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

**e-Meeting, January 25th – February 5th, 2021**

**Agenda Item:** 8.2.5

**Source:** Moderator (LG Electronics)

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

**Document for:** Discussion and decision

# Introduction

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

# Multi-PDSCH/PUSCH scheduling

## General aspects

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| Company | Views |
| [1] FUTUREWEI | Proposal 9: Evaluate the multi-PDSCH/PUSCH scheduling in 60GHz shared spectrum band for:   * The impact of PDCCH failure on data transmission and HARQ feedback * The impact of beam failure on data transmission and HARQ feedback |
| [2] 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 a single DCI to schedule both PDSCH and PUSCH across multiple slots (TTIs). |
| [4] OPPO | Proposal 1: The multi-PUSCH scheduling mechanism in NR-U should be baseline to support the multi-PUSCH scheduling with different TBs with a single DCI for 480kHz and 960kHz SCSs in the new frequency range. |
| [5] Huawei | Proposal 5: Support multiple TBs with configurable number of TBs and configurable repetitions for multi-PDSCH scheduling with multiple consecutive slots to compromise between coverage and peak data rate flexibly. |
| [6] Nokia | Proposal 2: For PDSCH, enhance single TB repetition functionalities and define functionality for supporting multiple TBs scheduled over multiple slots.   * Maximize the commonality between multi-PUSCH and multi-PDSCH. |
| [7] CAICT | Proposal 3: When single DCI schedules multiple slots, multiple slots with one TB could be considered. |
| [16] Sony | Proposal 2: Multi-PDSCH/PUSCH scheduling by one DCI should be supported for NR above 52.6 GHz. |
| [18] NEC | Proposal 1: The multi-PDSCH scheduling scheme should be discussed and decided |
| [19] Xiaomi | Proposal 1: UE processing capability for PDSCH/PUSCH should be defined for SCS 480/960kHz to allow 1 TB of PDSCH/PUSCH per several slots. |
| [20] Samsung | Proposal 5: RAN1 shall clarify the working scope for multi-PDSCH/PUSCH scheduled by a single DCI in Rel-17:   * Support either multi-PDSCH or multi-PUSCH scheduled by a single DCI; * The multi-PDSCH or multi-PUSCH are associated with the same UE and same cell; * TBs in the multi-PDSCH or multi-PUSCH are different. |
| [21] Ericsson | Proposal 2: Support multi-PDSCH scheduling with a single DCI, where each PDSCH is confined within a slot.  Proposal 3: Do not support multi-slot PDSCH/PUSCH, i.e., single TB over multiple slots or “TTI bundling” for PDSCH/ PUSCH. |
| [25] Qualcomm | Observation 5: By allowing a single TB to span more than one slot, the throughput gains are evident from the reduction of the DMRS overhead, and the BLER performance is almost the same independent from the number of DMRS symbols with v=3Kmph, even for high MCS, such as 22 and 26 (64QAM).  Proposal 6: For larger SCSs, allow a single TB to span more than one slot.  Proposal 7: For a single TB that spans more than one slot, study increasing the TB size based on the total number of granted symbols. |
| [26] NTT DOCOMO | Proposal 4:   * Both multi-PUSCH scheduling and multi-PDSCH scheduling should be supported.   + Mechanism of multi-PUSCH scheduling in Rel-16 NR-U can be a starting point. |

### Summary #1 (on the scope of multi-PDSCH/PUSCH scheduling):

On the scope of multi-PDSCH/PUSCH scheduling, it seems that companies have different views at least on the following aspects:

* Whether scheduling both multiple PDSCHs and multiple PUSCHs by single DCI is supported or not
* Whether TB repetition can be enabled by DCI scheduling multiple PDSCHs and/or PUSCHs or not
* Whether scheduling a single TB over multiple slots is supported or not

On the 1st aspect, most companies consider single DL DCI to schedule multiple PDSCHs or single UL DCI to schedule multiple PUSCHs, while at least one company (Lenovo) considers single DCI to schedule both multiple PDSCHs and multiple PUSCHs.

On the 2nd aspect, several companies (Huawei, Nokia) consider single DCI to schedule multiple TBs where a TB can be repeated over multiple slots (or mini-slots).

On the 3rd aspect, several companies (CAICT, Qualcomm) consider DCI to schedule a TB over multiple slots, while at least one company (Ericsson) opposes to support scheduling a TB over multiple slots.

From the Moderator’s point of view, it would be important to have a clear and common understanding on the scope of multi-PDSCH/PUSCH scheduling for future discussion. Considering majority view on the 1st aspect and a note in WID (i.e., coverage enhancement for multi-PDSCH/PUSCH scheduling is not pursued) for the 2nd and 3rd aspects, the following proposal can be made.

### Proposal #1:

* 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 and each TB is confined with a slot.
* The followings will not be considered in this WI.
  + Single DCI to schedule both PDSCH(s) and PUSCH(s)
  + Single DCI to schedule a TB over multiple slots
  + Single DCI to schedule multiple TBs where a TB can be repeated over multiple slots (or mini-slots)

Companies are encouraged to provide views on Proposal #1.

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| Company | Views |
| Qualcomm | * We support the main proposal of scheduling multiple PDSCHs by single DL DCI and scheduling multiple PUSCHs by single UL DCI are supported. * Using single DCI to schedule both PDSCH(s) and PUSCH(s) will require large DCI size and/ or some parameters will be shared between the grants, e.g., MCS, which will limit the flexibility of such scheduling. Therefore, it should not be considered in this WI * Using single DCI to schedule a TB over multiple slots will help in reducing the HARQ process IDs and can help in achieving higher throughput by saving the DMRS overhead, so it should be considered within in this WI. This is being discussed in the coverage extension work item, therefore it is beneficial to be involved in this design as well so the overall design can help with potential problem of the new band and larger SCS. * Single DCI to schedule multiple TBs where a TB can be repeated over multiple slots should not be considered in this WI as the coverage enhancements is not in the focus of this WI. |
| Futurewei | Support moderator’s proposal. |
| DCM | Support the proposal. |
| Xiaomi | Our proposal is not correctly capture. In fact, we are talking about PDSCH/PUSCH processing capability by our listed proposal (“*Proposal 1: UE processing capability for PDSCH/PUSCH should be defined for SCS 480/960kHz to allow 1 TB of PDSCH/PUSCH per several slots.* ”) in the above summary table , that is the number of TBs that can be processed in a time unit, for example 2 TB per slot or 1TB per 4 slots. So we modify the above summary a little bit by revision marks.  For moderator’s Proposal 1, we suggest to delete the last bullet, since currently, we think it is a little early to exclude TB repetition case. Discussion on justification may be needed. Proposal #1:  * 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 and each TB is confined with a slot. * The followings will not be considered in this WI.   + Single DCI to schedule both PDSCH(s) and PUSCH(s)   + Single DCI to schedule a TB over multiple slots |
| ZTE, Sanechips | Support moderator’s proposal. |
| Nokia/NSB | Support the first bullet.  For the second bullet, one could clarify that it relates to SCS>120 kHz.  We think that solution where single DCI is used for TB repetition over multiple slots should be supported also for SCS>120 kHz. It’s natural since the functionality is already there.   * For PUSCH, NR Rel-16 solution can support single TB scheduled over multiple slots (Repetition type A, Repetition type B) * For PDSCH, NR Rel-16 can support single TB scheduled over multiple slots according to Repetition type A -framework. * We think that PDSCH repetition functionalities should be enhanced such that the DL functionality would be on par with UL, e.g. dynamic indication of the number of repetitions should be supported also for PDSCH. |
| Ericsson | Support moderator's proposal – it is very good to set the scope appropriately at the beginning.  We don't need to preclude existing Rel-15/16 functionality on PUSCH repetition and PDSCH slot aggregation, but our view is that we don't need to enhance it in this WI. |
| Huawei, HiSilicon | The case in the first bullet is acceptable, but we should clarify that this does not remove the functionality of TB repetition already specified for PDSCH and PUSCH since Rel-15, which is also scheduled with a single DCI (based on RRC configuration), because this is unclear considering the second sub-bullet of the second bullet.  We think that depending on the maximum number of multiple slots scheduled by a single DCI, allowing a TB to map to multiple slots can help reduce the DCI size. Even if full flexibility is not designed for, it may be beneficial to decide whether the maximum number of slots equals the maximum number of TBs. Scheduling many TBs with a single DCI also impacts the HARQ design. So we may need to discuss those maximum numbers first.  So we suggest revising as follows, and continue discussing whether to allow that one TB could be mapped to multiple slots:   * For a UE and for a serving cell in [52.6-71] GHz, support scheduling multiple PDSCHs over multiple slots by single DL DCI, and scheduling multiple PUSCHs over multiple slots by single UL DCI.   + Each PDSCH or PUSCH has individual/separate TB   + Each TB is confined within N consecutive slots     - Support at least N=1     - FFS: maximum value of N |
| Intel | We are fine with the proposal #1. |
| Apple | We think that a single DCI to schedule multiple TBs where a TB can be repeated over multiple slots (or mini-slots) can be easily incorporated into the design framework. Otherwise, we are fine with the proposal. |
| Samsung | We support proposal 1.  Regarding repetition, we share the similar view with E/// and HW that existing Rel-15/16 PUSCH/PDSCH repetition is not precluded, but no enhancement in this WI, i.e. no mix of repetition and multi-PxSCH scheduling. |
| Fujitsu | Support the proposal. |
| Sony | We support moderator’s proposal. |
| NEC | Support moderator's proposal. |
| Lenovo, Motorola Mobility | In our view, and as also mentioned in our contribution, scheduling multiple PDSCH and PUSCH using single DCI has two main benefits. One it helps with the cases where DL/UL traffic have similar pattern and huge gaps between DL and UL TBs are not possible. Second is that it further helps with PDCCH monitoring as UE is not required to monitor separate DCI formats for DL assignment and UL grant.  However, respecting the majority views, we are okay to not consider single DCI scheduling both PDSCH and PUSCH further  Regarding multiple or single TB transmission over multiple slots, we agree with the moderator’s proposal and also as indicated in WID, coverage enhancements are not within the scope of this WI. |
| InterDigital | We are fine with the proposal. |
| vivo | Support moderator’s proposal in principle. But for the final bullet on repetition, maybe it is too early to exclude this for multi-PUSCH/PDSCH scheduling. |

### Summary #1a (on the scope of multi-PDSCH/PUSCH scheduling):

For the first main bullet of Proposal #1,

* 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 and each TB is confined with a slot.

