule multiple PDSCHs or PUSCHs”.  For 3rd FFS, since we already agreed the maximum number of PDSCH/PUSCH can not be larger than 8, then, this bullet can be deleted. |
| Huawei, HiSilicon | We can accept the proposal, also for multi-PDSCH DCI, but we should avoid a formulation such as “for a DCI that can schedule multiple PDSCHs or PUSCHs” since it may imply that the same DCI format could schedule either PDSCH or PUSCH, but there is no such proposal.    The FFS point on Alt3 seems already covered by the first FFS on signalling details. |
| Xiaomi | We support proposal #3a. and we also support it for PDSCH. |
| DOCOMO | We support the proposal in principle.  For the 2nd FFS, we prefer it applicable to multi-PDSCH.  For the 3rd FFS, agree with Samsung it can be deleted since there is agreement the maximum number of PDSCH/PUSCH can not be larger than 8. |
| Intel | We are fine with the proposal. Also share similar views as other companies that 3rd FFS should be removed.  We are also fine to apply this to multi-PDSCH scheduling. |
| InterDigital | We are fine with proposal #3a with following modification.  For the 3rd FFS, we agree with Samsung and DOCOMO. We already agreed the maximum number of PDSCH/PUSCH cannot be larger than 8. Therefore, this bullet can be deleted. |
| Qualcomm | We support the proposal for both multi-PDSCH/PUSCH grants, and agree with the other companies that the 3rd FFS can be removed. Based on the companies comments, we may be able to remove the 2nd FFS and modify the main bullet to capture both PDSCH and PUSCH. |
| CATT | We are fine with the proposal. For the second FFS we think this should also be applicable for PDSCH. We also agree with some other companies that the 3rd FFS should be removed. |

Based on commented so far, Proposal #3a can be updated as follows:

### Proposal #3b (High priority):

* For a DCI that can schedule multiple PUSCHs,
  + 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 implicitly indicated by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.), as per agreement made in RAN1#104-e
    - FFS: signaling details, e.g., considering DCI overhead
    - ~~FFS: applicability to multi-PDSCH DCI~~
    - ~~FFS: whether to support Alt 3 (as per agreement made in RAN1#104-e) if more than 8 PUSCHs can be scheduled by a single DCI~~
  + Note: Alt 2 does not preclude continuous resource allocation in time-domain.
  + Note: It’s up to gNB’s implementation how to overcome LBT failure in unlicensed spectrum (e.g., by using COT sharing mechanism)
* For a DCI that can schedule multiple PDSCHs,
  + TDRA: TDRA table is extended such that each row indicates up to [X, FFS for X] multiple PDSCHs (that can be non-continuous in time-domain). Each PDSCH has a separate SLIV and mapping type. The number of scheduled PDSCHs is implicitly indicated by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.
    - FFS: signaling details, e.g., considering DCI overhead
  + Note: This does not preclude continuous resource allocation in time-domain.
  + Note: It’s up to gNB’s implementation how to overcome LBT failure in unlicensed spectrum (e.g., by using COT sharing mechanism)

Above Proposal #3b seems to be agreeable to companies who gave comments so far. Please continue making comments on Proposal #3b.

Companies are encouraged to provide views on Proposal #3b.

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| --- | --- |
| Company | Views |
| Futurewei | We prefer to keep the FFS: applicability to multi-PDSCH. We would like to see more evidence that the same observation still holds for the case of multi-PDSCH and multi-PUSCH, regarding Samsung’s view that ‘It is natural to support same TDRA mechanism for both UL and DL transmission…’. |
| OPPO | We also prefer to keep the FFS: applicability to multi-PDSCH. Besides, in our understanding, for uplink transmission, it is up to UE implementation for LBT in unlicensed spectrum and it is independent of UL grant, so we prefer to remove the second note for uplink:   * + ~~Note: It’s up to gNB’s implementation how to overcome LBT failure in unlicensed spectrum (e.g., by using COT sharing mechanism)~~ |
| ZTE, Sanechips | For PUSCH, we can accept the proposal with the first note to include the continuous configuration to avoid LBT failure.  For PDSCH, in the last note the example should be deleted since COT sharing is used by UE to share gNB initiated COT. |
| Ericsson | We support Proposal #3b  Minor comment: it seems that we can replace "…up to [X, FFS for X] multiple PUSCHs …" simply with "…up to 8 PUSCHs" since we agreed maximum 8. Same thing for PDSCH.  Agree with OPPO that the Note can be removed for multi-PUSCH. |
| Spreadtrum | We are fine with the proposal in principle. Regarding the value of X, we recommend changing it to 8, because we already have reached an agreement on the maximum number of PUSCH/PDSCH scheduled by a single DCI. |
| Panasonic | We are fine with the proposal 3b in general. |
| Apple | To answer FW’s question, a gap for multi-PDSCH is even more important than for PUSCH as the gNB can keep possession of the medium while sending urgent/important signals to other UEs or broadcast signals to all UEs.  We can set [X, FFS for X] to 8 for PUSCH based on the agreement “The maximum number of PUSCHs that can be scheduled with a single DCI in Rel-17 is 8.”.  For PDSCH, we can still keep X as FFS due to agreement “The maximum number of PDSCHs that can be scheduled with a single DCI in Rel-17 is 8 for SCS of 480 and 960 kHz” with FFS for 120 kHz.  Agree with ZTE, Ericsso and Oppo that the note can be removed. |
| Fujitsu | We support Proposal 3b.  Agree with Ericsson and Spreadtrum that we can set X as 8 for both PUSCH and PDSCH, because it is agreed to be 8 at least for 960kHz, even though we have FFS for other SCSs. |
| Samsung | We support Proposal #3b.  To FW: please find our response as below, hope it can be helpful for better understanding.   * The motivation to only support continuous TDRA in Rel-16 NR-U is to avoid additional LBT in unlicensed band. Now, 52.6~71GHz band can be unlicensed as well as licensed band. For licensed band, LBT impact is not the factor to consider for TDRA, I believe, it is true for both DL and UL, * Non-continuous UL transmission can avoid the impact on DL transmission latency, because gNB can transmit DL (unicast or broadcast DL) to same or other UEs before the end of last PUSCH. Similarly, Non-continuous DL transmission can avoid the impact on UL transmission latency, because the same UE or other UE can transmit UL, e.g. PUCCH, before the end of last PDSCH. I think latency reduction and scheduling flexibility is beneficial for both UL and DL.   We’d also like to ask companies to share their view why separate handling for DL and UL is needed ? |
| Nokia/NSB | We are generally fine with the proposal. The last “Note” is not necessary. It can be discussed under other agenda items. |
| Lenovo, Motorola Mobility | We support the proposal |
| CEWiT | We are fine with the proposal #3b. |
| Moderator | To Futurewei and OPPO, based on clarification for necessity of the gap between adjacent PDSCHs from Apple and Samsung, could it be OK to apply also to PDSCH?  2nd Note for each case is now removed.  For X, we can replace X with 8 according to agreement. In addition, to address Apple’s comment, one note (same as the previous agreement) for PDSCH is added. |

### Proposal #3c (High priority):

* For a DCI that can schedule multiple PUSCHs,
  + TDRA: Alt 2 (TDRA table is extended such that each row indicates up to 8 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 implicitly indicated by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.), as per agreement made in RAN1#104-e
    - FFS: signaling details, e.g., considering DCI overhead
  + Note: Alt 2 does not preclude continuous resource allocation in time-domain.
* For a DCI that can schedule multiple PDSCHs,
  + TDRA: TDRA table is extended such that each row indicates up to 8 multiple PDSCHs (that can be non-continuous in time-domain). Each PDSCH has a separate SLIV and mapping type. The number of scheduled PDSCHs is implicitly indicated by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.
    - FFS: signaling details, e.g., considering DCI overhead
  + Note: This does not preclude continuous resource allocation in time-domain.
  + Note: Multi-PDSCH scheduling for the case of 120 kHz SCS is still FFS as per prior agreement. This case can be addressed after this FFS has been decided.

Companies are encouraged to provide views on Proposal #3c.

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| --- | --- |
| Company | Views |
| Vivo | We support moderator’s proposal. Just one clarification on the FFS part especially on “e.g. considering DCI overhead” part. In our understanding, RRC will configure TDRA list and DCI overhead is only related to the number of entries in the TDRA list. So our question is what does “considering DCI overhead” means here? |
| DOCOMO | Support the proposal. |

### Proposal #4 (Low priority):

* For a DCI that can schedule multiple PUSCHs,
  + 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.

|  |  |
| --- | --- |
| Company | Views |
| Qualcomm | We agree with the moderator’s proposal |
| Huawei, HiSilicon | This topic was not discussed in many Tdocs so it may be a bit premature to draw conclusions, even if it seems to make sense if all TBs are used for URLLC service.  Here also the main bullet is about PDSCH whereas the sub-bullet is about PUSCH. |
| Moderator | Apology for my typo in the main bullet, which should be PUSCH. Now, it’s fixed. |
| Panasonic | Support the proposal. |
| Lenovo, Motorola Mobility | This discussion is not high priority and should be deprioritized for now |
| OPPO | We prefer not to discuss URLLC related fields in R17. |
| Vivo | Support this proposal. |
| DOCOMO | We support the proposal in principle with clarification for the intention of the “This applies to all of scheduled PUSCHs”. We want to clarify that the intention is “open-loop power control command is only applied once for the first PUSCH if accumulated power control is configured”. |
| ZTE, Sanechips | Agree with the proposal. |
| Spreadtrum | We share the same views as Huawei and Lenovo, and it is too early to draw a conclusion without thorough discussion. |
| Futurewei | Suggest deprioritizing this discussion, since the observations here are premature. |
| Nokia/NSB | Support the proposal. |
| InterDigital | We are fine with the proposal. |
| Ericsson | Support the proposal |
| Apple | We are fine with the moderator’s proposal. |
| CATT | This can be discussed later. |
| Sony | We support the proposal. |
| Samsung | We support proposal #4. |
| Xiaomi | We support Proposal #4 |
| Intel | We share similar view as other companies that it is a bit early to decide on this issue. |

## Details on multi-PDSCH scheduling

|  |  |
| --- | --- |
| 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.

