**3GPP TSG RAN WG1 #104-e R1-2101799**

**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 (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. |

## 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 4：The number of PDSCHs/PUSCHs scheduled by one DCI should be adapted to the SCS of PDSCH/PUSCH.  Proposal 5: 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 (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.

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| 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 |

# 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 (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. |

## 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 6: In order to save PUCCH/PUSCH overhead, feedback one HARQ-ACK value and assign one HARQ process for the set of PDSCHs.  Proposal 7: 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 (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. |

## 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. |

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