All companies seem to be OK but Nokia, Ericsson, Huawei, and Samsung request one clarification that this does not preclude slot aggregation and/or repetition for PDSCH and PUSCH by single DCI (which are already supported in Rel-15/16).

For the second main bullet of Proposal #1, most companies seem to be OK except the companies captured below:

* The followings will not be considered in this WI.
  + Single DCI to schedule both PDSCH(s) and PUSCH(s)
  + Single DCI to schedule a TB over multiple slots: Qualcomm propose to support it in this WI, but the work scope can be overlapped with other WI such as coverage enhancement.
  + Single DCI to schedule multiple TBs where a TB can be repeated over multiple slots (or mini-slots): Xiaomi, Huawei, Apple, vivo propose to support it in this WI. However, it seems to be out of WID scope according to the note “coverage enhancement for multi-PDSCH/PUSCH scheduling is not pursued”.

Furthermore, it should be clarified that a TB over multiple slots doesn’t mean that the TB which confines within a slot is repeated over multiple (mini-)slots, but mean that a single TB is mapped to multiple slots (similar to one considered for PUSCH in coverage enhancement WI).

Therefore, considering the above company views, the Proposal #1 can be updated as follows:

### Proposal #1a:

* For a UE and for a serving cell in 52.6-71 GHz, 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 and each PDSCH/PUSCH is confined with a slot.
* The followings will not be considered in this WI.
  + Single DCI to schedule both PDSCH(s) and PUSCH(s)
  + Single DCI to schedule a TB over multiple slots
  + Single DCI to schedule multiple TBs 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 in 52.6-71 GHz.

Companies are encouraged to provide views on Proposal #1a.

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| Company | Views |
| Charter Communications | Support the proposal. |
| Qualcomm | We think that supporting a single DCI to schedule a TB over multiple slots is worth considering in this work item. The overlap with coverage enhancement discussions motivates considering it for our WI to ensure that the overall design can help with potential issue of the new band, e.g., save HARQ processes. The design goals for coverage enhancements are different which may lead to have a small TB size to be sent over the span of multi-slot.  Additionally, consider that the # of HARQ process increase is still pending discussion, if we do not end up with substantially increase # of HARQ processes, restricting a TB in a slot will limit the duration a UE can be served continuous and force unnecessarily frequent DL/UL switching |
| Ericsson | We support the proposal.  However, we don't think it is desirable to add "52.6-71 GHz." It can be treated in UE capability discussions to what frequency bands this feature applies. |
| Spreadtrum | We support the proposal. |
| vivo | We support the proposal in general. Just one clarification on the last sub-bullet: multiple TBs mean more than one TB? If so, I suggest the following change to be more clear:   * + Single DCI to schedule ~~multiple~~ *N* TBs (*N*>1) where a TB can be repeated over multiple slots (or mini-slots) |
| Huawei | Dear Seonwook,  One question for clarification on your summary of the responses on proposal 1 and the updated proposal 1a.  In your summary you wrote: Furthermore, it should be clarified that a TB over multiple slots doesn’t mean that the TB which confines within a slot is repeated over multiple (mini-)slots, but mean that a single TB is mapped to multiple slots (similar to one considered for PUSCH in coverage enhancement WI)  So is the intent that proposal 1a doesn’t preclude the following?   * Single DCI to schedule multiple TBs where a TB can mapped over multiple slots, where mapping is not by repetition   While precluding:   * Single DCI to schedule both PDSCH(s) and PUSCH(s) * Single DCI to schedule a TB over multiple slots * Single DCI to schedule multiple TBs where a TB can be repeated over multiple slots (or mini-slots)   Regarding the second bullet, is this your intention?   * Single DCI to schedule only one TB over multiple slots   Best regards,  David (Huawei) |
| Moderator | To Qualcomm: Obviously, supporting a single DCI to schedule a TB over multiple slots is overlapped with other WI and this overlap should be avoided.  To Ericsson, vivo: Reflected  To Huawei: Based on email discussion, the second sub-bullet of the second main bullet is updated. |

### Proposal #1b:

* 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 and each PDSCH/PUSCH is confined with a slot.
* 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.

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

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| Company | Views |
| Fujitsu | Support the proposal. |
| DCM | Fine with the proposal. |
| NEC | Support the proposal. |
| OPPO | Support the first bullet of proposal #1b. And we are open to:   * + Single DCI to schedule one or multiple TBs where any single TB can be mapped over multiple slots, where mapping is not by repetition |
| Nokia/NSB | We think that PDSCH repetition functionalities should be enhanced compared to Rel-16. At least dynamic indication of the number of repetitions should be supported also for PDSCH. It’s is a low hanging fruit and can improve the scheduling flexibility quite much.  So, we are thinking that the first bullet in the proposal is enough. |

## Details on multi-PDSCH/PUSCH scheduling

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| Company | Views |
| [2] 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 beams (multiple TCI states with QCL type-D assumption) indication via single DCI and corresponding applicability/duration of each beam within the scheduled duration. |
| [3] ZTE | Proposal 3:   * The scheme used in Rel-16 NR-U for one UL grant scheduling multiple PUSCHs can be a starting point, further enhancement on DCI design (e.g., HARQ-ACK codebook construction, CBG transmission and beam indication) should be considered. |
| [4] OPPO | Proposal 1: The multi-PUSCH scheduling mechanism in NR-U should be baseline to support the multi-PUSCH scheduling with different TBs with a single DCI for 480kHz and 960kHz SCSs in the new frequency range. |
| [5] Huawei | Proposal 8: The multi-PUSCH scheduling defined in NR-U Rel-16 can be directly extended to 52.6 GHz to 71 GHz. K2 indicates the gap between the slot of the scheduling DCI and the first slot of the multi-slot scheduled PUSCH corresponding to the DCI; The unit of k2 should be defined as multiple slots for multi-PUSCH scheduling for 480 kHz and 960 kHz. |
| [6] Nokia | Proposal 3: 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.  Proposal 4: Multiple beam indication and association with multi-PDSCH/PUSCH scheduling is outside the scope of current WI. |
| [7] CAICT | Proposal 4: When single DCI schedules multiple PDSCH slots, the symbol distribution of each time slot could be different. |
| [8] CATT | Proposal 3: DCI design for multi-PDSCH/PUSCH transmission needs to have the flexibility of supporting multiple concurrent HARQ operation.  Proposal 4: for fall back DCI (e.g format 1\_0/0\_0) does not support multi-PDSCH/PUSH transmission |
| [9] vivo | Proposal 1：The number of PDSCHs/PUSCHs scheduled by one DCI should be adapted to the SCS of PDSCH/PUSCH.  Proposal 2: Indicate the number of slots in DCI, and each PDSCH/PUSCH occupies the same OFDM symbols (partial or whole) in a slot by default, except the first PDSCH/PUSCH. |
| [12] Intel | Proposal 2   * Multi-PUSCH scheduling as defined for NR-U can be considered as baseline for multi-PUSCH scheduling. * For multi-PDSCH scheduling,   + Supported both TB and CBG based scheduling.   + Maximum number of PDSCHs for TB based scheduling is 8   + Maximum number of PDSCHs for CBG based scheduling is 2.   Proposal 3   * For multi-PDSCH scheduling   + Separate SLIVs are configured for each PDSCH as part of TDRA configuration. Number of PDSCHs is determined based on the number of SLIVs.   + 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.   + HARQ process ID for the first PDSCH is based on the indicated HARQ process ID in the DCI and increased by 1 for subsequent PDSCHs.   + NDI and RV bitmap for each scheduled PDSCH is included in the DCI.   + A single PDSCH-to-HARQ\_feedback timing indicator is used to indicate the slot offset between the last scheduled PDSCH and PUCCH. |
| [13] Fujitsu | Proposal 1: To support multi-PUSCH scheduling for the new frequency range (52.6~71GHz), take the design of Rel-16 multi-PUSCH scheduling as the baseline.  Proposal 2: To support multi-PDSCH scheduling for the new frequency range (52.6~71GHz), reuse the framework of Rel-16 multi-PUSCH scheduling. A DCI with format 1\_1 can schedule 2~8 PDSCH in consecutive slots, each PDSCH with a TB.   * RRC signaling (i.e. *pdsch-TimeDomainAllocationList* in *pdsch-Config*) for configuring time domain allocation list for PDSCH can contain a row indicating resource allocation for 2~8 PDSCHs in 2~8 consecutive slots, each PDSCH having a separate SLIV and mapping type. The *K0* for the row indicates the slot where UE shall receive the first PDSCH of the multiple PDSCHs. * HARQ process ID signaled in the DCI applies to the first scheduled PDSCH. HARQ process ID is then incremented by 1 for subsequent PDSCHs in the scheduled order (with modulo operation as needed). * The bits of rv field and NDI field, respectively, in the DCI are one to one mapped to the scheduled PDSCHs with the corresponding transport block(s) in the scheduled order where the LSB bits of the rv field and NDI field, respectively, correspond to the last scheduled PDSCH. |
| [14] Spreadtrum | Proposal 2: The method of multi-slot PUSCH scheduling introduced in Rel-16 can be the starting point of the multi-slot PUSCH/PDSCH scheduling method. |
| [15] InterDigital | Proposal 3: It is preferred to support a semi-static configuration of scaling factor per SCS for multi-slot scheduling.  Proposal 4: The benefits from frequency domain resource allocation enhancements should be carefully evaluated. |
| [16] Sony | Proposal 3: Rel-15/16 RBG size should be reused for NR above 52.6 GHz.  Proposal 4: No new DCI format is needed for multi-PDSCH scheduling.  Observation 3: Rel-16 multi-PUSCH scheduling is a baseline.  Proposal 7: For indication of HARQ process ID, NDI and RV, the same mechanism as Rel-16 multi-PUSCH scheduling should be used for multi-PDSCH scheduling.  Proposal 8: No new DCI format is needed for multi-PUSCH scheduling. |
| [17] LG Electronics | Proposal #2: Consider Rel-16 multi-PUSCH scheduling DCI as starting point, with the following further discussion points.   * + Whether/how to provide more flexibility for time domain resource allocation, e.g., non-contiguous PUSCHs in time domain   + How to apply URLLC related fields such as priority indicator or open loop power control parameter set indication for multiple scheduled PUSCHs   + Whether/how to indicate different transmission beams for multiple scheduled PUSCHs   Proposal #3: Do not introduce new DCI format and use DCI format 1\_1 to schedule multiple PDSCHs with a single DCI.  Proposal #4: For multi-PDSCH scheduling with a single DCI,   * + Time domain resource assignment (TDRA): TDRA table is extended such that each row indicates up to 8 multiple PDSCHs. Each PDSCH has a separate SLIV and mapping type. The number of scheduled PDSCHs is signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.     - FFS on whether/how to provide more flexibility for time domain resource allocation, e.g., non-contiguous PDSCHs in time domain   + 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     - TCI     - CBGFI     - Priority indicator |
| [19] Xiaomi | Observation 1: The current DCI 0-2/1-2 can be reused to allow frequency domain resource by multi-PRB granularity.  Proposal 6: Support dynamic indication by DCI to determine the number of scheduled TTIs.  Proposal 7: Support to study intra-TTI frequency hopping and its enabling mechanism for multi-TTI scheduling. |
| [20] Samsung | Proposal 6: Rel-16 NR-U multi-PUSCH scheduling DCI can be reused for multi-PUSCH in 52.6~71GHz except the following bit field:   * PUSCH TDRA: non-continuous PUSCH transmissions can be considered * DMRS determination: DMRS indication to support DMRS time domain density lower than one DMRS per PUSCH and DMRS bundling can be considered * QCL: multi-beam indication for multiple PUSCHs can be consider * A-CSI feedback: A-CSI in first PUSCH that satisfies the multiplexing timeline for licensed band * UL frequency hopping: UL frequency hopping can be supported, e.g. inter-PUSCH/intra-PUSCH hopping.   Proposal 7: For multi-PDSCH scheduling, the bit field common for DL and UL grant can use the same design as discussed above for multi-PUSCH scheduling, and the DL-specific bit field should be enhanced.  Proposal 8: A single DCI for single or multi-PDSCH/PUSCH scheduling as Rel-16 NR-U.  Proposal 9: Further investigate whether CBG or TB-based HARQ-ACK feedback should be supported for multi-PDSCH scheduling with the consideration of HARQ-ACK feedback efficiency and potential standard complexity. |
| [21] Ericsson | Proposal 4: Support multi-PDSCH/PUSCH scheduling with non-contiguous allocations in the time domain.  Proposal 5: Introduce new RBG configuration for PDSCH/PUSCH frequency resource allocation Type 0 to reduce FDRA granularity and DCI size.  Proposal 6: Extend the Resource Allocation Granularity *P* value for PDSCH/PUSCH frequency resource allocation Type 1 to reduce FDRA granularity and DCI size.  Proposal 12: Do not support CBG based HARQ feedback for multi-PDSCH/PUSCH scheduling |
| [24] Apple | Proposal 7: multi-PDSCH/PUSCH transmission with a single DCI should support single or multiple non-continuous PDSCHs/PUSCHs in multiple scheduled slots/mini-slots.  Proposal 10: The FDRA size should be optimized to reduce the FDRA overhead by   * Increasing the RBG sizes or modifying the RIV calculation. * Enabling signaling of the FDRA to be disabled to support TDMA transmission   Proposal 8: For the single scheduling DCI, study the DCI fields that should be separate and combined to maximize parameter independence while reducing overhead.   * For PUSCH transmission, the following DCI fields should be discussed: FDRA, TDRA, MCS, NDI, RV, HARQ process number, DAI, priority, and CBGTI. * For PDSCH transmission, the following DCI fields should be discussed: FDRA, TDRA, MCS1/2, NDI 1/2, RV 1/2, HARQ process number, DAI, PRI, K1, priority, CBGTI, and CBGFI. |
| [25] Qualcomm | Proposal 8: For multi-PDSCH grant, reuse the multi-PUSCH design on HARQ process ID, NDI, RVID, TDRA, CBG based retransmission  Proposal 9: Support multi-PDSCH/PUSCH scheduling with single grant while allow TDRA configuration with discontinuous SLIV fields |
| [26] NTT DOCOMO | Proposal 4:   * Both multi-PUSCH scheduling and multi-PDSCH scheduling should be supported.   + Mechanism of multi-PUSCH scheduling in Rel-16 NR-U can be a starting point.   Proposal 5: In addition to multi-PUSCH scheduling framework in Rel-16 NR-U, the following aspects can also be considered   * HARQ-ACK feedback related aspects for multi-PDSCH scheduling   + HARQ-ACK feedback for multiple PDSCHs scheduled by one DCI can be reported in one PUCCH.   + HARQ-ACK codebook generation impact * Scheduling flexibility for both multi-PUSCH/PDSCH scheduling   + Consecutive scheduling, and potentially non-consecutive scheduling |