|  |  |
| --- | --- |
| Company | Views |
| Qualcomm | We agree with the moderator’s proposal |
| Huawei, HiSilicon | The moderator’s proposals looks acceptable. |
| Intel | We are fine with the proposal in principle. We suggest to make the following changes. MCS/NDI/RV already includes all scheduled PDSCHs. We do not need to further differentiate the first and 2nd TB in the proposal. Further, the last bullet is for multi-PUSCH scheduling, which is not related to the main bullet.   * For a DCI that can schedule multiple PDSCHs,   + MCS ~~for the 1~~~~st~~ ~~TB~~: This appears only once in the DCI and applies commonly to all scheduled PDSCHs   + NDI ~~for the 1~~~~st~~ ~~TB~~: This is signaled per PDSCH   + RV ~~for the 1~~~~st~~ ~~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 2~~~~nd~~ ~~TB, including whether the 2~~~~nd~~ ~~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~~ |
| Moderator | Clarification to the very last sub-bullet: TDRA, FDRA, CBGTI, and priority indicator are the common field applicable both to DL DCI and UL DCI. The intention was that, once how to signal them for multi-PUSCH scheduling DCI is decided, we may apply the same principle for them to multi-PDSCH scheduling DCI. |
| Panasonic | It is not clear to us when in first sub-bullet mentions “MCS for the 1st TB: This appears only once in the DCI and applies commonly to all scheduled PDSCHs”, then in FFS mentions “MCS/NDI/RV for the 2nd TB, including whether the 2nd TB can be scheduled or not”. We would like to clarify motivation of this conflict of statement (highlighted in red color) in the proposal.  In addition, we do not support CBG-based (re)transmission for multi-PDSCH/PUSCH scheduling by a DCI, hence, CBGFI in FFS should be removed. |
| Lenovo, Motorola Mobility | We agree with Intel’s suggested updates. |
| WILUS | We support the proposal updated by Intel and suggest to remove CBGFI since CBG-based transmission is not suitable to multi-PDSCH scheduling by a DCI. |
| OPPO | We are fine with the proposal. |
| Vivo | Support this proposal. |
| DOCOMO | We are supportive of the proposal in principle.  In our understanding, “MCS for the 1st TB: This appears only once in the DCI and applies commonly to all scheduled PDSCHs” means the “MCS for the 1st TB” field indication will be applied for the 1st TB of each PDSCH.  For the first FFS, we prefer not to support scheduling two TBs if multiple PDSCHs are scheduled considering DCI overhead (at least NDI and RV field will need to be doubled).  For the third FFS of CBGFI, it is talking about CBG based transmission as the CBGTI field in the fourth bullet. So we think it is related with whether to support CBGTI discussion for multiple PDSCHs. In our view, unified design for support of CBG based transmission for scheduling multiple PDSCHs/PUSCHs is preferred. And we don’t want to support CBG based transmission for scheduling multiple PDSCHs/PUSCHs.  For the last FFS, we prefer to reuse common design with multi-PUSCH scheduling for TDRA/FDR/CBGTI/priority indicator fields. |
| Fujitsu | We agree with Intel’s view on MCS/NDI/RV, and prefer to retain the last sub-bullet:   * For a DCI that can schedule multiple PDSCHs,   + MCS ~~for the 1~~~~st~~ ~~TB~~: This appears only once in the DCI and applies commonly to all scheduled PDSCHs   + NDI ~~for the 1~~~~st~~ ~~TB~~: This is signaled per PDSCH   + RV ~~for the 1~~~~st~~ ~~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 2~~~~nd~~ ~~TB, including whether the 2~~~~nd~~ ~~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 |
| ZTE, Saenchips | We are fine with the proposal. |
| Spreadtrum | We support this proposal. |
| Futurewei | Support to update the proposal considering suggestions from Intel/Docomo, among other useful recommendations. |
| Nokia/NSB | Support moderator’s proposal. |
| InterDigital | We agree with Intel’s suggested updates. |
| Ericsson | We support the first 4 bullets  We understand that it is necessary to make a distinction between 1st and 2nd TB as in legacy DCI 1\_1. While we don’t expect that two TBs will be used since rank >= 5 is unlikely in mmWave, the signaling should still support it since we will reuse DCI 1\_1 for multi-PDSCH.  Regarding the FFS, we have a strong concern against simultaneous use of multi-PDSCH and CBGs. CBGs are more useful for FR1 and low SCSs where the slots are long enough to experience some time selective fading. However, for 52.6 – 71 GHz, CBGs are useless: either all CGs will pass or all will fail, so there is no gain from the use of CGGs. Furthermore, we should strive for a common design between multi-PUSCH and multi-PDSCH, and CBGs are not supported for multi-PUSCH.  Hence, we prefer to write the FFS as follows:   * + FFS     - MCS/NDI/RV for the 2nd TB, including whether the 2nd TB can be scheduled or not     - Details of Resource allocation related fields such as VRB-to-PRB mapping, PRB bundling size indicator, rate matching indicator, and ZP CSI-RS trigger     - ~~CBGFI~~     - Details of Fields that ~~can apply the~~ are common ~~design~~ with multi-PUSCH scheduling, e.g., TDRA, FDRA, ~~CBGTI~~, priority indicator, including potential enhancements   The reason for adding “potential enhancements,” is that enhancements are still being discussed to reduce the FDRA field size, for example. |
| Apple | We are fine with Ericsson’s update |
| CATT | In principle fine but we prefer Intel or Fujitsu’s wording |
| Sony | We support Fujitsu’s update. |
| Sony | We support Fujitsu’s update. |
| Samsung | Generally OK with the proposal, but we think some sub-bullet of FFS can be agreed without FFS   * common bit field for PDSCH and PUSCH (last sub-bullet). It seems straightforward to apply same mechanism for these bit field, no need of separate handling. * CBGFI: though this filed does not exist in UL grant, considering it is part of CBG-based transmission information, CBGTI and CBGFI should be treated together, and it should be same as UL grant. Rel-16 NR-U already discussed CBG transmission, and agreed not support it for multi-PUSCH case. We’d like to follow Rel-16 NR-U mechanism to avoid duplicated discussion.   For 1st sub-bullet of FFS, we share the same understanding with E/// that it is very unlikely to use rank ≥ 5 in 52.6~71GHz. Therefore, we don’t support 2 TB for multi-PDSCH with large DCI payload. In our understanding, UE can re-interpret some bit field when UE identifies the number of PDSCHs from TDRA, e.g. > 1 PDSCH is scheduled, MCS for 2nd TB can be used for RV, NDI indication for other PDSCHs. |

**Summary on comments for Proposal #5:**

Moderator’s note #1: To Panasonic, let’s assume that 2-TB PDSCHs can be scheduled by a multi-PDSCH scheduling. Then, if N PDSCHs are scheduled by the DCI, there are N 1st TBs for N PDSCHs and N 2nd TBs for N PDSCHs. In that case, a single MCS value signaled for the 1st TB applies to N 1st TBs for N PDSCHs. Hope it can clarify the implication of MCS signaling.

Moderator’s note #2: Considering companies have different views on the support of 2-TB for multi-PDSCH scheduling DCI, we can pursue agreeing only on the 1st TB.

Moderator’s note #3: For CBGFI/CBGTI, it seems better to treat them at once.

**Proposal #5a (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
    - Details of resource allocation related fields such as VRB-to-PRB mapping, PRB bundling size indicator, rate matching indicator, and ZP CSI-RS trigger
    - Whether/how to signal CBGFI/CBGTI
    - Details of fields that are common with multi-PUSCH scheduling, e.g., TDRA, FDRA, priority indicator, including potential enhancements

On 4/15 GTW session, the following agreement was made:

### Agreement:

For a DCI that can schedule multiple PDSCHs,

* MCS for the 1st TB: This appears only once in the DCI and applies commonly to the first TB of each PDSCH
* NDI for the 1st TB: This is signaled per PDSCH and applies to the first TB of each 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 and applies to the first TB of each PDSCH
* 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 for each PDSCH, including whether scheduling of the 2nd TB for each PDSCH can be supported or not
  + Details of resource allocation related fields such as VRB-to-PRB mapping, PRB bundling size indicator, rate matching indicator, and ZP CSI-RS trigger
  + Whether/how to signal CBGFI/CBGTI if CBGFI/CBGTI is supported for multi-PDSCH scheduling
  + Details of fields that are common with multi-PUSCH scheduling, e.g., TDRA, FDRA, priority indicator, including potential enhancements

# 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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| --- | --- |
| Company | Views |
| Qualcomm | We agree with the moderator’s proposal and support Option 1 |
| Huawei, HiSilicon | We agree that something will have to be fixed, which may depend on how to signal K1 in a multi-slot PDSCH DCI. We may consider DCI format 1\_0 and 1\_1 separately in this discussion. |
| Intel | Option 2 is problematic. If the last SLIV of a row is overlapped with a UL symbol, i.e. the SLIV is not valid and is not considered in Type1 codebook generation, Option 2 will not reserve a PDSCH reception occasion for the row. However, some other SLIV(s) of the row may be valid for DL transmission. Finally, there is no PDSCH reception occasion to carry the HARQ-ACK for the row.  Therefore, we believe each SLIV of a row must be checked to decide whether a PDSCH reception occasion needs to be reserved for the row or not. Such principle seems covers by Option 1. There exists multiple interpretation for Option 1.  In our view of Option 1, if any SLIV of a row is available for PDSCH transmission (i.e. not overlapped with UL symbol), a PDSCH reception occasion needs to be reserved. The reserved occasion could be always allocated in the slot n-K1 containing the last SLIV of the row. In other words, even for the case that the last SLIV of the row is overlapped with UL symbol, the last SLIV is considered as available for PDSCH transmission in the slot n-K1, so that a PDSCH reception occasion can be allocated to carry the HARQ-ACK for the PDSCH transmission of the row. |
| Lenovo, Motorola Mobility | We are fine with the proposal and support Option 1 |
| WILUS | We agree with the proposal and support option 1. For option 2, it is unclear to us how to generate type-1 CB in the case where the last SLIV overlaps with semi-static UL symbol. |
| OPPO | We are fine with the proposal and support Option 1. |
| Vivo | Support this proposal in principle. |
| DOCOMO | We prefer option 2 with more details FFS, since K1 set extension for option will result in a huge number of candidate PDSCH occasions considering extended slots.  In our understanding, to maintain robust HARQ-ACK CB size, the K1 set extension would be based on maximum number of slots can be scheduled (or maximum number of slots in the configured TDRA table). If maximum 8 slots is supported, K1=1 should be extended to K1 = {1,2,3,4,5,6,7,8}. We think it will lead to significant payload size issue with huge redundancy, resulting in degraded PUCCH reliability performance.  So we prefer a method with less redundancy than K1 extension method. |
| Fujitsu | We are generally fine with the proposal.  Regarding Option 2, we think it is simple and feasible. But it may bring stringent restriction on scheduling, because a row is not valid for scheduling once the last SLIV is invalid. Therefore, Option 1 is slightly preferred.  As for interpretation on Option 1, we have similar view as Intel. ‘extension of K1 set’ seems unnecessary. |
| ZTE, Sanechips | We are fine with the proposal. |
| Spreadtrum | We support this proposal. |
| Futurewei | Prefer Option 1 and suggest to keep FFS open for discussion of the possibility of improving Option 1 further regarding redundancy. |
| Nokia/NSB | Fine with the formulation, and support option 1 |
| Ericsson | We are okay with the direction although we think some clarification is needed for Option 1:   * Pruning based on TDD configuration is missing * There is an inherent “union” operation. It can be captured as “… according to the union of ~~each~~ SLIVs over all ~~of each~~ rows in the TDRA table …”   It is not clear what is meant by “and/or based on extension of K1 set”. We prefer to remove this to provide a clean/clear Option 1. |
| Apple | We agree with this proposal and support Option 1 |
| CATT | We support this proposal. |
| Sony | We support this proposal. |
| Samsung | We support proposal #6.  We’re open to further discuss and down select from option 1 and option 2, with the consideration of the impact on codebook size, standard effort, etc.  Regarding Intel’s comment for option 2, Option 2 more focuses on the location of HARQ-ACK bits, i.e. put all bits in SLIV of last PDSCH, while how to delete a row according to UL/DL configuration can be further discussed.  For option 1, extension of K1 is to include slots containing PDSCHs other than last PDSCH. especially when K1 is non-consecutive. Regarding how to handle the interaction of UL/DL configuration, it can be further discussed. |
| Xiaomi | We support proposal #6 and prefer Option 1. |

### Summary on comments for Proposal #6:

Two discussion point:

* Handling of TDD configuration for each option, but details should be discussed further
* Ericsson’s option seems to be different from Option 1, so new Option 3 is created

### Proposal #6a (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
  + Option 3: The set of candidate PDSCH reception occasion is determined according to the union of SLIVs over all rows in the TDRA table
  + FFS: Codebook generation details, including how to handle the collision with TDD DL/UL configuration

Companies are encouraged to provide views on Proposal #6a.

