3GPP TSG RAN WG1 #102-E R1-200xxxx

e-Meeting, August 17th – 28th, 2020

Source: Moderator (ZTE)

Title: Summary of AI 8.4.3 for HARQ for NTN

Agenda Item: 8.4.3

**Document for: Discussion and Decision**

# **Introduction**

The following WI scope w.r.t HARQ enhancement is endorsed in RAN#86 meeting:

* *HARQ*
	+ *Number of HARQ process [RAN1]*
	+ *Enabling / disabling of HARQ feedback as described in the TR 38.821 [RAN1&2]*

In this meeting, companies’ views are summarized with corresponding observations/proposals on following aspects with detailed proposals from each company listed in appendix.

* Enhancement on HARQ process number
* Disabling/enabling HARQ feedback
* Other

# **Enhancement on HARQ process number**

In existing NR, up to 16 HARQ processes are supported for UE via the configuration as cited below.

TS 38.214 section 5.1:

For downlink, a maximum of 16 HARQ processes per cell is supported by the UE. The number of processes the UE may assume will at most be used for the downlink is configured to the UE for each cell separately by higher layer parameter *nrofHARQ-ProcessesForPDSCH*, and when no configuration is provided the UE may assume a default number of 8 processes.

TS 38.331:

**– *PDSCH-ServingCellConfig***

The IE *PDSCH-ServingCellConfig* is used to configure UE specific PDSCH parameters that are common across the UE's BWPs of one serving cell.

*PDSCH-ServingCellConfig* information element

-- ASN1START

-- TAG-PDSCH-SERVINGCELLCONFIG-START

PDSCH-ServingCellConfig ::= SEQUENCE {

 ……

 nrofHARQ-ProcessesForPDSCH ENUMERATED {n2, n4, n6, n10, n12, n16} OPTIONAL, -- Need S

 ……

For NTN, due to the large RTT (e.g., 25.77 ms for LEO-600) and potential scheduling with larger SCS (e.g., SCS = 30 KHz), the existing maximal supported HARQ process number is not sufficient for corresponding the DL/UL. Meanwhile, this value is also not feasible to enable the ATG operation in TDD mode.

For dealing with the aforementioned issue, as mentioned in [Huawei, Xiaomi, Lenovo, Samsung, CMCC, Panasonic, LG, ZTE, Apple, QC, CATT, Sony, Thales, Nomor Research GmbH, OPPO], extension of maximum supported HARQ process number can be supported with following solutions:

* Slot/SFN-based solution:

In this way, the determination of HARQ process ID will be coupled with the index of slot(s)/SFN(s) carrying the corresponding transmission/scheduling [QC, Lenovo, Samsung, Panasonic, Sony, Huawei, OPPO, Intel]. For example, as highlighted in [Samsung], a slot number based HARQ process ID constructor can be considered as the LSB value for HARQ ID calculation. And in [Huawei], group ID of slots are considered as the MSB for HARQ ID determination and for enhancing scheduling flexibility, additional information, e.g., DM-RS sequence, is also proposed to be considered.

* Reuse HARQ process ID time window/segments:

In this way, the determination of HARQ process ID will be coupled with division of time domain resource [CMCC, Xiaomi, Panasonic]. For example, the calculation on HARQ process ID is based on the window index and supported HARQ process number within each window [CMCC].

* Re-interpretation of existing DCI fields:

In this way, the determination of HARQ process ID relies on the re-interpretation of existing DCI bit [CATT, Apple, ZTE]. For example, as mentioned in [Apple], the bit within the existing RV field can be considered as the MSB for HARQ calculation.

* CCE index:

In this way, the determination of HARQ process ID will be coupled with the index of CCE, which carrying the scheduling information for transmission [LG].

* Additional scrambling for scheduling grant:

In this way, the determination of HARQ process ID will be up to additional scrambling on the scheduling grant [Xiaomi].

Prior to the solution selection, [CAICT] highlight that the determination of target number of HARQ process (e.g., 32 [ZTE, CMCC], 64 for S-band (FR1) and 256 for Ka-band (FR2) [Panasonic]) should be determined and it should be up to the peak data rate expected for NTN.