### Summary #2 (on the details of multi-PUSCH scheduling by a UL grant):

Most companies agree to use Rel-16 NR-U design as the baseline of multi-PUSCH scheduling by a UL grant. However, at the same time, several companies suggest to enhance/modify part of DCI fields compared to NR-U design, as follows:

* TDRA
  + In NR-U, TDRA table is extended such that each row indicates up to 8 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.
  + LG Electronics, Samsung, Ericsson, Apple, Qualcomm, NTT DOCOMO propose to consider non-continuous allocations in time domain.
  + vivo proposes that the number of PUSCHs scheduled by one DCI should be adapted to the SCS of PUSCH and each PUSCH occupies the same OFDM symbols (partial or whole) in a slot by default, except the first PUSCH.
* FDRA
  + Ericsson, Apple propose to enhance FDRA to reduce DCI overhead while Sony opposes to enhancement of FDRA.
* Beam indication
  + Lenovo, Samsung consider to indicate multiple beams for scheduled multiple PUSCHs while Nokia considers multiple beam indication and association with multi-PDSCH/PUSCH scheduling is outside the scope of current WI.
* Frequency hopping
  + Xiaomi, Samsung propose to support frequency hopping for scheduled multiple PUSCHs, e.g., inter-PUSCH/intra-PUSCH hopping.
* CSI request
  + In NR-U, when a DCI schedules M PUSCHs, the PUSCH that carries the AP-CSI feedback is M-th scheduled PUSCH for M <= 2, or (M-1)-th scheduled PUSCH for M > 2.
  + Samsung proposes to carry AP-CSI feedback on the first PUSCH that satisfies the multiplexing timeline for licensed band.
* Antenna ports
  + Samsung proposes to support DMRS time domain density lower than one DMRS per PUSCH and consider DMRS bundling
* URLLC related fields such as priority indicator and open-loop power control parameter set indication
  + LG Electronics addresses the issue on how to apply URLLC related fields for scheduled multiple PUSCHs

### Proposals #2:

* The multi-PUSCH scheduling defined in NR-U Rel-16 can be extended to multi-PUSCH scheduling for NR from 52.6 GHz up to 71 GHz except for the following DCI fields:
  + TDRA: FFS to down-select among
    - Alt 1: Same as NR-U, i.e., TDRA table is extended such that each row indicates up to [8] 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 [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 signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.
    - Alt 3: Each PUSCH occupies the same OFDM symbols (partial or whole) in a slot by default, except the first PUSCH.
  + FDRA: FFS whether/how to reduce bit-width e.g., by increasing RBG size or changing allocation granularity
  + Beam related fields (e.g., SRI): FFS whether/how to indicate multiple beams for scheduled PUSCHs
  + Frequency hopping: FFS whether/how to support frequency hopping for scheduled PUSCHs, e.g., inter-PUSCH/intra-PUSCH hopping
  + CSI request: Same as NR-U at least for unlicensed band, i.e., when a DCI schedules M PUSCHs, the PUSCH that carries the AP-CSI feedback is M-th scheduled PUSCH for M <= 2, or (M-1)-th scheduled PUSCH for M > 2.
    - FFS whether to apply same or different rule (e.g., the PUSCH that carries the AP-CSI feedback is the first PUSCH that satisfies the multiplexing timeline) for licensed band.
  + Antenna ports: FFS whether/how to support DMRS time domain density lower than one DMRS per PUSCH and support DMRS bundling
  + URLLC related fields such as priority indicator and open-loop power control parameter set indication: FFS how to apply URLLC related fields for scheduled PUSCHs
* FFS on the applicability of above DCI fields to multi-PDSCH scheduling

Companies are encouraged to provide views on Proposal #2.