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| Company | Views |
| Samsung | For option 3, it is unclear how to determine the union of SLIVs over all rows, when SLIVs within a row are in different slots, or SLIVs in different rows are in different slots. If the intention is to include all DL slots for all SLIVs in TDRA table, it seems aligned with option 1.  Let me further explain our understanding of option 1. Option 1 is also intends to include all DL slots for all SLIVs in TDRA table. Then, how to achieve that goal based on existing pseudo-code structure? We think we can include DL slots containing PDSCH other than last PDSCH in each row into the set  in section 9.1.2.1 in TS 38.213, and then, reuse existing loop “while” to enter each DL slot. Take figure 1 provided by FL as an example, K1=2, “based on extension of K1 set” means, we add additional K1’=K1+slot offset to last PDSCH=2+1=3. So,  = {2,3}, and we reuse “while” to determine candidate PDSCH occasion in slot N-2 (K1=2) and slot N-3(K1=3). For another example, if a row includes 8 PDSCH in 8 consecutive slots, then, there’re 7 slot offset to last PDSCH, so K1’= K1+1,2,3,4,5,6,7 = 3,4,5,6,7,8,9. So,  = {2,3,4,5,6,7,8,9}.  If the current wording for option 1 is not accurate, how about:  Option 1: The set of candidate PDSCH reception occasion is determined according to each SLIV of each row in the TDRA table and extension of K1 set based on K1 and slot offset between last PDSCH and other PDSCHs in a row.    Figure 1. |
| Xiaomi | Support the proposal and slightly prefer Option 1. For Option 3, it is necessary to define the ‘union of SLIVs’, if only one SLIV in each union, Option 1 is a special case of Option 3. |
| DOCOMO | We think the current description is a little confusing since companies seem to have different understandings on these options. After thinking about companies’ views on these options, we suggest to modify candidate alternatives as:   * Alt 1: HARQ-ACK window (i.e. slots associated with the HARQ-ACK PUCCH determined based on K1 set) is extended to include slots of scheduled PDSCHs by the DCI. Procedures after HARQ-ACK window determination for type 1 HARQ-ACK CB in Rel-16 can be reused. (In other words, PDSCH candidate occasion determination for each slot and HARQ-ACK bit generation is the same as Rel-16 procedure.)   + With Alt 1, HARQ-ACK information for the multiple PDSCHs are mapped to different PDSCH candidate occasions (and in different slots for PDSCHs in different slots). * Alt 2: HARQ-ACK window determination is the same as Rel-16, i.e. no extension. After PDSCH candidate occasion is determined, HARQ-ACK information of the multiple PDSCHs scheduled by one DCI will be mapped to one PDSCH candidate occasion.   The main difference of Alt 1 and Alt 2 is where we put the specification impact (red color).  For Alt 1, the specification impact is HARQ-ACK window determination is enhanced. And we understand it is the intention of current option 1 in Proposal #6a. And more details on how to extend the HARQ-ACK window may be FFS.  For Alt 2, the specification impact is how to determine corresponding PDSCH candidate occasions in one slot with considering multiple PDSCHs will be mapped to one candidate occasion, and also how to map HARQ-ACK information to the which PDSCH candidate occasion. Therefore, we understand Alt 2 is the intention of option 2 and option 3 in the Proposal#6a since the option 2 and option 3 are describing how to derive the candidate PDSCH occasion. We think Alt 2 leaves more space on how to determine the candidate occasion and mapping. It is a more high-level method so that companies can have more time to study the details.  From our perspective, we don’t prefer Alt 1 (option 1 in Proposal #6a) since it will cause very huge redundancy. If considering additional 8 slots are extended (as the example provided by Samsung), all PDSCH occasions in the 8 slots need to be reported. Huge redundancy will terribly degrade PUCCH reliability due to huge PUCCH payload size. So we prefer Alt 2 and details for further study. |
| Intel | We are fine for the FL proposal. |
| Qualcomm | We agree with Samsung and Xiaomi, the Union needs to be clarified for the third option |
| Futurewei | Agree with Qualcomm that the union of SLIVs need to be clarified. |
| OPPO | We are fine with the FL proposal. |
| CATT | We are fine almost fine but we would like to understand the exact definition of “the union of SLIV” before can agree with this bullet. |
| ZTE, Sanechips | We also think the third option should be clarified first. |
| Ericsson | Regarding Option 3 which the moderator created based on our initial comments about Option 1, the intention of introducing the “union” wording was to try to clarify Option 1. As Samsung points out above: “If the intention is to include all DL slots for all SLIVs in TDRA table, it seems aligned with option 1.” The answer to Samsung’s question is “yes.”  We agree to Samsung’s revised wording for Option 1, as it captures the “union” operation that we had in mind. Furthermore, it clarifies what is meant by “and/or K1 set extension” which we found very confusing.  Option 1: The set of candidate PDSCH reception occasion is determined according to each SLIV of each row in the TDRA table and extension of K1 set based on K1 and slot offset between last PDSCH and other PDSCHs in a row.  With this revised wording, we are fine to remove Option 3.  @Samsung: I would like to try to understand Option 2 better. Is the intention that there would be only 1 HARQ/ACK bit for all PDSCHs scheduled by the same DCI, where the last PDSCH occurs in the candidate slot, i.e., some form of time domain bundling? |
| Spreadtrum | We are fine with the updated proposal. |
| Panasonic | We are fine with FL proposal 6a. Our preference is Option 1 because it is simple and work well both consecutive and non-consecutive transmission occasions. For Option 2, it needs to be clarified how it works when multiple PDSCHs are transmitted in non-consecutive slots (or non-consecutive transmission occasions). For Option 3, we agree other company how to determine the union of SLIVs over all rows. |
| Apple | We have a preference for option 1. We suggest the following updated wording in red to help with understanding:  Option 1: The set of candidate PDSCH reception occasion is determined according to each SLIV of each row in the TDRA table and the extension of the K1 set based on K1 signaled by the DCI and the slot offset between the last PDSCH and other PDSCHs in a row. |
| Fujitsu | According to elaborations of Option 1 and Option 3 from companies, it seems whether/how to determine the set of candidate PDSCH reception occasion based on extension of K1 set and/or union of SLIVs are related to the exact way of modifying the Pseudo-code. We prefer to leave the details for later discussion. For current stage, we can have more generic wording for Option 1, like the way of Option 2.  Therefore, we suggest following modifications on the proposal:   * 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   + 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, including how to handle the collision with TDD DL/UL configuration and whether/how to extend the K1 set. |
| Samsung | To Docomo:  In our understanding, Alt 1 does not introduce huge redundancy. Yes, in my example, it is 8 slots, but the total number of bits for all these 8 slots depends on how to do pruning within these slots, e.g. we’ll delete some PDSCH candidate location within a slot conflicting with UL/DL configuration, and also delete some locations due to overlapping, etc. And as we mentioned, how to do pruning has impact on all alternatives. At this stage, it would be good to generally discuss alternative addressing the basic structure for type-1 codebook, and then, we can go to more details.  To E///:  HARQ-ACK bundling can be applied in Option 2, but currently, the description of Option 2 does not touch HARQ-ACK bundling. In Option 2, the intention is to keep existing K1 loop unchanged (without extension of K1 as in option 1), while try to ensure there is a HARQ-ACK bit location for PDSCHs other than the last PDSCH. So, we propose that, we can put HARQ-ACK bits for all PDSCHs in a candidate PDSCH location according to last PDSCH. In Rel-15/16, there is 1 bit associated with one candidate PDSCH location (let’s assume single TB case, and also no CBG). Option 2 suggests to put N bits associated with one candidate PDSCH location. The value of N can be FFS. One example is, N equals to the scheduled number of PDSCHs, another example is, N=1 with bundling of HARQ-ACK of all PDSCHs, or N=M with bundling of each M PDSCHs. These details are all open for the discussion.  To Apple:  Thanks for the update. I want to check the meaning of ‘singled by the DCI’ with you. gNB configures a set of K1, and a DCI indicates one value. Because any one of the set can be indicated, I think the extension of K1 should be performed for all values in the configured set of K1, rather than the one value indicated by DCI. Therefore, I think E///’s revision would be sufficient. If I miss-understand your intention, please correct me ☺  Option 1: The set of candidate PDSCH reception occasion is determined according to each SLIV of each row in the TDRA table and the extension of the K1 set based on K1 ~~signaled by the DCI~~ and the slot offset between the last PDSCH and other PDSCHs in a row.  To Fujitsu:  I’m afraid, if we delete K1 extension part, companies may not well-understand how Alt-1 works.  Therefore, we’d like to keep existing Option 1 with update from E///. |
| Nokia/NSB | We are fine with FL proposal for Alt 1 and Alt2. For Alt 3, similar as Samsung, Xiaomi and QC, union should be clarified. For Samsung’s clarification for alt1, the exact method to determine the values of K1 set can be further discussed, so we want to keep the current proposal. |
| Lenovo, Motorola Mobility | We support option1 and are not clear about option 3. Further clarification could be helpful if it is added as an option in the proposal. |
| Fujitsu | To Samsung,  We suggest the generic wording for Option 1 because it seems more discussion is needed to figure out whether/how to extend K1 set assuming the candidate PDSCH occasion set is determined.  Firstly, it is still unclear to us how it works by extending K1 set. In Rel-15/16, the set of K1 () is a pre-defined set {1, 2, 3, 4, 5, 6, 7, 8} or determined according to e.g. *dl-DataToUL-ACK.* Is the intention to further extending this set based on SLIVs of each row of TDRA table? Given so, if we assume the original is {1, 2, 3, 4, 5, 6, 7, 8} and jointly consider the example that ‘if a row includes 8 PDSCH in 8 consecutive slots, then, there’re 7 slot offset to last PDSCH, so K1’= K1+1,2,3,4,5,6,7 = 3,4,5,6,7,8,9. So,  (assuming it should be ) = {2,3,4,5,6,7,8,9}’, what the results of should be and how does it work by just reusing the loop “while”?  Secondly, there may be other alternatives which can work without extending . We’d also like to keep that open. For example, we can just take into account the SLIVs of each row of TDRA table in the step of handling the collision with TDD DL/UL configuration.  To sum up, still, we’d like to have more generic wording for Option 1:  Option 1: The set of candidate PDSCH reception occasion is determined according to each SLIV of each row in the TDRA table |
| WILUS | We are fine with the FL proposal.  One point to be clarified here is whether or not to type-1 HARQ-ACK CB includes HARQ-ACK information of both single PDSCH scheduling and multi-PDSCHs scheduling. Our understanding is that if type-1 CB is constructed separately, i.e., one for single PDSCH scheduling and another multi-PDSCHs scheduling by a single DCI, redundant bits cannot be avoided. So, we suggest to add the following note.  Note: the type-1 HARQ-ACK codebook includes HARQ-ACK information of both a single PDSCH scheduling and multi-PDSCHs scheduling |
| Samsung | To Fujitsu  Thanks for the follow-up.  For 1st question, sorry, I’m not sure I understand your question correctly. Do you ask, how option 1 works, if K1 has 8 values, e.g. 1~ 8 ? If K1 has 8 values, and a row includes 8 PDSCHs, then, K1’=2~15, so the new set  = 1~15, and we reuse the loop “while”. Hope it clarifies.  For 2nd question, currently, do you propose that we keep K1 unchanged, and add bit locations for PDSCHs other than last PDSCH in the step of handling collision with TDD DL/UL configuration? It sounds like one possible way for option 2. I don’t know why current wording for option 1 bothers. We’re open to discuss possible options, including existing option 1, 2 or new options (if any), but we still feel it would be more constructive to provide a more clear description for each option, so we’d still prefer Option 1 with E///’s update. |
| Moderator | Thank you-all for valuable technical discussion. Hope Samsung’s clarification can address concerns expressed by companies. Even though our understandings are approaching, it would be better to make proposal more generic, considering this is the first meeting to discuss details on enhancements for semi-static HARQ-ACK codebook. With this regard, I made a modification for K1 set extension part.  In addition, Option 3 is now removed.  To WILUS: I don’t think companies have a suggestion to have separate type-1 HARQ-ACK codebook for single-PDSCH scheduling DCI and multi-PDSCH scheduling DCI. However, we can check quickly company views. |

### Proposal #6b (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 occasions is determined according to each SLIV of each row in the TDRA table and/or based on extension of K1 set
  + Option 2: The set of candidate PDSCH reception occasions is determined according to the last SLIV of each row in the TDRA table
  + FFS: Codebook generation details, including how to handle the collision with TDD DL/UL configuration and whether/how to extend K1 set based on K1 and slot offset between last PDSCH and other PDSCHs in a row in the TDRA table

Companies are encouraged to provide views on Proposal #6b and please provide views on clarification question (whether type-1 HARQ-ACK codebook includes HARQ-ACK information of both a single PDSCH scheduling and multi-PDSCHs scheduling or not) from WILUS.