|  |  |
| --- | --- |
| Company | Views |
| Qualcomm | -TDRA: we support Alt 2 as it will provide more flexibility and the gaps with the multi-PUSCH/PDSCH grants can be used for several purposes, e.g., feedback transmission, PDCCH monitoring, etc.  -FDRA: we agree on studying the needed enhancements for FDRA field  - Beam related fields (e.g., SRI): The beam management related aspects are discussed in 8.2.4 if the multiple beams are supported for the scheduled PUSCHs, then we can discuss the DCI design. Therefore, there is no need to prioritize this item.  - Frequency hopping: we agree on studying the impacts of frequency hopping for multi-PUSCHs  -CSI request: We support following NR-U approach. We think that a unified design for both licensed and unlicensed operation is preferred for simplicity.  - Antenna ports:  DMRS bundling and overhead reduction should be studied in the light of the phase continuity capability  -URLLC related fields: we agree on the need of studying how to apply them for multi-PUSCH grants,  We support increasing the commonalities between multi-PDSCH and multi-PUSCH as much as possible. |
| Futurewei | We prefer Alt 2 of non-continuous in time domain. We are OK that the other items to be FFS. |
| DCM | Support the proposal in principle.   * For TDRA, we prefer Alt 2 with supporting non-contiguous scheduling. * For FDRA, we think FDRA field length reduction can be studied. * For multiple beams for multiple PUSCHs, we think the potential use case should be clarified first. Considering different TBs for different PUSCHs, it seems not to aim at diversity gain. If the motivation is beam change due to mobility, we need to clarify whether multi-PUSCH scheduling is proper for high mobility case with fast channel changes. * For frequency hopping, we didn’t see the motivation to have different frequency hopping schemes from that of lower frequency system. * For CSI request, we didn’t see the motivation to enhance current NR-U multi-PUSCH scheme. * For URLLC related fields, we agree they need to be considered since NR-U multi-PUSCH was designed without considering such fields due to the two simultaneously ongoing Wis. * For multi-PDSCH scheduling, we think some PDSCH specific fields are related with HARQ-ACK feedback scheme, e.g. K1/PRI/TPC for PUCCH/PDSCH group index, etc. Another difference between PDSCH and PUSCH scheduling is the possible maximum CW number. For PDSCH scheduling, maximum 2 CWs scheduled for one PDSCH is possible in Rel-16. If maximum 2 CWs is also supported for multi-PDSCH scheduling, TB specific fields (e.g. MCS/NDI/RV) need to be reserved for TB1 and TB2 for maximum number of scheduled PDSCHs. It may require to introduce too much DCI payload. Therefore, we think it can be discussed whether to limit maximum number of CWs for multi-PDSCH scheduling. |
| Xiaomi | For Proposal #2, except TDRA/ CSI-request, the others are all FFS and we are open to discuss.  For TDRA,  Comparing to the three Alts, Alt 2 is most flexible. But what benefit the flexibility will bring? We tend to support further discuss Alt 1 and Alt 3, and exclude Alt2.  For Alt1, it can enable same design on both licensed and unlicensed band. For Alt 3, it is more suitable for licensed band, and can also easily applied in case of TB repetition over multiple slots.  However, for Alt 3, we still have a question, why the first PUSCH TDRA can be different from others?  For CSI request  More inclined to support existing NR-U design, since the latency requirement for A-CSI is not that stringent thus no need to transmit A-CSI on the first PUSCH that satisfies the multiplexing timeline. |
| ZTE, Sanechips | For TDRA we prefer alt1 since LBT may be needed, then non-continuous TDRA may cause unnecessary LBT impact. Besides it can be added that “the single k0 is applied to the first scheduled PDSCH” as in NRU “the single k2 is applied to the first scheduled PUSCH”.  For FDRA, increasing RBG size is not needed as the RB number is not changed, the allocation granularity can still be RB or RBG, the scheme in DCI 1\_2 FDRA type1 for URLLC can be reused, new allocation unit does not need to be introduced.  Multiple beams for scheduled PUSCHs can be considered for UE mobility and directional LBT.  Besides, we propose to add the following FFS bullet:   * CBG based scheduling: FFS whether/how to support CBG based scheduling. |
| Nokia/NSB | Support in principle. But, for better progress, we are proposing to have two separate proposals.  We can first agree on the baseline, and we can discuss first on resource allocation aspect. Other issues are depend on the other Ais.  Also, we have following view on each item.   * TDRA: Support either Alt 1 or Alt 2 * FDRA: we think that this is a secondary priority topic (optimization) * Multi-beam: to be discussed in 8.2.4 BM AI. * CSI request: This can be decided at a later phase of WI. * Antenna Ports: consider after DMRS enhancement in the other e-mail thread. * URLLC related fields: We think that this is not the most urgent issue to discuss, keeping in mind that multi-PUSCH/PDSCH relate mainly to scenarios with SCS>120 kHz and a very short slot duration.  Proposals #2:  * The multi-PUSCH scheduling defined in NR-U Rel-16 is the baseline for multi-PUSCH scheduling for NR from 52.6 GHz up to 71 GHz   + FFS: further enhancement.   + FFS: applicability to multi-PDSCH scheduling.  Proposals #2-1:  * For the multi-PUSCH scheduling for NR from 52.6 GHz up to 71 GHz, study the enhancement of following in addition to Rel-16 NR-U multi-PUSCH scheduling   + TDRA: FFS to down-select among     - Alt 1: Same as NR-U, i.e., TDRA table is extended such that each row indicates up to [8] 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 [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 signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.     - Alt 3: Each PUSCH occupies the same OFDM symbols (partial or whole) in a slot by default, except the first PUSCH.   + FDRA: FFS whether/how to reduce bit-width e.g., by increasing RBG size or changing allocation granularity   + Frequency hopping: FFS whether/how to support frequency hopping for scheduled PUSCHs, e.g., inter-PUSCH/intra-PUSCH hopping |
| Ericsson | For TDRA: We support Alt-2 for more flexibility to adapt to TDD patterns and avoid periodic UL signals and RACH occasions.  Beam related fields: we don’t see the benefit of supporting separate SRS resource indication (SRI) for different PUSCHs. Due to the short slot duration, we don’t see a need for beam changes in multiple slots. Furthermore, there is a significant overhead impact.  DMRS ports: we think that for simplicity this should be left as it is in Rel-16. We don’t see significant gains from bundling to make it worth it.  For URLLC fields (last sub-bullet). It would be better to leave that a bit more open for now. Change “how” to “whether/how”.  Contrary to ZTE’s comment, we don’t see a benefit of CBG based transmission/re-transmission for larger subcarrier spacings due to very short slot duration. This feature exists primarily for lower SCSs (15/30 kHz) where the slots are significantly longer and there is more of a chance for time selective fading, so there could be a benefit from selectively retransmitting CBGs. However for large subcarrier spacings, it is more likely that all CBGs pass or all fail, which is equivalent to TB based transmission/re-transmission. We don’t think multi-PUSCH should be enhanced to include CBG based scheduling. |
| Huawei, HiSilicon | TDRA: Alt1 as baseline, i.e. same as NR-U, with some adaptation to the definition of SLIV if we allow mapping one PDSCH/TB to more than one slot.  FDRA: it is unclear whether there is really an overhead issue due to the FDRA field. But increasing the RBG size means losing frequency-selective precoding gain. Our understanding is that the question applies not only to multi-slot PUSCH scheduling but for all DL and UL cases.  Beam related fields: it is unclear how likely a UE would be able to have multiple good beam-pairs with the gNB (given the high penetration loss above 52.6 GHz), and even if the UE had multiple good beam-pairs it is unclear why the UE wouldn’t just use its best beam in all the consecutively scheduled slots.  Frequency hopping: more discussion is needed  CSI request: agree with the proposal for unlicensed operation, and for licensed operation the starting point could be the same as for unlicensed operation.  DMRS: we support changes to the DMRS to ensure that 1) DMRS don’t occur in all slots otherwise it won’t leave enough time for PDSCH decoding, 2) that there is a sufficient number of DMRS symbols (e.g. by DMRS bundling) to compensate for not having DMRS in all the slots of the multi-slot allocation, and 3) that the gNB can assume it can perform joint channel estimation across all the DMRS in the multi-slot PUSCH allocation. Note that this last part is also discussed in the WI on coverage enhancements, so we can just inherit the design from coverage enhancements and adapt it account for which slots have DMRS and which slots don’t have DMRS. |
| Intel | We are generally fine with the proposal, but we would like to also understand the discussion for other fields, e.g., CIF, BWP Index, etc. |
| Apple | In general we are fine with the proposal.  TDRA: we support Alt-2. This may be used to enable multiple UEs with various timing requirements to be scheduled as it allows interspaced scheduling of the UEs to satisfy the timing requirements in either downlink or uplink transmission. As an example, traffic from UE1 can be interspaced with traffic from UE2 in case both UEs have both high priority and low priority information to be scheduled.  FDRA: As there may be a limited number of UEs per beam due to the narrow beams in this frequency band, there may be a need to increase the FDRA granularity to allow larger frequency allocations to each UE. For DL/UL Resource Allocation Type 0, this can be done by increasing the RBG sizes above the current limit of 16. For Resource Allocation Type 1, this can be done by modifying the Resource Indicator Value to use a minimum number of allocated RBs and conceptually change the resolution. In addition, the FDRA bit may be disabled to allow allocation to a single UE especially in the downlink.  Beam Related Fields: should be discussed in 8.2.4  Frequency hopping : Should be supported. Details are FFS  Also need to discuss the HARQ related fields i.e. NDI 1/2, RV 1/2, HARQ process number, DAI, PRI, K1, priority, CBGTI, and CBGFI. |
| Samsung | We generally support proposal#2, except TDRA Alt 3.  TDRA: We understand the benefit of Alt 1 (same as NR-U, good for LBT case) and Alt 2 (can avoid a UE occupies the channel for a long time), but we fail to see the benefit of Alt 3 and it requires more standard effort. So, we suggest remove Alt 3.  Beam related fields: can be discussed in 8.2.4 BM AI.  CSI request: in Rel-15, in case of PUSCH repetition, A-CSI is multiplexed in 1st PUSCH (conclusion in RAN1 101e), and in Rel-16 URLLC, A-CSI is multiplexed in 1st nominal repetition of PUSCH (agreed in RAN1 101e).In NR-U, A-CSI multiplexed in M-th or (M-1) th PUSCH is supported. So, there’re already two different handling for licensed and unlicensed band. We think it is simple and reasonable to follow the same logic for 52.6GHz.  Antenna Ports: consider after DMRS enhancement in the other e-mail thread.  multi-PDSCH scheduling: for DL/UL common bit field, unified design for multi-PDSCH and PUSCH is desirable. For DL-specific bit field, especially HARQ relevant bit field and 2-CW cases, need some discussion. |
| Fujitsu | Support the proposal. For TDRA, we prefer Alt 2. |
| Sony | We are fine with Proposal#2.  For TDRA, we support alt 2 since it will bring more flexible.  For URLLC related field, we agree to discuss it. |
| Lenovo, Motorola Mobility | We support Alt2 for TDRA. For FDRA, we are open to further discussion on potential enhancements, if needed. For beam related fields, we support to indicate multiple beams for both multiple PUSCHs as well as multiple PDSCHs. In the current MIMO WI, TCI framework is being specified for UL beam indication also. Therefore, we can expect to apply those enhancements here as well. However, the number of TCI states (beams) that can be indicated for multiple PDSCH and multiple PUSCH should be specified here specific to 480kHz SCS and 960kHz. Also the duration for which each beam is applied. |
| InterDigital | TDRA: We support Alt 1.  For FDRA, we don’t see clear motivation as maximum number of PRBs is not changed. We also don’t see the need for frequency hopping as we think that this is out of scope based on the following work scope.   * + Support enhancements for multi-PDSCH/PUSCH scheduling and HARQ support with a single DCI   Note: coverage enhancement for multi-PDSCH/PUSCH scheduling is not pursued  Beam related fields (e.g., SRI): to be discussed in 8.2.4  CSI request: we agree that this can be discussed in later phase  Antenna ports: to be discussed in [104-e-NR-52-71GHz-05]  URLLC related fields: we also think that his is out of scope.  Based on our view, we suggest following update:   * + TDRA: FFS to down-select among     - Alt 1: Same as NR-U, i.e., TDRA table is extended such that each row indicates up to [8] 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 [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 signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.     - Alt 3: Each PUSCH occupies the same OFDM symbols (partial or whole) in a slot by default, except the first PUSCH.   + FDRA: FFS whether reducing bit-width is needed or not   FFS on the applicability of above DCI fields to multi-PDSCH scheduling |
| vivo | For TDRA, the key idea of Alt. 3 is to indicate SLIV and number of slots for a PUSCH group where the first PUSCH follows indicated TDRA and subsequent PUSCHs occupy the same OFDM symbols or the whole slots (corresponding to Xiaomi’s question, for the latter case, the first PUSCH is different with others). I agree that reusing NRU design could minimize the spec impact. However, NRU TDRA list can only support up to 8 PUSCHs. Here in NR operation from 52.6-71GHz, 8 is not enough especially for FR1 CA case (e.g. 30KHz in 5GHz cross carrier scheduling 480/960KHz in 60GHz). So, the maximum number of scheduled PDSCHs need to be increased (e.g. 32). In this case, 32 SLIVs and mapping type need to be configured for one entry. Alt. 3 could result in lower configuration overhead in this case. Besides, this could also be incorporated into NRU baseline design, i.e. PUSCH group list is configured and each PUSCH group is indicated by TDRA and number of slots. So, the following is proposed:   * + TDRA: FFS to down-select among     - Alt 1: Same as NR-U, i.e., TDRA table is extended such that each row indicates up to [8] 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 [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 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. |