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| Company | Views |
| vivo | We are generally fine with the proposal but it may need more clear description.  For Option 1, we support the wording clarification from Samsung. Besides, for Option 1, how to determine the set of SLIVs for each DL slot of the extended K1 set should be discussed further. E.g., the set of SLIVs for a candidate DL slot may contain every SLIV ending in the candidate DL slot when taking the TDRA row containing the SLIV and applying a K1 in the high-layer configured K1 set. Alternatively, the set of SLIVs for a candidate DL slot may be the union of SLIVs over all rows in the TDRA table.  For Option 2, we support the wording clarification from DCM for Alt 2, i.e., after PDSCH candidate occasions are determined based on the high-layer configured K1 set, HARQ-ACK information of the multiple PDSCHs scheduled by one DCI will be mapped to one PDSCH candidate occasion. |
| DOCOMO | We can be OK with the proposal for progress, even though we prefer more clarification as following:   * + Option 1: The set of candidate PDSCH reception occasions is determined according to each SLIV of each row in the TDRA table and/or based on extension of K1 set     - For option 1, HARQ-ACK information for each scheduled PDSCH will be mapped to PDSCH reception occasion for the SLIV of the PDSCH.   + Option 2: The set of candidate PDSCH reception occasions is determined according to the last SLIV of each row in the TDRA table     - For option 2, there is no K1 set extension and HARQ-ACK for all PDSCHs scheduled by one DCI will be mapped to one PDSCH reception occasion with or without HARQ-ACK bundling. |

## 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, Ericsson
* 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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| Company | Views |
| Qualcomm | Alt 1 only works when for each DCI, we report the fixed number of bits. This can be achieved by either zero padding to the fixed size in code book, or A/N bundle for all PDSCH granted by the DCI. Such details need to be clarified.  The two sub-codebooks can be considered as a different design, Alt 1 will work with single codebook if we ensured that for each DCI a fixed number of bits is reported.  In addition, there are additional complications under CA case where different SCS are used or different number of PDSCHs can be granted in each CC. |
| Huawei, HiSilicon | It is not clear why two sub-codebooks are needed. If each DAI needs M HARQ-ACK bits (M being the maximum number of scheduled PDSCHs) then a single codebook can be used when scheduling one or more PDSCHs, assuming that the number of scheduled PDSCHs depends on the entry of the TDRA table signaled in the DCI.  The main drawback of Alt1 is that if one DCI is missing, the UE cannot know how many PDSCHs scheduled by that DCI are missing, and therefore the HARQ-ACK codebook size would be different from the one expected at the gNB. We think this drawback outweighs the DCI payload size increase of Alt2. |
| Intel | In our view, when the number of actually scheduled PDSCHs is less than or equal to 2, i.e. up to 2 HARQ-ACK bits, we can include HARQ-ACK feedback into the sub-codebook for single PDSCH scheduling, which can help to reduce HARQ-ACK codebook size.  We suggest to add this in the observation #1 |
| Lenovo, Motorola Mobility | Error case happens when any one DCI is missed with Alt 1 because UE can’t know the number of scheduled PDSCHs by the missing DCI. In that sense, HARQ-ACK codebook ambiguity is caused.  Additionally, we don’t understand why two sub-codebooks are needed. When one DCI is missed, two sub-codebooks can’t solve the problem of HARQ-ACK codebook ambiguity. |
| WILUS | We are fine with the observation.  Basically, this observation is same as type-2 CB construction rule when CBG-based transmission is configured. Here, the first sub-codebook is for single PDSCH and the second sub-codebook is for multi-PDSCHs by a DCI. |
| vivo | Agree the observation in principle. It can be clarified further how to get the maximum configured number of PDSCHs. E.g., it may be the maximum number of SLIVs per row across each TDRA table for each serving cell belonging to the same PUCCH cell group. |
| DOCOMO | Firstly, the issue and intention of the second bullet is not clear. The sub-title is for “T-DAI in UL DCI”, but corresponding description is “need additional UL DAI field for multi-PDSCH DCI”. It is quite confusing whether it is talking about on UL DCI or for UL DCI. We guess the intention is to discuss T-DAI extension in UL DCI is required for what serving cells? If so, we agree with the observation and we suggest following updates:   * + 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   Secondly, we would like to add more observations for HARQ-ACK CB generation. If HARQ-ACK bundling across PDSCHs is applied, e.g. bundled into 1 bit, there is no need to apply separate sub-codebook. And the number of HARQ-ACK bits is determined by T-DAI indication. So we suggest some modifications:  HARQ-ACK payload size is increased compared to single PDSCH scheduling only, if ~~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. If HARQ-ACK bundling across PDSCHs is applied, additional HARQ-ACK payload size can be avoided (or even no additional HARQ-ACK payload size is considered if bundled into 1 bit). |
| Fujitsu | In our view, whether to have two sub-codebooks or a single codebook depends on the maximum number of HARQ-ACK bits corresponding to a multi-PDSCH DCI. In NR, one DCI can schedule maximum 8 CBGs and thus correspond to maximum 8 HARQ-ACK bits. Similarly, assume a multi-PDSCH DCI corresponds to maximum M HARQ-ACK bits based on the current CA configuration. If M is not larger than 8, a single codebook would be sufficient where multi-PDSCH TX is treated as CBG-based TX. This can be added to Alt.1. If M is larger than 8, then two sub-codebooks are defined. In this case, we share a similar view with Intel. HARQ-ACK bits for multi-PDSCH can be included in the sub-codebook for single-PDSCH. |
| NEC | We are fine with the observation. |
| ZTE, Sanechips | We are fine with the observation. But we don’t prefer Alt1 because UE will fail to know the exact number of scheduled PDSCH if one DCI is missed. |
| Spreadtrum | We support the observation in principle. However, as mentioned by many companies, the issue of Alt 1 is that when DCI is missing, the codebook size will be inconsistent at gNB and UE side. |
| Futurewei | Suggest a discussion on weighing the ambiguity issue associated with Alt1, and determine if not to include relevant observations with Alt1 further upon consensus. |
| Nokia/NSB | Fine in principle. But, the assumption of “two sub-codebooks” is unclear if we have restriction that only single codebook for single PDSCH scheduling with multi-PDSCH scheduling without CBG configuration. Thus, we suggest to replace it by  A separate sub-codebook is generated for multi-PDSCH scheduling case , exactly same handling with CBG configured |
| Ericsson | Generally okay  However, the description is missing the option of configuring time domain bundling (as pointed out by DOCOMO). To achieve a flexible trade-off in HARQ feedback overhead and retransmission efficiency, a configurable number of bundles can be configured, e.g., 2, 4 etc. Then the description would be as follows:   * + 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, similar to the way a 2nd sub-codebook is defined to handle ~~exactly same handling with~~ CBG-based scheduling ~~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. This may be reduced through time domain bundling by configuring a number of HARQ bundle groups.     - 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, or is fixed as the number of configured HARQ bundle groups, e.g., 2, 4.   We don't understand the comment from Huawei "the HARQ-ACK codebook size would be different from the one expected at the gNB". The number of bits is known. It is DAI\*M where M = max number of PDSCHs in a single DCI or if configured time domain HARQ bundling is used, then M = configured number of HARQ bundle groups. |
| Apple | We suggest that the following concept of HARQ bundling should be added to the observation. To limit codebook size, 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.  We agree that we are sending a fixed number of bits when the DCI is missing. If a DCI being missing maps to a fixed codebook size, not sure why there is an ambiguity between gNB and UE. |
| CATT | Ok in principle. Details about bundling can be discussed further. |
| Sony | We are fine with the observation. |
| Samsung | For Alt-1, it seems different companies have different understanding.  Some companies think the number of HARQ-ACK bits per DCI varies with scheduled number of PDSCH. We believe it is not the intention of the proponent of Alt-1.  Some companies think the number of HARQ-ACK bits per DCI is fixed, and it can be further divided into 2 alternatives:   * Alt-1a: Single HARQ-ACK codebook, one DCI is corresponding to N bit, N is the maximum number of schedulable PDSCHs * Alt-1b: Two sub-codebooks, one DCI is corresponding to 1 bit (or 2 bits for 2TB case) for single PDSCH sub-codebook, and one DCI is corresponding to N bits for multi- PDSCH sub-codebook.   We think observation #1 is based on Alt-1b, and it is aligned with our understanding (our original intention for Alt-1).  From our point of view, we support Alt-1b, with minimum standard impact by reusing CBG/TB-based HARQ-ACK feedback.  In Rel-15, all these alternatives or similar alternatives (including Alt 1/2/3) were discussed for several meetings, with the consideration of PDCCH overhead, PUCCH overhead, robustness to PDCCH miss-detection, standard impact….and finally RAN1 agreed two sub-codebooks. Unless new motivation is well-justified, we think Alt-1b should be the reused.  Regarding the bundling (if support), it seems applicable to all alternatives. At this stage, maybe no need to add the description for bundling alternative by alternative. |

### Summary on comments for Observation #1:

Main concerning point is how Alt 1 can resolve the ambiguity issue between gNB and UE in terms of HARQ-ACK codebook size, when UE misses any DCI. As several companies already pointed out, there is NO ambiguity issue since the number of HARQ-ACK bits per DAI is always fixed as N (where N=the maximum configured number of PDSCHs). If actually scheduled number of PDSCHs is less than N, the UE shall fill NACK for the HARQ-ACK bit location corresponding to NOT scheduled PDSCH(s).

Another point raised by Qualcomm, Huawei, Intel, and Fujitsu is about the necessity/benefit of two sub-codebooks. Two sub-codebooks, compared to single codebook, are beneficial in terms of HARQ-ACK codebook size reduction. In case of D1 (= # of DAIs for single-PDSCH case) and D2 (= # of DAIs for multi-PDSCH case),

* For single codebook, # of HARQ-ACK bits = (D1+D2) \* N
* For two sub-codebooks, # of HARQ-ACK bits = D1 + (D2 \* N)

Lastly, regarding time-bundling aspects, as Samsung commented, it can be applied all alternatives so I’m reluctant to include any observation for time-bundling aspects. If we agree to support later, we can update observation for each alternative as well.

Moderator’s note #1: To Qualcomm, Huawei, Lenovo, ZTE, and Spreadtrum, NO ambiguity issue even when a DCI is missed by UE, as described above.

Moderator’s note #2: To Qualcomm, NO issue even under CA case with different numerologies, from my understanding. These cases are also being handled in current specification for CBG-configured case.

Moderator’s note #3: To vivo, NTT DOCOMO, Nokia, and Ericsson, comments are reflected. However, as to HARQ-ACK bundling, it has not been agreed yet, so I didn’t reflect comments for time bundling.

### Observation #1a (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 all serving cells including one not configured with multi-PDSCH DCI
  + HARQ-ACK codebook generation:
    - A separate sub-codebook is generated for multi-PDSCH case, similar to the way a 2nd sub-codebook is defined to handle CBG-based scheduling
    - 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 across serving cells belonging to the same PUCCH cell group.
    - 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. Therefore, NO ambiguity issue between gNB and UE, in terms of HARQ-ACK payload size.

Companies are encouraged to provide views on Observation #1a, including comments on Moderator’s notes #1-3.

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| Company | Views |
| Samsung | We’re fine with the observation. |
| Huawei, HiSilicon | Thank you for the clarifications from the proponents. We understand that if the number of HARQ bits for each DCI is always equal to N (the maximum number of PDSCHs that can be scheduled by a single DCI) then there is no ambiguity. However, the overhead is greatly increased, as correctly reflected in the sub-bullet of observation #1a.  It is still not clear why 2 sub-codebooks are assumed, but it seems to come from an assumption that a UE would monitor two types of DCI formats: one DCI format used to schedule a single PDSCH, and one DCI format used to schedule multiple PDSCHs. Our assumption was rather that the UE monitors one DCI format, which can dynamically schedule 1 or more PDSCHs. In this case, the UE has to assume N bits for each detected DCI format and there is no need for two sub-codebooks. If the intent was to cover the case of a fallback DCI format, then we think that this will not occur frequently enough so it doesn’t justify the need for 2 sub-codebooks since it wouldn’t save much overhead once we assume that most scheduling is multi-slot. In any case, we think Alt1 could be defined without using sub-codebooks so it is not clear why Alt1 must be defined to have 2 sub-codebooks. |
| Xiaomi | We share same understanding of Observation #1a |
| DOCOMO | We are fine with the observation but we don’t prefer Alt 1 due to redundant PUCCH overhead. |
| Intel | We prefer to clarify two options to divide the two sub-codebooks   * Option 1: for the case one PDSCH is scheduled by a DCI for multi-PDSCH scheduling, the HARQ-ACK bit(s) for the PDSCH are included in the first sub-codebook * Option 2: for the case one or two PDSCHs are scheduled by a DCI for multi-PDSCH scheduling, i.e. one or two HARQ-ACK bits are generated and associated with the DCI, the HARQ-ACK bit(s) are included in the first sub-codebook   Further, we would like to add that HARQ-ACK codebook size can be reduced when time domain bundling is supported as commented by other companies. |
| Qualcomm | As we mentioned before, the two sub-codebooks are a separate design, and they should be decoupled from Alt 1. In other words, Alt 1 works as long as we fix the number ACK/NACK bits per DCI. Defining two codebooks may save some bits and optimize the overall feedback load but it is not necessary. |
| Futurewei | Recommend to separate the two codebook discussion from the proposal, if using two codebooks are supported by most of the companies. |
| ZTE, Sanechips | We have the same view as Huawei and QC, two sub-codebooks are a separate design and it is not essential for Alt1. |
| Ericsson | Generally okay with the observation, but one comment on wording clarity.  Regarding the following, I think the intention is to say that T-DAI counts downlink assignments over all serving cells. The way it reads now, it seems that there is a separate T-DAI field corresponding to each carrier, which is clearly not correct.   * + T-DAI in UL DCI: Need additional UL DAI field (with same bit-width of legacy UL DAI), that counts downlink assignments over ~~for~~ all serving cells including one(s) not configured with multi-PDSCH DCI   Also, in the last sub-bullet, why does it say "corresponding to each DAI?" This wording was removed from Observations #2-1a, #2-2a.  We share the understanding that Observation #1a assumes two sub-codebooks, and we think that is the simplest, most natural approach to follow. There is also precedent when comparing to Rel-15 where one sub-codebook is maintained for TB-based scheduling and another sub-codebook is maintained for CBG-based scheduling. Furthermore, it is always clear in what order they fed back. |
| Spreadtrum | Thanks for the clarification, now we are fine with the observation. |
| Apple | As mentioned in our last set of comments, we think that HARQ bundling can be used to reduce the size of the codebook. As in observation 2-1 below, we should have a discussion on time bundling aspects if supported. With time bundling, the following observation will be modified: “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 a function of the fixed as the maximum configured number of PDSCHs based on HARQ bundling”.  Also, agree that we may want to separate the 2 codebook discussion from the alternative discussion although there may be some value in have more than one codebook. |
| Nokia/NSB | The last sentence added is not necessary. There is no ambiguity with other alternatives because of C-DAI/T-DAI counting, only difference is the overhead for DAI field and UCI feedback.  We don’t need to have the sentence for comparison.  In case of last DCI missing, all options have problem, and it can be handled by blind detection in gNB receiver. |
| Lenovo, Motorola Mobility | We still think that the two sub-codebooks is not needed.  Otherwise, we are fine with the observation |
| Fujitsu | We are generally fine with the observation, but also have some details for confirmation.  For the single-PDSCH case, two sub-codebooks have been standardized. Assume sub-codebook #1 for TB-based transmission and sub-codebook #2 for CBG-based transmission. For the multi-PDSCH case, an additional sub-codebook #3 is defined. Then there are three sub-codebooks in total. Hope this is a correct understanding.  If yes, the following can be further clarified. For a cell configured with multi-PDSCH, a DCI can still schedule single PDSCH via TB-based or CBG-based manner. In this case, the HARQ-ACK bits for single PDSCH should be included into sub-codebook #1 if TB-based scheduled or included into sub-codebook #2 if CBG-based scheduled.  Additionally, we think it can be another option to generate the codebook. It has been agreed that the maximum number of PDSCHs for multi-PDSCH is 8. In NR, the maximum number of CBG is also 8. In terms of the required number of HARQ-ACK bits, multi-PDSCH and CBG have a similar value range. Therefore, HARQ-ACK bits for multi-PDSCH can be just included into sub-codebook #2 (for CBG-based). By this way, there are totally two sub-codebooks. |
| WILUS | Fine with the observation.  Regarding “Therefore, NO ambiguity issue between gNB and UE, in terms of HARQ-ACK payload size,” our understating is there are still ambiguity issues if 1) a UE misses more than 3 consecutive DCIs for a sub-codebook and 2) a gNB schedules at least one DCI for a sub-codebook but the UE does not receive the DCIs for the sub-codebook. Thus, we prefer to remove the sentence to avoid any potential misleading. |
| Moderator | Main issue is whether to separate two sub-codebooks discussion or not. However, from my perspective, Alt 1 should be discussed with two sub-codebooks which are already supported for CBG-configured case from Rel-15 and are assumed by proponents of Alt 1. Let’s take an example of 2-CC CA where only CC#1 is configured with up to 8 multiple PDSCH scheduling DCI while CC#2 is not. If UE is scheduled with 2 DL DCIs (scheduling multiple PDSCHs) from CC#1 and 2 DL DCIs from CC#2,   * With single codebook: 4x8 HARQ-ACK bits * With two sub-codebooks: 2 + 2x8 HARQ-ACK bits   If we compare Alt 1 + single codebook with Alt 2, it must be unfair.  To Huawei: What is the problem if UE monitors two types of DCI formats and DAI is counted per DCI format? This behavior is also applied when UE is configured with CBG.  To Intel: Even though I can understand two options, this level of details can be discussed later.  To Ericsson: The intention was to point out the additional UL DAI field is needed for UL grant for all serving cells including a serving cell not configured with multi-PDSCH DCI.  To Apple and Intel: Time bundling can be applied to Alt 2 as well, as other companies already commented. If it needs to be described for Alt 1, it is also to be described for Alt 2.  To Nokia, WILUS: Understood. Last DAI missing case is applied to any alternative. Thus, the last sentence can be removed.  To Fujitsu: Please note that already several companies stated how to handle CBG+multi-PDSCH DCI in their Tdoc. But, this discussion can be done later at least after deciding how CBGTI/CBGFI is signaled in multi-PDSCH DCI. |

### Observation #1b (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), in UL DCI for all serving cells including a serving cell not configured with multi-PDSCH DCI
  + HARQ-ACK codebook generation:
    - A separate sub-codebook is generated for multi-PDSCH case, similar to the way a 2nd sub-codebook is defined to handle CBG-based scheduling
    - 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 across serving cells belonging to the same PUCCH cell group.
    - The number of HARQ-ACK bits 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.

Companies are encouraged to provide views on Observation #1b.

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| Company | Views |
| vivo | It seems that this observation assumes two separate sub-codebook which is not agreed yet for Alt. 1. Maybe this should be discussed first and then agree this observation. Otherwise, the observation should be divided into two parts: one single codebook case and two sub-codebook case. |
| DOCOMO | We agree with the observation. |

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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| Company | Views |
| Qualcomm | We share the same understanding as Observation 2-1, however, we do not think that increasing DAI field is extremely critical for Alt 2. The increased bit-width is beneficial for all DAI based designs, as larger bit-width will make it more reliable. |
| Huawei, HiSilicon | Suggest naming this Alt2a. Similar as Qualcomm’s answer, we think the increased DAI size is beneficial and not critical. An assumption on the ordering of the PDSCHs counting in the DAI needs to be defined. We suggest the DCIs can be ordered in a frequency first, time second manner like the legacy case, then for each DCI the PDSCH counter is accumulated in time. The modulo order can be made configurable by RRC. |
| Intel | We are fine with the observations.  We prefer to add example on the calculation of overhead of DAI  To support up to 8 PDSCHs that can be scheduled by a single DCI, and to enable the identification of up to 3 missing PDCCHs (same capability as NR), the size of a DAI is 5 bits.  In enhanced Type2 HARQ-ACK codebook, if two NFI/T-DAI are configured in DL grant, the overhead is 15 bits (one C-DAI + two T-DAI)  For the T-DAI in UL grant, it can be up to 20 bits (2 T-DAI for each PDSCH group) |
| Lenovo, Motorola Mobility | We are generally OK with this observation and agree with QC and Huawei that increasing DAI size is beneficial but not critical.  One thing that is not clear to us is:   * + - HARQ-ACK payload size is the same with legacy case of single-PDSCH DCI |
| WILUS | We are fine with the observations. Since the number of DAI bits increases in Alt2, we further capture how many DAI bits are required to protect the same number of consecutive DTXs (e.g., 3 consecutive DTXs). |
| OPPO | We have same understanding as Observation 2-1. |
| vivo | Agree the observation in principle. Nevertheless, the statement that “The number of HARQ-ACK bits corresponding to each DAI depends on the number of actually transmitted PDSCHs but DAI is counted per PDSCH.” may be confusing. In our opinion, the number of HARQ-ACK bits corresponding to each DAI is just that corresponding to a scheduled PDSCH, dependent on configured codeword number, spatial bundling, etc. |
| DOCOMO | Agree with the observation. We are supportive of Alt 2 from PUCCH redundancy perspective. DAI bit increasement need further discussion.  And we would like to clarify the observations on HARQ-ACK CB generation are for the case when HARQ-ACK bundling across PDSCHs not applied. |
| Fujitsu | Firstly, the overhead for DAI should be considered carefully. It depends on the maximum number of PDSCHs scheduled by a multi-PDSCH DCI. A larger number will require a larger DAI size. Secondly, the DAI counting mechanism is totally different from the legacy one where DAI is counted per DCI. Therefore, the standard impact should be considered. |
| NEC | We are fine with the observation. |
| ZTE, Sanechips | We have the same understanding as Observation 2-1 and share similar view with Qualcomm and Huawei that increasing DAI size is benefitial and not critical.  As for the HARQ-ACK codebook generation process, it can be consistent with that of one DCI scheduling one PDSCH. |
| Spreadtrum | We are fine with the observation. Regarding the DAI size, we share the same view with Qualcomm and Huawei, that is, increasing DAI size is beneficial but not critical. |
| Futurewei | Recommend to decide which is the more severe issue, payload size increment of Alt-2, or ambiguity associated with Alt-1. |
| Nokia/NSB | We are generally OK with Observation #2-1. |
| Ericsson | Generally okay with the observation  Clearly the bitwidth of the DAI fields will increase with Alt2. In the current spec a DAI is 2-bits, which implies that the HARQ codebook can still be constructed correctly even with up to 3 consecutive DCI mis-detections (unless the last DCI before PUCCH is lost). If the same robustness is to be maintained with DAI counted per PDSCH (Alt-2), the DAI needs to be extended by bits, assuming the maximum number of PDSCHs scheduled by a single DCI is . So, this would be an extra 3 bits if it is agreed to support scheduling of up to 8 PDSCHs.  A key aspect that is missing is that DAI counting per PDSCH is a deviation from current specifications. DAI counting per PDCCH is assumed in current specs, and this approach was also used in LTE. A large spec impact is envisioned if such a fundamental change is made. |
| Apple | We are in general, fine with the observation. In essence, we are trading off DCI size in Alt -2 vs codebook size in Alt-1. The codebook size can be mitigated with HARQ bundling. |
| CATT | In principle we are OK with this observation. But the details need further clarification. For example the aspects of HARQ-ACK bundling etc. |
| Sony | We are fine with the observation. We share the same view with Qualcomm and Huawei. DAI increment is beneficial, but not critical. |
| Samsung | We confirm observation #2 aligned with our understanding.  From our point of view, we do not think increasing DAI is not critical drawback. DAI is not a single bit field, it has C-DAI, T-DAI, T-DCI for 2nd PDSCH group, UL-DAI, UL-DAI for 2nd PDSCH group. Then, increase X bit for one DAI bit field, e.g., it will increase 3X bits for DL DCI.  PDCCH coverage will be degraded by increasing DAI bit length, which is indeed a critical issue. |