### Summary #2a (on the scope of multi-PDSCH/PUSCH scheduling):

All companies seem to be OK in principle having NR-U multi-PUSCH design as the starting point and company views for each DCI field are as follows:

* + TDRA: FFS to down-select among
    - Alt 1: Same as NR-U, i.e., TDRA table is extended such that each row indicates up to [8] 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.
      * Supported by Xiaomi, ZTE, Nokia, Huawei, InterDigital
    - 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 signalled by the number of indicated valid SLIVs in the row of the TDRA table signalled in DCI.
      * Supported by Qualcomm, Futurewei, NTT DOCOMO, Nokia, Ericsson, Apple, Fujitsu, Sony, Lenovo
      * Objected by Xiaomi
    - 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.
      * Supported by Xiaomi, vivo
      * Objected by Samsung
  + FDRA: FFS whether/how to reduce bit-width e.g., by increasing RBG size or changing allocation granularity
    - Supported by Qualcomm, NTT DOCOMO, Apple
    - Low priority: Nokia
    - Objected by ZTE, Huawei, InterDigital
  + Beam related fields (e.g., SRI): FFS whether/how to indicate multiple beams for scheduled PUSCHs
    - Supported by ZTE, Lenovo
    - Low priority or to be handled in AI 8.2.4: Qualcomm, Nokia, Apple, Samsung, InterDigital
    - Objected by NTT DOCOMO, Ericsson, Huawei
  + Frequency hopping: FFS whether/how to support frequency hopping for scheduled PUSCHs, e.g., inter-PUSCH/intra-PUSCH hopping
    - Supported by Qualcomm, Apple
    - Objected by NTT DOCOMO, InterDigital
  + CSI request: Same as NR-U at least for unlicensed band, i.e., when a DCI schedules M PUSCHs, the PUSCH that carries the AP-CSI feedback is M-th scheduled PUSCH for M <= 2, or (M-1)-th scheduled PUSCH for M > 2.
    - FFS whether to apply same or different rule (e.g., the PUSCH that carries the AP-CSI feedback is the first PUSCH that satisfies the multiplexing timeline) for licensed band.
      * Supported by Samsung
      * Low priority: Nokia, InterDigital
      * Objected by Qualcomm, NTT DOCOMO, Xiaomi, Huawei
  + Antenna ports: FFS whether/how to support DMRS time domain density lower than one DMRS per PUSCH and support DMRS bundling
    - Low priority or to be handled in other thread: Nokia, Huawei (inheriting ones in coverage enhancement WI), Samsung, InterDigital
    - Objected by Ericsson
  + URLLC related fields such as priority indicator and open-loop power control parameter set indication: FFS whether/how to apply URLLC related fields for scheduled PUSCHs
    - Supported by Qualcomm, NTT DOCOMO, Sony
    - Low priority: Nokia
    - Objected by InterDigital
  + CBGTI: FFS whether/how to support CBG based scheduling
    - Supported by ZTE
    - Objected by Ericsson

Since no company expressed support for enhancement of Antenna ports to be discussed in this AI, we may remove the corresponding bullet. In addition, considering Nokia’s reformulation, the Proposal #2 can be updated as follows:

### Proposals #2a:

* The multi-PUSCH scheduling defined in Rel-16 NR-U is the baseline for multi-PUSCH scheduling for NR from 52.6 GHz up to 71 GHz
  + FFS: Further enhancement.
  + FFS: Applicability to multi-PDSCH scheduling.

### Proposals #2a-1:

* For the multi-PUSCH scheduling for NR from 52.6 GHz up to 71 GHz, study the enhancement of the followings in addition to Rel-16 NR-U multi-PUSCH scheduling.
  + TDRA: FFS to down-select among
    - Alt 1: Same as NR-U, i.e., TDRA table is extended such that each row indicates up to [8] 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 [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 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: FFS whether/how to reduce bit-width e.g., by increasing RBG size or changing allocation granularity
  + Beam related fields (e.g., SRI): FFS whether/how to indicate multiple beams for scheduled PUSCHs
  + Frequency hopping: FFS whether/how to support frequency hopping for scheduled PUSCHs, e.g., inter-PUSCH/intra-PUSCH hopping
  + CSI request: Same as NR-U at least for unlicensed band, i.e., when a DCI schedules M PUSCHs, the PUSCH that carries the AP-CSI feedback is M-th scheduled PUSCH for M <= 2, or (M-1)-th scheduled PUSCH for M > 2.
    - FFS whether to apply same or different rule (e.g., the PUSCH that carries the AP-CSI feedback is the first PUSCH that satisfies the multiplexing timeline) for licensed band.
  + ~~Antenna ports: FFS whether/how to support DMRS time domain density lower than one DMRS per PUSCH and support DMRS bundling~~
  + URLLC related fields such as priority indicator and open-loop power control parameter set indication: FFS whether/how to apply URLLC related fields for scheduled PUSCHs
  + CBGTI: FFS whether/how to support CBG based scheduling

Companies are encouraged to provide views on Proposals #2a and #2a-1.

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| Company | Views |
| Charter Communications | In Proposal #2a, the main bullet is fine, but the FFS on further enhancements can be removed since this is addressed in Proposal #2a-1. In Proposal #2a-1, we support Alt. 2 for TDRA, and propose that similar scheme also be supported for configured grant multi-PUSCH. Other points are fine to discuss further. |
| Qualcomm | * For TDRA, we support Alt 2 as it provides more flexibility compared with Alt 3 * We are fine with moving the Antenna ports discussion to the other email thread. * Following Rel. 16 multi-PUSCH grant, the CBG retransmission should be supported in case of scheduling one PDSCH   FFS: additional enhancements for more than one PDSCH |
| Ericsson | Generally fine with the proposals, with the following modifications:   * Like we commented earlier, remove "for 52.6 – 71 GHz". This can be treated in UE capability discussions where it is discussed to what frequency band(s) this feature applies. * Beam related fields can be removed * We don't think Alt-3 makes sense from a deployment perspective, and is not the right optimization. While it is theoretically possible to schedule an SCell in the 52.6-71 GHz band from an FR1 PCell, it is not necessarily a good idea to do so, as the coverage differences between the SCell and PCell are just too big to make this a meaningful scheme. One of the most important benefits of cross-carrier scheduling is to have UCI sent on a lower frequency / larger SCS carrier. It is not desirable to have UCI for 480/960 kHz SCS cells sent on the 30 kHz SCS cell PCell. The coverage boost is in some sense too big: the meaningful DL coverage area of the 480/960 kHz SCS cells is much smaller than the UCI coverage area on 30 kHz SCS cells. The UL resources on the 30 kHz SCS cells are hence wasted on carrying 480/960 kHz SCS cell UCI in a small area. |
| Spreadtrum | We are generally ok with proposal#2a-1.  Regarding TDRA, we support Alt 2. Some companies debate that Alt 2 may introduce the risk of LBT failure due to gap between multi-PDSCH transmissions. However, the slot duration with SCS of 480KHz and 960KHz is much shorter than eCCA duration. Therefore, as long as the duration of the gap is restricted to be shorter than that of the eCCA, the risk of LBT failure will not be introduced. |
| vivo | We are generally fine with this proposal. Just one question to clarify: what does the bracket [8] mean here? If my understanding is correct, this number will be extended.  To Qualcomm: it depends on how much flexibility we need. If 16/32 PUSCH needs to be scheduled, do we really need that all SLIVs are different? I think most of them may occupy the whole slot. Alt. 3 already provide enough flexibility by configuring 8 different PUSCH groups each with a separate SLIV.  To Ericsson: It is also a valid case that FR1 provide a cell coverage and 60GHz provide a hotspot coverage for peak data rate (e.g. indoor) support. The scenario here is just an extreme case to verify that the number of PUSCHs scheduled by a single DCI needs to be increased to 16 or more (e.g. 32). In this sense, configuring 16/32 different SLIVs (+mapping type) for one entry is not needed. Alt. 3 provide a good trade-off of flexibility and overhead. |
| Fujitsu | We are fine with the proposals.  For TDRA, we prefer Alt 2 for flexibility and simplicity. We understand the intention of Alt 3 is to saving signalling payload assuming number of scheduled PUSCH/PDSCH scheduled by a single DCI need to be increased as much larger than 8. However, we do not see the DCMessity of significantly increasing the number and reducing signalling payload. |
| DCM | Support the proposal in principle.   * For Antenna ports, we are fine to remove it. * For CBG based transmission, we don’t see the motivation to support CBG based scheduling. It is not supported in NR-U multi-PUSCH scheduling. Moreover, higher SCS in NR52.6-71GHz will have shorter time duration than NR-U lower frequency. * For TDRA, we prefer Alt 2 with supporting non-contiguous scheduling and we are open to discuss Alt 3. * For other aspects, our views are not changed.   + For FDRA, we think FDRA field length reduction can be studied. * For multiple beams for multiple PUSCHs, we think the potential use case should be clarified first. Considering different TBs for different PUSCHs, it seems not to aim at diversity gain. If the motivation is beam change due to mobility, we need to clarify whether multi-PUSCH scheduling is proper for high mobility case with fast channel changes. * For frequency hopping, we didn’t see the motivation to have different frequency hopping schemes from that of lower frequency system. * For CSI request, we didn’t see the motivation to enhance current NR-U multi-PUSCH scheme. * For URLLC related fields, we agree they need to be considered since NR-U multi-PUSCH was designed without considering such fields due to the two simultaneously ongoing Wis. * For multi-PDSCH scheduling, we think some PDSCH specific fields are related with HARQ-ACK feedback scheme, e.g. K1/PRI/TPC for PUCCH/PDSCH group index, etc. Another difference between PDSCH and PUSCH scheduling is the possible maximum CW number. For PDSCH scheduling, maximum 2 CWs scheduled for one PDSCH is possible in Rel-16. If maximum 2 CWs is also supported for multi-PDSCH scheduling, TB specific fields (e.g. MCS/NDI/RV) need to be reserved for TB1 and TB2 for maximum number of scheduled PDSCHs. It may require to introduce too much DCI payload. Therefore, we think it can be discussed whether to limit maximum number of CWs for multi-PDSCH scheduling. |
| OPPO | We prefer to remove the last bullet and add one note:   * + ~~CBGTI: FFS whether/how to support CBG based scheduling~~   + Note: Other potential enhancements are not precluded |
| Nokia/NSB | we have following view on each item.   * TDRA: Support either Alt 1 or Alt 2, do not support Alt 3. * FDRA: we think that this is a secondary priority topic (optimization), but fine to study * Multi-beam (SRI): to be discussed in 8.2.4 BM AI. * CSI request: This can be decided at a later phase of WI. * URLLC related fields: We think that this is not the most urgent issue to discuss, keeping in mind that multi-PUSCH/PDSCH relate mainly to scenarios with SCS>120 kHz and a very short slot duration. * CGBTI : We don’t see any need to enhance CBG based scheduling beyond the existing Rel-16 NR-U multiple PUSCH scheduling functionality. |