### Summary on comments for Observation #2-1:

In general, Observation #2-1 seems to be acceptable to all. The following aspects are additionally discussed.

* To capture the exact amount of increased DCI bits
* Companies have different suggestions on details of codebook generation method (e.g., freq-first & time-second order including configurability for the order, one scheduling DCI assumed per PDSCH, etc)
* Time-bundling aspects, if supported
* Interpretation of the current specification, regarding DAI is counted per PDCCH or PDSCH

Moderator’s note #1: The exact amount of increased DCI bits is captured in the observation.

Moderator’s note #2: Other discussion points are not captured yet since companies have different views each other.

Moderator’s note #3: Regarding the criticality of DCI increase, one question to proponents supporting Alt 2, are DAI fields also required to be increased for DCI format 1\_0?

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

* For Alt 2a (C-DAI/T-DAI is counted per PDSCH with a single codebook) of generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs,
  + 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
  + C-DAI/T-DAI in DL DCI and T-DAI in UL DCI need to be extended by log2(N\_max) bits for each field where N\_max equals to the maximum configured number of PDSCHs for multi-PDSCH scheduling DCI across serving cells belonging to the same PUCCH cell group
  + HARQ-ACK codebook generation:
    - The number of HARQ-ACK bits depends on the number of actually transmitted PDSCHs but DAI is counted per PDSCH.

Companies are encouraged to provide views on Observation #2-1a, including comments on Moderator’s notes #1-3.

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| Company | Views |
| Samsung | We’re fine with the observation.  We’d like to emphasise that >10 bits overhead is not non-critical for PDCCH coverage. As observed by some companies in SI phase, there would be PDCCH coverage issue in 52.6GHz. Increasing tens of bits makes DL coverage even much worse. |
| Huawei, HiSilicon | As commented on observations #1a, there seems to be an assumption that a UE would monitor two types of DCI formats: one DCI format used to schedule a single PDSCH, and one DCI format used to schedule multiple PDSCHs. Our assumption was rather that the UE monitors one DCI format, which can dynamically schedule 1 or more PDSCHs. So the single-PDSCH DCI mentioned in the first sub-bullet point is not clear. If it is meant to be DCI format 1\_0, then it should be clear that there is no need to increase the DAI field in DCI format 1\_0 since it can only schedule a single DCI.   * + C-DAI/T-DAI in DL DCI: Bit-width is increased for a multi-PDSCH DCI (when at least one entry of the TDRA table allows scheduling more than one PDSCH)   The ordering of the PDSCHs should at least be mentioned as a spec impact that would have to be resolved for Alt2a, as an additional sub-bullet under HARQ-ACK codebook generation, such as:   * + HARQ-ACK codebook generation:     - The number of HARQ-ACK bits depends on the number of actually transmitted PDSCHs but DAI is counted per PDSCH.     - FFS: ordering of the PDSCHs |
| Xiaomi | We are general fine of Observation #2-1a. but for “The number of HARQ-ACK bits corresponding to each DAI depends on the number of actually transmitted PDSCHs but DAI is counted per PDSCH”, is it “The number of HARQ-ACK bits corresponding to each DAI depends on the number of scheduled PDSCHs” |
| DOCOMO | We are fine with the observation except the expression of number of extended bits.  We think the required field extension is determined by original field length and the new field length, where the new field length is not only related with maximum number of scheduled PDSCHs, but also related with the maximum number of consecutively missed DCIs. If MDCI is the number of maximum consecutively missed DCIs, the new DAI field is log2(N\_max\* MDCI).  We prefer Alt 2 since the extended DCI fields can result in non-redundant PUCCH payload. From perspective of PDCCH/PUCCH reliability and coverage perspective, we think increased PDCCH overhead may be better than redundant PUCCH payload since UL channel is usually the bottleneck channel for coverage. |
| Intel | We prefer to explicitly clarify that size of C-DAI in DCI 1\_0 is 2+log2(N\_max) bits |
| Qualcomm | The increase of DAI field needs to be decoupled from Alt 2 as we believe it still works without increasing the field size. The extension of the DAI field size will increase the reliability of the 3 Alternatives and is not contingent to Alt 2, so we can discuss it separately. |
| Futurewei | We think the PDCCH coverage is not impacted much by increasing a few bits and prefer Alt-2. |
| ZTE, Sanechips | The bit-width of DAI/T-DAI in DL DCI and T-DAI in UL DCI depends on the reliability requirement, if identification of up to 3 missing PDCCHs (same capability as NR), the DAI/T-DAI in DL DCI and T-DAI in UL DCI need to be extended by log2(N\_max) bits for each field where N\_max equals to the maximum configured number of PDSCHs for multi-PDSCH scheduling DCI, otherwise, the bit-width of DAI/T-DAI in DL DCI and T-DAI in UL DCI do not need to change. |
| Ericsson | Generally okay, but similar question on wording clarification as in Observation #1a.  If proponents of Alt-1 insist that the DAI field size in DCI does not need to be increased, then there should be a bullet added to Observation #2-1a that says if the DAI fields are not increased, then there is a loss in robustness when it comes to recovering from missed PDCCH detections. In Rel-15, with 2 bits in DAI and DAI counted per PDCCH, up to 3 consecutive PDCCHs can be missed. If Rel-17 adopts DAI counting per PDSCH (Alt-2), and only 2 bits are used for DAI, then up to 3 consecutive PDSCH schedulings could be missed. But multi-PDSCH scheduling will support up to 8 PDSCHs, so it seems that 2 bits wouldn't even allow for a single missed PDCCH. |
| Spreadtrum | We are generally fine with the updated observation. |
| Apple | In general, we are okay with the observations.  We are fine with Huawei’s update on the single/multi-PDSCH DIC issue and with Xiaomi’s update on the # of HARQ-ACK bits.  We agree with Samsung that the increase in DCI payload may be non-trivial. Note that the increase in PUCCH payload pointed out by DOCOMO may be alleviated by HARQ bundling.  Finally, from our understanding, there would need to be an increase in the DAI field for this alternative with the increase in the number of PDSCHs scheduled by a single PDCCH. We assume that we would like the capability to be the same as NR as highlighted by ZTE and agree with Ericsson that we will not be able to miss one PDCCH. |
| Nokia/NSB | Agree with Xiaomi on the last sentence. Also, increase of DAI field is one key comparison aspect, so we cannot decouple this from Alt 2. Any DAI reduction with alt 2 should be discussed together with these options. |
| Lenovo, Motorola Mobility | We are generally fine with the observation and also agree with Huawei’s update |
| WILUS | We prefer to capture explicitly how many bits for C-DAI/T-DAI are additionally needed to identify up to 3 missing consecutive DCIs. In addition, DAI interpretation rules are further needed if a DCI (e.g. DCI scheduling single PDSCH) have 2-bit DAI field and another DCI (e.g., DCI scheduling multi-PDSCHs) has more than 2-bit DAI field. It is because two DAI fields with different bit-size have different value range of C-DAI/T-DAI. |
| Moderator | To Huawei and Qualcomm: From my perspective, DAI size increment should not be decoupled with Alt 2. In the exemplary figure below, if CC#1 is configured with DCI which can schedule up to 4 PDSCHs, DAI field should be increased to 4 bits. If DAI field size for DL DCI (e.g., fallback DCI) is kept as 2 and UE misses DCI1 on CC#1, UE cannot differentiate C-DAI = 1 or 5 for CC#2. |

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

* For Alt 2a (C-DAI/T-DAI is counted per PDSCH with a single codebook) of generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs,
  + C-DAI/T-DAI in DL DCI: Bit-width is increased, in DL DCI not only for multi-PDSCH DCI but also for single-PDSCH DCI for all serving cells including a serving cell not configured with multi-PDSCH DCI
  + T-DAI in UL DCI: Bit-width is increased, in UL DCI for all serving cells including a serving cell not configured with multi-PDSCH DCI
  + C-DAI/T-DAI in DL DCI and T-DAI in UL DCI need to be increased to 2+log2(N\_max) bits for each field where N\_max equals to the maximum configured number of PDSCHs for multi-PDSCH scheduling DCI across serving cells belonging to the same PUCCH cell group
  + HARQ-ACK codebook generation:
    - The number of HARQ-ACK bits depends on the number of scheduled PDSCHs.
    - FFS: ordering of the PDSCHs

Companies are encouraged to provide views on Observation #2-1b.

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| Company | Views |
| vivo | Fine with the updated observation generally. As pointed out by Huawei, the multi-PDSCH DCI and single-PDSCH DCI may be misleading, and the update from Huawei seems fine to us. |
| DOCOMO | Maximum number of consecutively missed DCIs needs to be considered to determine necessary bit extension. We suggest to remove observation for the bullet of DAI field increment and further study this issue. |