# HARQ

## Timing related

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| Company | Views |
| [5] Huawei | Proposal 6: For multi-slot PDSCH scheduling with a single DCI for 480 kHz and 960 kHz:   * k0 indicates the gap between the slot of the scheduling DCI and the first slot of the multi-slot PDSCH scheduled by the DCI * k1 indicates the gap between the last slot of the multi-slot PDSCH and the slot carrying the HARQ information feedback corresponding to the multi-slot PDSCH   Proposal 7: The unit of k0 and k1 should be defined as multiple slots for multi-PDSCH scheduling for 480 kHz and 960 kHz SCS.  Proposal 8: The multi-PUSCH scheduling defined in NR-U Rel-16 can be directly extended to 52.6 GHz to 71 GHz. K2 indicates the gap between the slot of the scheduling DCI and the first slot of the multi-slot scheduled PUSCH corresponding to the DCI; The unit of k2 should be defined as multiple slots for multi-PUSCH scheduling for 480 kHz and 960 kHz. |
| [12] Intel | Proposal 3   * For multi-PDSCH scheduling   + Separate SLIVs are configured for each PDSCH as part of TDRA configuration. Number of PDSCHs is determined based on the number of SLIVs.   + 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.   + HARQ process ID for the first PDSCH is based on the indicated HARQ process ID in the DCI and increased by 1 for subsequent PDSCHs.   + NDI and RV bitmap for each scheduled PDSCH is included in the DCI.   + A single PDSCH-to-HARQ\_feedback timing indicator is used to indicate the slot offset between the last scheduled PDSCH and PUCCH. |
| [16] Sony | Proposal 5: Indication of HARQ feedback timing earlier than the PDSCH processing time for the last PDSCHs should be allowed. |
| [17] LG Electronics | Proposal #5: For a DCI scheduling multiple PDSCHs, a single PUCCH resource is indicated by PUCCH resource indicator and corresponding multiple HARQ-ACK bits are multiplexed on the indicated single PUCCH, where HARQ-ACK feedback timing is determined by applying PDSCH-to-HARQ\_feedback timing indicator from the last scheduled PDSCH. |
| [18] NEC | Proposal 2: The multi-PDSCH scheduling by a single DCI can report HARQ Feedback in an uplink slot or multiple uplink slots. |
| [25] Qualcomm | Proposal 10: For HARQ timing indication K1, uses the last PDSCH granted in the multi-PDSCH grant as reference slot. |

### Summary #3 (on timing relationship):

Based on company views, the following proposal for HARQ timing can be made.

### Proposal #3:

* 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.
    - FFS whether to allow indicating HARQ feedback timing earlier than the PDSCH processing time for the last PDSCH(s)
  + FFS if HARQ-ACK information corresponding to the PDSCHs scheduled by single DCI can be carried in multiple uplink slots

Companies are encouraged to provide views on Proposal #3.

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| Company | Views |
| Qualcomm | We agree with the main proposal, i.e., K1 defines the offset from the slot of the last scheduled PDSCH, the remaining enhancements on top of singling a single value of K1 could be discussed. |
| Futurewei | Support moderator’s proposal. |
| DCM | Support the proposal in principle.  For the sub-bullet of the first bullet, if the indicated HARQ-ACK feedback timing is earlier than the PDSCH processing time for the last PDSCH(s), UE is not able to report HARQ-ACK for all PDSCHs in the PUCCH. We don’t see why to study this possibility.  For the second bullet, we are fine to further discuss HARQ-ACKs reported in multiple slots if the possible use case is clarified. |
| Xiaomi | Support moderator’s proposal, with a little modification on the structure   * 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.     - FFS whether to allow indicating HARQ feedback timing earlier than the PDSCH processing time for the last PDSCH(s) * FFS if HARQ-ACK information corresponding to the PDSCHs scheduled by single DCI can be carried in multiple uplink slots |
| ZTE, Sanechips | We are fine with the FL’s proposal and Xiaomi’s modification.  We also support HARQ-ACK information corresponding to the PDSCHs scheduled by single DCI carried in multiple uplink slots considering the HARQ-ACK feedback delay, otherwise, the HARQ-ACK delay for the first scheduled PDSCHs might be too large. |
| Nokia/NSB | Support in principle.  While the UE processing times and the number of HARQ processes are open, there is possibility for HARQ process starvation with multi-PDSCH scheduling. Hence, it is important to include the identified FFS points. |
| Ericsson | We share a similar view as DCM. We don’t understand how it would work to indicate HARQ feedback timing earlier than the Ues PDSCH processing time, therefore this sub-bullet can be removed. We also think the final bullet on feedback spread over multiple slots should be removed. This seems very complicated. |
| Huawei, HiSilicon | We agree with the proposal and with the comments on the FFS points. We would like to add a point on the granularity of the indication of k1, which could be redefined as multiple slots.   * 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 last slot of the last PDSCH scheduled by the DCI and the slot carrying the HARQ-ACK information corresponding to the scheduled PDSCHs.     - ~~FFS whether to allow indicating HARQ feedback timing earlier than the PDSCH processing time for the last PDSCH(s)~~     - FFS: granularity of k1 (e.g. one or multiple slots)   + ~~FFS if HARQ-ACK information corresponding to the PDSCHs scheduled by single DCI can be carried in multiple uplink slots~~   “the slot of the last PDSCH scheduled” was changed to “the last slot of the last PDSCH scheduled” since there isn’t yet a decision on limiting one PDSCH to one slot. |
| Intel | We are fine with the proposal. We are not sure whether first sub-bullet “FFS whether to allow indicating HARQ feedback timing earlier than the PDSCH processing time for the last PDSCH(s)” is needed. We suggest removing it. |
| Apple | Support the proposal. Agree with Huawei on “last slot of last PDSCH”. |
| Samsung | We generally support proposal #3.  Regarding 2 FFS points, we think more clarification is needed. For 1st FFS, we’d like to know the motivation of indicating a K1 without sufficient UE PDSCH processing time for last one/several PDSCHs, and whether it implies separate HARQ-ACK of PDSCHs with sufficient processing time and PDSCHs without sufficient processing time? If separate feedback, it seems to be a special case of 2nd FFS. |
| Fujitsu | Fine with the proposal but we also think the FFS points are not clear and may need to be clarified. |
| Sony | We are basically fine with moderator’s proposal. At least it should be supported that multiple HARQ-ACKs corresponding to PDSCHs scheduled by single DCI is multiplexed with a single PUCCH.  For first FFS, it could be removed since it’s related discussion with second FFS.  For second FFS, we think to need studying it further. It would be beneficial for URLLC operation or 60 GHz unlicensed band. |
| NEC | We are fine with moderator's proposal. We also support HARQ-ACK information corresponding to the PDSCHs scheduled by single DCI can be carried in multiple uplink slots, it can help to decrease the HARQ-ACK delay and release HARQ process earlier. |
| Lenovo, Motorola Mobility | We support moderator’s proposal |
| InterDigital | We are fine with the proposal with Intel’s update |
| vivo | I am a little confusing by the main bullet and 2nd FFS point. In the main bullet, it means HARQ for all PDSCHs multiplexing in single PUCCH in a slot but FFS it could be spreading in multiple slots. |

### Summary #3a (on timing relationship):

All companies seem to be OK in principle, but Ericsson, Huawei, Intel, Fujitsu, Sony, and vivo show concerns for two FFS points. Considering ZTE and Samsung’s comments, two FFS points in Proposal #3 can be merged into one. Also, Huawei’s comments adding ‘last’ and new FFS (for K1 granularity) are reflected. Therefore, the Proposal #3 can be updated as follows:

### Proposal #3a:

* 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 last slot of the last PDSCH scheduled by the DCI and the slot carrying the HARQ-ACK information corresponding to the scheduled PDSCHs.
    - FFS: Granularity of K1 (e.g., one or multiple slots)
* FFS: If needed, further discuss whether or not HARQ-ACK information corresponding to PDSCHs scheduled by single DCI can be carried in multiple uplink slots considering the HARQ-ACK feedback delay