### 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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| Company | Views |
| Qualcomm | We do not see a need for having two sub-codebooks for Alt 2 |
| Huawei, HiSilicon | Suggest naming this Alt2b  Similar as our comment on Alt1, it is not clear why two sub-codebooks would be needed, assuming that the number of scheduled PDSCHs can be dynamically selected between 1 or more. |
| Intel | We are fine with the observations.  We prefer to add example on the calculation of overhead of DAI  To support up to 8 PDSCHs that can be scheduled by a single DCI, and to enable the identification of up to 3 missing PDCCHs (same capability as NR), the size of a DAI is 5 bits.  In enhanced Type2 HARQ-ACK codebook, if two NFI/T-DAI are configured in DL grant, the overhead is 15 bits (one C-DAI + two T-DAI)  For the T-DAI in UL grant, it can be up to 20 bits (2 T-DAI for each PDSCH group) |
| Lenovo, Motorola Mobility | We don’t understand why two sub-codebooks are needed. With DAI counted per PDSCH, this is no need to use two sub-codebooks.  One thing that is not clear to us is:   * + - HARQ-ACK payload size is the same with legacy case of single-PDSCH DCI |
| WILUS | We are fine with the observations, but we don’t see benefits to use two sub-codebooks. Since the number of DAI bits increases in Alt2, we further capture how many DAI bits are required to protect the same number of consecutive DTXs (e.g., 3 consecutive DTXs). |
| Vivo | Agree to the observation in principle. However, we have the same confusion as that for Observation #2-1. |
| DOCOMO | We have following questions on the observation:  Can we guess the motivation for two sub-codebooks here is to only extend DAI field for “multi-PDSCH DCI”? However, it is not clear to us why field extension of “multi-PDSCH DCI” and “single-PDSCH DCI” are separately considered? Does it mean separate DCI formats are used for single-PDSCH scheduling and multi-PDSCH scheduling respectively?  As discussed in Proposal #2, we prefer current DCI format for single PDSCH scheduling to be reused for as multi-PDSCH DCI format, i.e. same DCI format for both single PDSCH scheduling and multi-PDSCH scheduling For a same DCI format, it seems not reasonable that the field is extended when multiple PDSCHs are scheduled case and not extended for single PDSCH case. |
| Fujitsu | Firstly, the overhead for DAI should be considered carefully. It depends on the maximum number of PDSCHs scheduled by a multi-PDSCH DCI. A larger number will require a larger DAI size. Secondly, the DAI counting mechanism is totally different from the legacy one where DAI is counted per DCI. Therefore, the standard impact should be considered. |
| ZTE, Sanechips | We think single codebook is enough, there is no need to introduce 2 sub-codebooks for Alt2. |
| Spreadtrum | We also have a concern on why two sub-codebooks are needed. |
| Futurewei | Recommend to clarify the motivation of using two codebooks. |
| Nokia/NSB | Generally OK, but we have the same question on two sub-codebooks. |
| Ericsson | Generally okay with the observation  Clearly the bitwidth of the DAI fields will increase with Alt2. In the current spec a DAI is 2-bits, which implies that the HARQ codebook can still be constructed correctly even with up to 3 consecutive DCI mis-detections (unless the last DCI before PUCCH is lost). If the same robustness is to be maintained with DAI counted per PDSCH (Alt-2), the DAI needs to be extended by bits, assuming the maximum number of PDSCHs scheduled by a single DCI is . So, this would be an extra 3 bits if it is agreed to support scheduling of up to 8 PDSCHs.  A key aspect that is missing is that DAI counting per PDSCH is a deviation from current specifications. DAI counting per PDCCH is assumed in current specs, and this approach was also used in LTE. A large spec impact is envisioned if such a fundamental change is made. |
| Apple | Need to understand the motivation for 2 codebooks as well. |
| CATT | Single codebook should be the baseline. FFS for two sub-codebook. |
| Sony | We don’t see the motivation to have sub-codebook for Alt 2 |
| Samsung | We don’t see the motivation to have sub-codebook for Alt 2 |

### Summary on comments for Observation #2-2:

The main argument point is the benefit of two sub-codebooks, compared to Alt 2 with single codebook.

* The main difference between them is whether C-DAI/T-DAI in DL DCI needs to be increased for single-PDCH DCI, e.g., DCI format 1\_0.
  + For Alt 2 with single codebook, C-DAI/T-DAI in DL DCI needs to be increased both for multi-PDSCH DCI and for single-PDSCH DCI
  + For Alt 2 with two sub-codebooks, C-DAI/T-DAI in DL DCI needs to be increased only for multi-PDSCH DCI and not for single-PDSCH DCI

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

* For Alt 2b (C-DAI/T-DAI is counted per PDSCH with two sub-codebooks) of generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs,
  + 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
  + C-DAI/T-DAI in DL DCI (only for multi-PDSCH DCI) and T-DAI in UL DCI need to be extended by log2(N\_max) bits for each field where N\_max equals to the maximum configured number of PDSCHs for multi-PDSCH scheduling DCI across serving cells belonging to the same PUCCH cell group
  + 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
    - The number of HARQ-ACK bits depends on the number of actually transmitted PDSCHs but DAI is counted per PDSCH.

Companies are encouraged to provide views on Observation #2-2a.

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| Company | Views |
| Samsung | We can understand the motivation explained by FL. But we don't see the necessity to support such complicated mechanism, i.e. new DAI definition + increased DAI overhead + two sub-codebook.  Therefore, we suggest to remove this Alternative. |
| Huawei, HiSilicon | We see limited benefits to define Alt2 with 2 sub-codebooks including one sub-codebook for DCI format 1\_0 since most scheduling occasions would likely use multi-slot scheduling with multiple PDSCHs, so the overall savings in HARQ codebook overhead would be limited even with the introduction of 2 sub-codebooks. |
| Xiaomi | We think there is no need of two sub-codebooks |
| DOCOMO | We can understand FL’s intention for this observation is to discuss whether field extension also for DCI 1\_0 which doesn’t support multi-PDSCH scheduling. And we generally agree with the observation.  But the current description looks a little confusing. We suggest to modify the “multi-PDSCH DCI” and “single-PDSCH DCI” into “DCI format supporting multi-PDSCH scheduling” and “DCI format supporting only single-PDSCH scheduling”. Since in our understanding, multi-PDSCH DCI can also scheduled single PDSCH. |
| Intel | The size of DAI field in a DCI depends on which sub-codebook is used to carry HARQ-ACK bits.   * C-DAI/T-DAI in a DL DCI that associates with the first sub-codebook is still 2 bits. * C-DAI/T-DAI in a DL DCI that associates with the second sub-codebook is increased, i.e. 2+log2(N\_max) bits. * Each T-DAI in UL DCI is 2 or ‘2+log2(N\_max)’ bits for the first sub-codebook or the second sub-codebook   We prefer to clarify that the division of the two sub-codebooks   * Option 1: for the case that one PDSCH is scheduled by a DCI for multi-PDSCH scheduling, the HARQ-ACK bit(s) are included in the first sub-codebook * Option 2: for the case that one or two PDSCHs are scheduled by a DCI for multi-PDSCH scheduling, the HARQ-ACK bit(s) are included in the first sub-codebook   Option 3: irrespective of the number of PDSCHs that is scheduled by a DCI for multi-PDSCH scheduling, the HARQ-ACK bit(s) are included in the second sub-codebook |
| Qualcomm | The two sub-codebooks design has a potential to enhance   * Alt 1 if more than one feedback bit is defined per DCI, to reduce the overall codebook size of single PDSCH grant. * Alt 2 if the DAI filed size is increased only for multi-PDSCH grant, to avoid increasing DAI filed for single-PDSCH DCI   However, both Alt 1 (counting DAI per DCI) and Alt 2 (counting DAI per PDSCH) can work with single codebook. Therefore, the two sub-codebook design should be decoupled from both Alt 1 and Alt 2 and has its own discussion. |
| Futurewei | We do not see benefits, and therefore the necessity to support the two-codebook design yet. Recommend to remove this alternative. |
| ZTE, Sanechips | We think single codebook is enough, two sub-codebooks design can be an enhancement. |
| Spreadtrum | Due to the limitation use case of single DCI scheduling single PDSCH, the benefits of Alt 2b is limited. |
| Apple | We understand the FL’s motivation for the single/multi-codebook split based on the explanation. We suggest the 2 codebook concept be discussed separately. |
| Lenovo, Motorola Mobility | We still don’t agree with the need for two sub-codebooks |
| WILUS | We don’t see benefits to use two sub-codebooks.  Consider the case where a gNB schedule two DCI formats; the first DCI format is associated to the first sub-codebook and the second DCI format is associated to the second DCI format. If a UE misses one of two DCI formats, then the UE does not know how many bits are needed for the sub-codebook (associated to the missing DCI format). Therefore, in terms of codebook size ambiguity, the single codebook design(Alt 2a) is preferred. |
| Moderator | Clear majority companies expressed concerns when two sub-codebooks are applied to Alt 2. So, Alt 2b can be deprioritized. |

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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| Company | Views |
| Qualcomm | We agree that Alt 3 is a superset of Alt 1 and Alt 2 (without the two sub-codebooks case). Therefore, we can discuss it if we agreed on supporting both Alt 1 and Alt 2. |
| Huawei, HiSilicon | Similar to Alt1, the main drawback of Alt3 is that if one DCI is missing, the UE cannot know how many PDSCHs scheduled by that DCI are missing when the number of scheduled PDSCHs by one DCI is smaller than M, and therefore the HARQ-ACK codebook size would be different from the one expected at the gNB. This drawback outweighs the DCI payload size increase of Alt2. |
| Intel | We are fine with the observations.  The size of a DAI is 3 or 4 bits if M equals to 4 or 2. Correspondingly, the DAI overhead can be up to 9 or 12 bits in DL assignment, 12 or 16 bits in UL grant. |
| Lenovo, Motorola Mobility | Error case happens when any one DCI is missed with Alt 3 because UE can’t know the number of scheduled PDSCHs by the missing DCI. In that sense, HARQ-ACK codebook ambiguity is caused. |
| WILUS | We are fine with the observations. Since the number of DAI bits increases also in Alt3, we further capture how many DAI bits are required to protect the same number of consecutive DTXs (e.g., 3 consecutive DTXs) according to the configured value M. |
| vivo | Agree to the observation for Alt 3. |
| DOCOMO | Agree with the observation and we think that Alt 3 is a trade-off between Alt 1 and Alt 2. |
| ZTE, Sanechips | We are generally fine with the observation and we also observe that:   * + - NACK bits may be padded if scheduled PDSCH number is not an integer of M in Alt2. |
| Spreadtrum | We agree with the observation. |
| Futurewei | Recommend to decide where to weigh the ambiguity issue with Alt-1 before the discussion of Alt-3, which inherits the issue. |
| Nokia, NSB | We would propose one clarification:   * For Alt 3 (C-DAI/T-DAI is counted per M scheduled PDSCH(s) that are scheduled by the same DCI and where M is configurable) of generating type-2 HARQ-ACK codebook corresponding to DCI that can schedule multiple PDSCHs,   Otherwise we are fine with formulation.  We think Alt 3 is a good compromise of Alt 1 and Alt 2. |
| Ericsson | Generally okay with the observation  Similar to Alt-2, the bitwidth of the DAI fields will increase with Alt3, but not by as much. In the current spec a DAI is 2-bits, which implies that the HARQ codebook can still be constructed correctly even with up to 3 consecutive DCI mis-detections (unless the last DCI before PUCCH is lost). If the same robustness is to be maintained with DAI counted per PDSCH (Alt-2), the DAI needs to be extended by bits, assuming the maximum number of PDSCHs scheduled by a single DCI is . So, if M = 2 and it is agreed to supported scheduling of up to 8 PDSCHs, then an extra 2 bits is needed.  Again, key aspect that is missing is that DAI counting per PDSCH is a deviation from current specifications. DAI counting per PDCCH is assumed in current specs, and this approach was also used in LTE. A large spec impact is envisioned if such a fundamental change is made. |
| Apple | Agree with observations. |
| CATT | Fine with the observation. |
| Sony | We are fine with the observation. |
| Samsung | We have different understanding for 1st sub-bullet.  If M equals to the number of maximum configured number of PDSCHs, Alt-3 leads to larger UCI payload than Alt-1, if we assume single HARQ-ACK codebook (I guess that is aligned with the understanding of proponents of Alt3), because UE has to report M bits also for a DCI scheduling single PDSCH, while UE only reports 1 bit by Alt-1. |

### Summary on comments for Observation #3:

Similar argument points with Observations #1/2-1/2-2 were discussed and similar updates are required for Observation #3.

### Observation #3a (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 maximum configured number of PDSCHs, Alt 3 is the same with Alt 1 if two sub-codebooks are generated.
  + Else if M equals to 1, Alt 3 is the same with Alt 2.
  + Otherwise (i.e., 1<M<the maximum configured number of PDSCHs), Alt 3 is similar to Alt 2, except that
    - The increment of DCI fields reduces as M increases. To be specific, C-DAI/T-DAI in DL DCI and T-DAI in UL DCI need to be extended by log2(N\_max/M) bits for each field where N\_max equals to the maximum configured number of PDSCHs for multi-PDSCH scheduling DCI across serving cells belonging to the same PUCCH cell group
    - The number of HARQ-ACK bits corresponding to each DAI increases by M times.
    - NACK bits may be padded if the number of scheduled PDSCHs is not an integer multiple of M.
  + In addition, new RRC parameter to configure M needs to be introduced.