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

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| Company | Views |
| Charter Communications | Support the updated proposal, though neutral on the second main bullet with FFS on UCI in multiple slots. |
| Qualcomm | The granularity of K1 and the other timeline aspects are discussed in the other email thread, so we do not need to replicate it in this discussion. |
| Ericsson | We support the first main bullet and sub-bullet. Agree with Qualcomm, the FFS on granularity of K1 can be removed for now.  The FFS needs further justification; only one company has proposed it, and it potentially adds a lot of complexity to split UCI across different PUCCHs. |
| Spreadtrum | We support the updated proposal. |
| vivo | We support the updated proposal |
| Fujitsu | We are generally fine with the proposal with a little bit concern on the ‘last’.  In Proposal #1a, there is a sub-bullet as below which means a PDSCH would locate within a slot:  o Each PDSCH or PUSCH has individual/separate TB and each PDSCH/PUSCH is confined with a slot  However, the ‘last’ here seems implying a PDSCH may locate across multiple slots. Is this the intention?  If it is and the above bullet in Proposal #1a is agreed after discussion, it would be better to remove the ‘last’ here to avoid misleading. And another way of modification for consideration:   * 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 last slot of ~~the last~~ PDSCHs scheduled by the DCI and the slot carrying the HARQ-ACK information corresponding to the scheduled PDSCHs. |
| DCM | We are fine for the updated proposal. |
| NEC | We support the updated proposal |
| OPPO | We are fine with the proposal. |
| Nokia/NSB | On the first FFS point, we see also that the granularity of K1 should be discussed in the BW/timeline/RS email thread. Otherwise we are fine with the updated proposal. The need for shorter HARQ-ACK latency for the first PDSCHs, i.e., the second FFS point. depends on the UE processing times and number of HARQ processes. We see that the FFS point should be kept. |

## HARQ-ACK multiplexing

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| Company | Views |
| [4] OPPO | Proposal 3: Enhancements to Type-1 HARQ-ACK codebook, Type-2 HARQ-ACK codebook and eType-2 HARQ-ACK codebook for multi-PDSCH scheduling with different TBs with a single DCI should be supported. |
| [6] Nokia | Observation 9: HARQ-ACK codebook determination may need to be revised depending on the HARQ-ACK timing mechanism for multi-PDSCH scheduling. |
| [9] vivo | Proposal 3: In order to save PUCCH/PUSCH overhead, feedback one HARQ-ACK value and assign one HARQ process for the set of PDSCHs.  Proposal 4: Create a virtual PDCCH for each PDSCH, then the subsequent UE processing and code-book generation process can be consisted with that of one PDCCH scheduling one PDSCH. |
| [12] Intel | Proposal 4   * For multi-PDSCH scheduling,   + Time domain bundling of HARQ-ACK feedback is supported.   + If CBG based transmission is configured, HARQ-ACK feedback for multi-PDSCH scheduling is included in the sub-codebook which carries HARQ-ACK feedback for CBG based transmission.   + If CBG based transmission is not configured, HARQ-ACK feedback for multi-PDSCH scheduling is included in     - the sub-codebook for TB-based HARQ-ACK if up to two PDSCHs are scheduled;     - otherwise, the sub-codebook for CBG-based HARQ-ACK. |
| [14] Spreadtrum | Proposal 3: The issues related HARQ-ACK feedback should be further studied and specified in case of multi-slot PUSCH/PDSCH scheduling. |
| [16] Sony | Proposal 6: NR-U HARQ enhancement features (Non-numerical K1, enhanced Type-2 HARQ CB, and Type-3 HARQ CB) should be supported for multi-PDSCH scheduling.   * FFS how to indicate/determine non-numerical K1 and PDSCH group. |
| [17] LG Electronics | Proposal #5: For a DCI scheduling multiple PDSCHs, a single PUCCH resource is indicated by PUCCH resource indicator and corresponding multiple HARQ-ACK bits are multiplexed on the indicated single PUCCH, where HARQ-ACK feedback timing is determined by applying PDSCH-to-HARQ\_feedback timing indicator from the last scheduled PDSCH.  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.  Proposal #7: For (enhanced) type-2 HARQ-ACK codebook,   * + 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 DCI and per each sub-codebook   + Include individual UL DAI for each sub-codebook in UL grant   + FFS: If CBG is configured |
| [18] NEC | Proposal 3: Consider optimization for type-1 HARQ-ACK codebook overlapping issue when higher SCS is supported  Proposal 4: Consider increasing the bit length of c-DAI and t-DAI for type-2 HARQ-ACK codebook determination in CA case. |
| [19] Xiaomi | Proposal 9：HARQ-ACK payload optimization may need to be considered to reduce HARQ-ACK feedback overhead if HARQ process number increases for SCS 480/960kHz.  Proposal 10：Possible solution to reduce overhead is to feedback the HARQ-ACK information of multiple PDSCHs scheduled by one DCI in a single PUCCH resource. |
| [20] Samsung | Proposal 10: To support Type-1 codebook, the following modifications should be considered:   * Candidate DL slots determination for PDSCHs other than last PDSCH of multi-PDSCHs. * Candidate PDSCH occasions determination within candidate slots, including using which PDSCH’s (last PDSCH or all PDSCHs) SLIV, do pruning by separate or joint determination of SLIVs of one TDRA row, and deletion of redundant SLIVs incapable to feedback in corresponding UL slot.   Proposal 11: To support Type-2 codebook, the following solutions can be considered:   * Separate sub-codebooks for single and multi-PDSCHs scheduling and DAI is separately accumulated within each sub-codebook. * Single sub-codebook for single and multi-PDSCHs scheduling and the number of DAI bits is increased. |
| [21] Ericsson | Proposal 11: Support HARQ bundling groups for dynamic HARQ codebook for multi-PDSCH scheduling. The HARQ feedback corresponding to multiple PDSCHs scheduled by a single DCI is distributed evenly amongst the HARQ bundling groups.  Observation 2: The current semi-static HARQ codebook can be reused in multi-PDSCH scheduling. Certain clarification might be needed in the specification for the HARQ ACK bit multiplexing ordering and HARQ ACK reporting. |
| [24] Apple | Proposal 9: Specify a multi-slot HARQ procedure to support multi-slot HARQ processing. |
| [25] Qualcomm | Proposal 11: For each DCI that grants multi-PDSCH retransmission, a number of virtual DCIs, equal to the number of granted PDSCHs – 1, should be assumed by the UE and used to update its observation of the DAI. Similarly, gNB will assume the existence of these virtual DCIs while calculating the DAI of the next DCI transmission, i.e., gNB decides the DAI value based on the total number of the previously granted PDSCHs.  Proposal 12: Studying increasing the size of DAI field. |
| [26] NTT DOCOMO | Proposal 5: In addition to multi-PUSCH scheduling framework in Rel-16 NR-U, the following aspects can also be considered   * HARQ-ACK feedback related aspects for multi-PDSCH scheduling   + HARQ-ACK feedback for multiple PDSCHs scheduled by one DCI can be reported in one PUCCH.   + HARQ-ACK codebook generation impact * Scheduling flexibility for both multi-PUSCH/PDSCH scheduling   + Consecutive scheduling, and potentially non-consecutive scheduling |

### Summary #4 (on HARQ-ACK multiplexing):

Based on company views, the following discussion points can be observed.

* Whether/how to support time domain bundling of HARQ-ACK bits corresponding to multiple PDSCHs scheduled by single DCI, e.g., by feeding back one HARQ-ACK value and assigning one HARQ process, or by introducing HARQ bundling group
  + Supported by vivo, Intel, Ericsson
* For type-1 HARQ-ACK codebook,
  + LG Electronics, Samsung, NEC point out several enhancement points while Ericsson observed that the current semi-static HARQ codebook can be reused in multi-PDSCH scheduling.
* For type-2 HARQ-ACK codebook,
  + Intel, LG Electronics, NEC, Samsung, Ericsson, Qualcomm suggest several alternatives on DAI counting and codebook construction.
    - Alt 1: C-DAI/T-DAI is counted per DCI.
      * If separate sub-codebooks are introduced for single PDSCH scheduling and multi-PDSCH scheduling cases, DAI is separately accumulated within each sub-codebook. The number of HARQ-ACK bits corresponding to sub-codebook for multi-PDSCH scheduling DCI is determined based on the number of maximum schedulable PDSCHs.
      * If time domain bundling (e.g., HARQ bundling group) is configured, the number of HARQ-ACK bits corresponding to multi-PDSCH scheduling DCI can be less than that of the maximum schedulable PDSCHs.
    - Alt 2: C-DAI/T-DAI is counted per PDSCH.
      * If M PDSCHs are scheduled, UE may generate type-2 HARQ-ACK codebook assuming that the virtual PDCCH/DCI for M-1 PDSCHs will be transmitted with the corresponding DAI value in ascending order.
      * This alternative may require increase of DAI bits, considering DCI missing case.
* Sony proposes that NR-U HARQ enhancement features (Non-numerical K1, enhanced Type-2 HARQ CB, and Type-3 HARQ CB) should be supported for multi-PDSCH scheduling.

### Proposal #4:

* 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.
  + Alt 1: C-DAI/T-DAI is counted per DCI.
    - FFS on codebook generation details (e.g., separate sub-codebooks for single and multi-PDSCHs scheduling)
    - FFS on whether to apply time domain bundling (e.g., HARQ bundling group)
  + Alt 2: C-DAI/T-DAI is counted per PDSCH.
    - FFS on codebook generation details (e.g., virtual PDCCH/DCI)
    - FFS on how to signal DAI values (e.g., increase of DAI bits)

Companies are encouraged to provide views on Proposal #4.