Companies are encouraged to provide views on Observation #3a.

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| Company | Views |
| Samsung | We’re fine with observation #3.  We’d like emphasis that the number of DAI is still quite large, as calculated by Intel, “The size of a DAI is 3 or 4 bits if M equals to 4 or 2. Correspondingly, the DAI overhead can be up to 9 or 12 bits in DL assignment, 12 or 16 bits in UL grant”. Therefore, the impact of DL coverage wouild be still critical. |
| Huawei, HiSilicon | See our comments on Alt1, Alt2a and Alt2b. We think that Alt1 and Alt2a/b can be discussed first. |
| Xiaomi | We are fine with the Observation #3a. but we prefer Alt 1 and Alt 2 more than Alt 3. Alt 3 is just a tradeoff of alt 1 and alt 2. |
| DOCOMO | We’re fine with observation #3.  But we don’t prefer such a design which is not as straightforward as At 1 or Alt 2. |
| Intel | We support the observation in general. Just some elaborations  Better to clarify the second sub-bullet   * Else if M equals to 1, Alt 3 is the same with Alt 2 if two sub-codebooks are generated.   Better to clarify the size of C-DAI in DCI 1\_0 is 2 bits. |
| Qualcomm | We want to decouple the two codebooks from this discussion and similarly increasing the DAI field as they should be separately discussed. |
| Futurewei | Based on the previous comments, we prefer a simplified the discussion of observations by focusing on 2 of the 4 alternatives, Alt-2 and Alt-3. |
| ZTE, Sanechips | The following should be removed since it is not the condition.   * + if two sub-codebooks are generated. |
| Spreadtrum | We are fine with the observation#3a. |
| Apple | We are fine with the observations but would prefer to discussion the merits of the Alt 1 and Alt 2 first. |
| Nokia/NSB | @Samsung, E.g. with M = 4, DAI field increase is not much higher than Alt 2, and UL feedback size is lower.  Also, this is compromise of Alt 1 and Alt 2 for better network scheduling flexibility. In addition, according to the number of multi-PDSCH, either alt 1, alt 2 or something middle of alt 1 and alt 2 may be efficient.  Because multi-PDSCH/PUSCH may have options for more DCI overhead, lowering DCI overhead should be matter. However, in general, UE’s increase of UL feedback is important for coverage perspective. So, the balance between them is needed. |
| Lenovo, Motorola Mobility | We are fine with the observation |
| WILUS | In the observation, it seems that single codebook is applied for the case of 1<M<the maximum configured number of PDSCHs. If it is right understanding, we suggest to clarify the single codebook is used in the case that 1<M<the maximum configured number of PDSCHs. |
| Moderator | To Intel and ZTE: After further thought, we don’t need the condition on either single codebook or two sub-codebooks. Regardless of single or two, Alt 3 is the same with Alt 1 or Alt 2 depending on M.  To Intel: The size of C-DAI in DCI 1\_0 can be discussed for Alt 2.  To WILUS: We don’t need to restrict only single sub-codebook, but we can see how companies are thinking.  In general, majority companies expressed that Alt 3 can be deprioritized. However, considering strong proponent of Alt 3, we can continue discussing updated Proposal #3b. |

### Observation #3b (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 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 maximum configured number of PDSCHs), Alt 3 is similar to Alt 2, except that
    - The increment of DCI fields reduces as M increases. To be specific, C-DAI/T-DAI in DL DCI and T-DAI in UL DCI need to be increased to 2+log2(N\_max/M) bits for each field where N\_max equals to the maximum configured number of PDSCHs for multi-PDSCH scheduling DCI across serving cells belonging to the same PUCCH cell group
    - The number of HARQ-ACK bits corresponding to each DAI increases by M times.
    - NACK bits may be padded if the number of scheduled PDSCHs is not an integer multiple of M.
  + In addition, new RRC parameter to configure M needs to be introduced.

Companies are encouraged to provide views on Observation #3b and please provide views on clarification question (whether single codebook is applied for the case of 1<M<the maximum configured number of PDSCHs or not) from WILUS.

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| Company | Views |
| vivo | We support moderator’s proposal |
| DOCOMO | Maximum number of consecutively missed DCIs needs to be considered to determine necessary bit extension. We suggest to remove observation for the bullet of DAI field increment and further study this issue. |

## 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 |
| Huawei, HiSilicon | One possibility is that a first PUCCH carries the HARQ-ACK information for all the PDSCHs that meet the processing timeline for this first PUCCH, and a second PUCCH ensures that the remaining PDSCHs meet the processing timeline, according to the UE capability. |
| Lenovo, Motorola Mobility | Agree |
| OPPO | In case of multi-PDSCH scheduling, if all the PDSCHs are supposed to be transmitted in one PUCCH, the first scheduled PDSCH will suffer a much longer delay than the last scheduled PDSCH. Allowing earlier feedback for the earlier scheduled PDSCHs will help quick release HARQ processes, hence to improve the scheduling efficiency. Also, in unlicensed carrier, there may be the case that some of the scheduled PDSCHs are satisfied with the PDSCH processing time while others of the scheduled PDSCHs are not when the multi-PDSCH are scheduled at the end of a COT. In this case, it is more reasonable to report the HARQ-ACK for those PDSCHs which fulfill the processing time instead of not report HARQ-ACK at all. |
| vivo | Support the proposal. In our opinion, it is beneficial to allow HARQ-ACK feedback on multiple PUCCHs. |
| DOCOMO | We are fine with the proposal.  We think the key point on whether supporting transmitting HARQ-ACK in separate PUCCHs is HARQ-ACK feedback latency issue. If latency is an important issue for certain cases supported in NR 52.6-71GHz, separate PUCCH reporting may be necessary.  If supported, we think at least K1 and DAI indication can be further discussed. |
| NEC | We support the proposal |
| ZTE, Sanechips | We are fine with the proposal. In our opinion, transmitting HARQ-ACK in different PDCCHs would be benefitial from the perspective of latency. |
| Spreadtrum | We support the proposal. |
| Futurewei | Recommend multiple PUCCH, as also mentioned in one of our figure. Details of how HARQ-ACK information maps to each PUCCH needs to be further studied. If the number of HARQ-ACK bits on each PUCCH is larger than that associated with the single PDSCH, it might be needed to evaluate the detection performance. |
| Nokia, NSB | The proposal of further discussions is ok for us, as we support the splitting of HARQ-ACK information to different PUCCH only if the number of HARQ processes is not increased causing HARQ process starvation. |
| InterDigital | In our opinion, multiple PUCCHs each carrying HARQ-ACK information of a group of PDSCHs would be beneficial for reducing latency. The number of PUCCHs carrying HARQ-ACK information of the PDSCHs scheduled by the same DCI should be determined after agreeing on the maximum number of PDSCHs can be scheduled. |
| Ericsson | We have strong concerns on the proposal. The motivation is to reduce HARQ latency; however, it is not clear that latency can be improved very much. For example, if the agreed N1 in absolute time is the same as for 120 kHz, then this translates to 12 slots for the case of 960 kHz SCS. If the number of scheduled PDSCHs is, say 4, then the first 2 PDSCHs could be Ack'd as early as slot n+14 and the last 2 PDSCHs at slot n+16. If only a single PUCCH is used, then the earliest the 4 PDSCHs could be Ack'd is slot n+16. So there would be only a 2 slot reduction in latency for the first two PDSCHs which translates to roughly 30 us. We don't think the added complexity of supporting multiple PUCCHs is worth it. |
| Apple | Given that we are considering a maximum of 8 PDSCHs, this maps to e.g. 120 kHz duration with 960 kHz. This is already pretty short and for low latency transmissions, the # of PDSCHs scheduled can be reduced. |
| CATT | The necessity of multiple PUCCH will depend on the number of PDSCH scheduled. We are open for further study. |
| Sony | We are fine with the proposal. Multiple PUCCH would be beneficial to reduce HARQ feedback delay. |
| CEWiT | When a multi-PDSCH is scheduled to a UE, then the UE has to wait until the processing of the last PDSCH in order to send HARQ ACK information for first PDSCH. Because of this, the HARQ process corresponding to the first PDSCH will be blocked for a long period of time and also increases the HARQ latency. Therefore, to reduce HARQ latency we support the proposal of transmitting HARQ-ACK in different PDCCHs. |
| Samsung | We’re fine with proposal #7 to further discuss the necessity. |
| Xiaomi | Support the proposal #7 |
| Intel | We are fine with the proposal. |

## 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 |
| Qualcomm | 16 HARQ processes are still sufficient for 480kHz and 960kHz SCS operation. Increasing the number of HARQ processes to 32 should be a UE capability not mandatory by the specs. As this will have implications on the UE soft combining buffer size. |
| Huawei, HiSilicon | Is the assumption that increasing the number HARQ processes to 32 for 120 kHz SCS will be taken care of by the NTN WI? It is not clear whether the NTN agreement would apply to above 52.6 GHz, so we would suggest clarifying that increasing the number of HARQ processes to 32 applies to 120, 480 and 960 kHz SCS, if we assume consistency with the NTN agreement. It should also be clarified that 32 HARQ processes would be an optional UE capability. |
| Panasonic | We support the proposal. We don’t see the specific linkage to NTN WI as RTT and the bit rates are so different, although there is a relation between longer RTT and shorter slot length. |
| Lenovo, Motorola Mobility | Agree with Qualcomm’s views that this is part of UE capability. |
| OPPO | Although increase the maximum number of HARQ processes in NTN was agreed based on UE capability, how to indicate HARQ process number for more HARQ processes is still a pending issue. We don’t think this is an essential issue here and to avoid potential parallel discussion on HARQ process number indication, we prefer to deprioritize this discussion. |
| Vivo | The impacts on UE implementation and complexity should be discussed further when increasing the maximum number of HARQ processes. |
| DOCOMO | We agree with Huawei’s comments. |
| Spreadtrum | We share the same view with Qualcomm and Huawei. |
| Futurewei | It is an option to increase the number of HARQ process from 16 to 32 to avoid the HARQ starvation issue. While if multiple PUCCH is supported, the HARQ starvation issue can be addressed if properly mappings between PDSCHs and each PUCCH are established. Therefore, since we supported multi-PUCCH, we do not see need to increase the number of HARQ processes. |
| Nokia/NSB | Support Moderator’s proposal. |
| InterDigital | We agree with proposal. Increasing the number of HARQ process from 16 to 32 as agreed in Rel17 NTN WI will give more flexibility. |
| Ericsson | Support Moderator's proposal.  Furthermore, we see a large problem with companies that simultaneously propose to not improve N1 beyond the absolute time for 120 kHz and not increase the number of HARQ processes. This can seriously hamper usage of the wide available bandwidth in the 52.6 – 71 GHz band. |
| Apple | We agree there may be a need to increase the maximum # of HARQ processes, but this can be set as a UE capability. |
| CATT | We are open to discuss this as an optional UE capability |
| Sony | We support to increase the maximum number of DL and UL HARQ processes from 16 to 32 for 480 kHz and 960 kHz SCS as optional feature. |
| Samsung | We share same view with QC that 16 HARQ processes are still sufficient for 480kHz and 960kHz SCS operation. And We don’t see the specific linkage to NTN WI as RTT, because RTT is much longer in NTN and it is large even for single PDSCH case. |
| Xiaomi | We are open to discuss it. |
| Intel | We are open to discuss this as an optional UE capability |

## 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.