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| Company | Views |
| Qualcomm | Support Alt 2, and increasing the DAI number of bits, Alt 2 ensures the alignment of the codebook sizes at both UE and gNB, unlike Alt 1, where missing one grant will cause the codebook size to be unknown |
| DCM | Support the proposal in principle to down-select between Alt 1 and Alt 2.  From our perspective, we prefer Alt 2 due to less specification impact on HARQ-ACK CB procedure. Moreover, HARQ-ACK CB size is more robust and less redundant for Alt 2 than Alt 1. |
| Xiaomi | Support Alt 1. Currently C-DAI/T-DAI only has 2 bits, means its counting in a 4-cycle. If Alt 2 is adopted, the number of scheduled PDSCH/PUSCH by a single DCI is also 4(which is very possible), then the C-DAI/T-DAI would always keep the same. And is one DCI is missed, nothing can be reflected on the C-DAI/T-DAI. |
| ZTE, Sanechips | We prefer alt2, which can reuse the existing the type-2 HARQ-ACK codebook scheme as much as possible. |
| Nokia/NSB | A configurable trade-off between these two alternatives should also be considered  Proposed new alternative   * + Alt 3: C-DAI/T-DAI is counted per M scheduled PDSCH, where M is configurable (e.g. 1,2, 4, …)     - FFS on codebook generation details     - FFS on how to signal DAI values (e.g., increase of DAI bits) and whether to apply bundling. |
| Ericsson | We support Alt-1 to maintain the existing Rel-16 approach of counting DCIs. We view this approach as the one with less specification effort; not Alt-2. |
| Huawei, HiSilicon | The proposal is acceptable as a list of options for further consideration for type-2 HARQ-ACK codebook generation corresponding to scheduling multiple PDSCHs with a single DCI. The FFS bullet points could be simplified (e.g. by removing the examples especially since some are undefined such as virtual PDCCH/DCI). |
| Intel | We are fine with the proposal. But before we agree on Proposal #4, we suggest that first we discuss whether TB or CBG based transmission are supported for multi-PDSCH/PUSCH scheduling. |
| Apple | We support Alt 1. Modifications can be made to accommodate any ambiguity if a grant is missed. |
| Samsung | For type-2 codebook, we’re fine with the proposal. Just one clarification, time domain bundling is not Alt-1 specific issue, it may also apply for Alt-2.  We’d like to hear the views for type-1 codebook. In our understanding, both type-1 and type-2 codebook should be supported for 52.6GHz. For type-1 codebook, we can first discuss whether existing mechanism can work. If not, what would be the potential enhancement? In our understanding, existing mechanism does not work, because (1) only the slot of last PDSCH is counted as candidate slots derived by K1, while other PDSCHs is omitted, then, no place to transmit HARQ-ACK for these PDSCHs. (2) TDRA pruning is based on a row within a slot, then, it is undefined how to handle a row with multiple SLIVs in different slot. |
| Fujitsu | Support Alt 1. NR already supports type-2- HARQ-ACK codebook for CBG-based Tx where DAI is counted per DCI and one DCI can correspond to up to 8 HARQ-ACK bits. This is similar with multi-PDSCH where one DCI also corresponds to multiple HARQ-ACK bits. We don’t see an issue when counting DAI per DCI also for the multi-PDSCH case. |
| Sony | Support moderator’s proposal at this stage. Down-selection between alt 1 and 2 will be discussed later. |
| NEC | We share the same view with Qualcomm. |
| Lenovo, Motorola Mobility | We prefer Alt 1 where the counting is done per DCI. |
| InterDigital | We are fine with the proposal and prefer Alt-1. |
| vivo | Support the proposal and we prefer Alt. 2 |

### Summary #4a (on HARQ-ACK multiplexing):

Companies’ preferences are as follows:

* + Alt 1: C-DAI/T-DAI is counted per DCI.
    - Xiaomi, Ericsson, Huawei, Apple, Fujitsu, Lenovo, InterDigital
  + Alt 2: C-DAI/T-DAI is counted per PDSCH.
    - Qualcomm, NTT DOCOMO, ZTE, NEC, vivo
  + Alt 3: C-DAI/T-DAI is counted per M scheduled PDSCH(s), where M is configurable (e.g., 1, 2, 4, …).
    - Nokia

As a response to Samsung, only few companies showed their views on type-1 HARQ-ACK codebook so, Moderator encourages to provide views in this meeting or at least in the next meeting.

Considering this is the first meeting for the WI, it would be good to list up proposed alternatives and continue technical discussion. Alt 3 proposed by Nokia is incorporated, FFS points are simplified based on Huawei’s comment, and time domain bundling related FFS is applied to all alternatives based on Samsung’s comment. Therefore, the Proposal #4 can be updated as follows:

### Proposal #4a:

* 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.
  + 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 on codebook generation details
  + FFS on how to signal DAI values (e.g., increase of DAI bits for Alt 2 and Alt 3)
  + FFS on whether to apply time domain bundling

Companies are encouraged to provide views on Proposal #4a.

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| Company | Views |
| Qualcomm | We are open for discussing Alt 2 and 3  For Alt 3, we ask for more clarifications: whether it will restrict the number of scheduled PDSCH(s) to be M or multiple of M, or the A/N will be zero-padded to fit the number feedback bits assigned for the DCI |
| Ericsson | It is not clear what benefit Alt-3 brings? If M is equal to the number of scheduled PDSCHs, isn't Alt-3 the same as Alt-1? |
| Spreadtrum | We support the proposal and we prefer Alt 2. |
| vivo | We support the proposal and prefer Alt. 2 |
| Fujitsu | We are fine with the proposal and prefer Alt 1 for less standardization effort as it is following the legacy approach. |
| DCM | We are fine for the updated proposal. And we prefer Alt 2 for more robust and less redundant HARQ-ACK CB size. |
| NEC | We support the proposal and prefer Alt 2. |
| OPPO | We are fine with the proposal. |
| Nokia/NSB | We are fine with the updated proposal.  Alt 3 is configurable trade-off between alt 1 and alt 3. (e.g. Alt 1: M= scheduled PDSCH, Alt 2: M=1).  On Alt.3, there is no restriction on the number of scheduled PDSCHs. The A/Ns are zero-padded to fit the number of feedback bits to assigned for the DCI. When DAI is incremented N values for the DCI, UE reports A/Ns for N\*M PDSCHs. (The number of A/Ns can be capped by the configured maximum number of schedulable PDSCHs). We share Samsung’s view that the current Type 1 codebook mechanism does not work properly with the multiple PDSCH scheduling and should be discussed further. |

## HARQ process

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| --- | --- |
| Company | Views |
| [19] Xiaomi | Proposal 8: Tx/Rx HARQ buffer capacity will needs to be enhanced if HARQ process number increases for SCS 480/960kHz. |
| [21] Ericsson | Proposal 10: Increase maximum number of DL and UL HARQ processes in Rel-17 from 16 to 32. |

### Proposal #5:

* Further discuss the necessity of increasing the maximum number of DL and UL HARQ processes from 16 to 32, for NR from 52.6 GHz to 71 GHz.

Companies are encouraged to provide views on Proposal #5.

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| --- | --- |
| Company | Views |
| Qualcomm | Study the need of increasing number of HARQ processes in the light of the other proposals such as having a DCI that schedules a single TB that span more than one slot. In addition, it should only be considered for 480/ 960kHz SCSs |
| Futurewei | Support further discussions to increase of number of HARQ processes to 32. |
| DCM | Support further discussion. |
| Xiaomi | Support moderator’s proposal. |
| ZTE, Sanechips | We are fine to further discuss HARQ process number.  Considering UE buffer burden, we prefer to keep the maximum number of DL and UL HARQ processes as 16. |
| Nokia/NSB | Support the proposal. From PDSCH/PUSCH processing times point of view, it seems that 16 HARQ processes is not enough for SCS > 120 kHz. |
| Ericsson | Support the moderator’s proposal. We point out that increasing the # of HARQ processes to 32 has also been agreed in NTN. |
| Huawei, HiSilicon | This discussion should proceed after a decision is made on the maximum number of schedulable slots with a single DCI, and whether each TB is mapped to only one slot. |
| Intel | We are not sure whether number of HARQ processes need to be increased. Further discussion is needed. |
| Apple | Support increasing the number of HARQ processes. |
| Samsung | There are still aspects like UE processing latency still under discussion and it’s too premature to judge right now whether the number of HARQ process number need to be increased. We prefer to delay this discussion until the major issues have be investigated, since the increasing of HARQ process number is too essential for UE implementation. |
| Fujitsu | Fine to further discuss. |
| Sony | Support moderator’s proposal. We are supportive to increase the maximum number of HARQ processes for NR above 52.6 GHz. |
| Lenovo, Motorola Mobility | We don’t see a strong need to increase the number of HARQ processes. But we are open to further discuss this. |
| InterDigital | We think that the maximum number can be discussed after having down selection from Alt 1 and Alt 2 in proposal 4. |
| vivo | Open to discuss |
| Charter Communications | Fine to discuss further, but one main difference compared to NTN is the very large carrier BW in 60 GHz which offsets the risk of HARQ process starvation. |
| Spreadtrum | We are open to further discuss. |

# Reference

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2. R1-2100061 PDSCH/PUSCH scheduling enhancements for NR from 52.6 GHz to 71GHz Lenovo, Motorola Mobility
3. R1-2100077 Discussion on the data channel enhancements for 52.6 to 71GHz ZTE, Sanechips
4. R1-2100153 Discussion on PDSCH/PUSCH enhancements OPPO
5. R1-2100201 PDSCH/PUSCH enhancments for 52-71GHz band Huawei, HiSilicon
6. R1-2100261 PDSCH/PUSCH enhancements Nokia, Nokia Shanghai Bell
7. R1-2100300 Discussions on PDSCH and PUSCH enhancements for 52.6-71GHz CAICT
8. R1-2100374 PDSCH/PUSCH enhancements for up to 71GHz operation CATT
9. R1-2100433 Discussions on PDSCH/PUSCH enhancements for NR operation from 52.6GHz to 71GHz vivo
10. R1-2100553 PT-RS enhancements for NR from 52.6GHz to 71GHz Mitsubishi Electric RCE
11. R1-2100605 On Enhancements of PDSCH Reference Signals MediaTek Inc.
12. R1-2100647 Discussion on PDSCH/PUSCH enhancements for extending NR up to 71 GHz Intel Corporation
13. R1-2100741 Considerations on multi-PDSCH/PUSCH with a single DCI and HARQ for NR from 52.6GHz to 71 GHz Fujitsu
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18. R1-2100940 PDSCH enhancements on supporting NR from 52.6GHz to 71 GHz NEC
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21. R1-2101310 PDSCH-PUSCH Enhancements Ericsson
22. R1-2101320 Enhancements on Reference Signals for PDSCH/PUSCH for NR beyond 52.6 GHz CEWiT
23. R1-2101330 PDSCH-PUSCH Enhancement Aspects for NR beyond 52.6 GHz Charter Communications
24. R1-2101376 PDSCH/PUSCH enhancements for NR between 52.6GHz and 71 GHz Apple
25. R1-2101457 PDSCH/PUSCH enhancements for NR in 52.6 to 71GHz band Qualcomm Incorporated
26. R1-2101609 PDSCH/PUSCH enhancements for NR from 52.6 to 71 GHz NTT DOCOMO, INC.