Meanwhile, consideration on the UE capability is also highlighted by [OPPO, Intel, CATT, QC, Apple, Sony, Thales, Nomor Research GmbH, Nokia]. For example, as mentioned in [CATT, Apple], supporting of extended value should be up to UE capability without increase on the UE buffer/cost [OPPO]. For achieving it, existing value should be considered as fallback case [CATT, Nomor Research GmbH, Thales] and supports on the extension value should be configurable to UE [QC]. Additional consideration on the introduction of constraints w.r.t maximum TBS for a HARQ process or maximum total TBS across all parallel HARQ processes is also mentioned in [Intel].

However, as another alternative, [MTK, Ericsson] prefer to keep the existing HARQ process number. In this way, with assumption on the disable of HARQ feedback, the transmission will conduct via relaying on the RLC-ARQ mechanism. For example, similar performance of enhanced HARQ process number and RLC-ARQ mechanism is shown in the simulation results from [Ericsson] in certain case. And configuration of shoter t-PollRetransmit and t-Reassembly in ul-AM-RLC and dl-AM-RLC is proposed by [MTK] to match the satellite RTD without change to specifications. But, according to the results shown in [ZTE, Panasonic], benefits on both throughput and latency can be achieved with extended HARQ process number. And as mentioned by [QC, ZTE], the impact on UE’s power consumption due to lower BLER target and RLC reports by using RLC-ARQ should also be evaluated.

According to the above summary, the following proposals are listed as majority views:

***Proposal 1:*** *Extension of maximal HARQ process number is supported.*

* *FFS: candidate value for maximal HARQ process number, e.g., [32] or [64]*
* *FFS: addition restriction due to the UE capability if any.*
* *FFS: solution for HARQ process ID indication*

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| **Company** | **Comments and Views** |
| MediaTek | Proposal 1 should further discuss need for extension of maximal HARQ process number. There was no consensus on need for > 16 HARQ processes in Rel-16 NR NTN SI. SLS evaluation of HARQ R1-2005321 by Nomor Research GmbH, Thales showed marginal gain at system level for >16 HARQ processes. The network can configure shorter RLC window with the RLC status report transmitted by the UE at least once or several times per satellite RTD for LEO and GEO. The discussion should be on UL feedback efficiency at MAC layer or RLC layer, and whether the signalling overhead difference justify > 16 HARQ processes. |
| Lenovo&MotoM | Support proposal 1. The extended maximal HARQ process number is configured by higher layer signalling based on UE capability report, RTT and SCS etc.The size of HARQ process field in DCI should be the same as legacy, and the extended HARQ process number is implicitly indicated. |
| Panasonic | We support proposal 1.We evaluated with SLS using the agreed assumptions in R1-2006327. User throughput performance is significantly improved by increasing the number of HARQ processes even without soft combining. The results also show HARQ-feedback disabled is inferior to HARQ-feedback enabled because of robust MCS choice to achieve lower (1%) BLER target. With 10% BLER operation with HARQ feedback, 90% of the transmission only requires the time/frequency resource corresponds to MCS of 10% BLER, and only 10% of the transmission requires additional resource for retransmission. With 1% BLER operation without HARQ feedback, 99% of the transmission requires the time/frequency resource corresponds to MCS of 1% BLER. Such resource usage difference makes larger HARQ process efficient. Even without soft combining (in spite of the name to increase HARQ process), resource efficiency gain of different BLER target can be obtained according to our simulation results. SLS in R1-2005321(Nomor, Thales) shows only marginal gain from 16 processes to 32 processes. The SLS is based on full buffer traffic, which is not aligned with agreed assumption. Our understanding is full buffer evaluation is not appropriate to evaluation the number of HARQ process because the waiting time from the buffer to resource assignment caused by the shortage of HARQ process is not modelled. Non-full buffer traffic based evaluation is essential.LLS in R1-2006465(Ericsson) shows no gain from HARQ-feedback disabled, but this might not reflect resource inefficiency to achieve lower BLER in a practical situation including interference fluctuation. We wonder why the difference on RTT is not influencing throughput when we compared figure 3 to 6. In addition, channel model used for the evaluation (NTN-TDL-D suburban with elevation angle 30$°$) seems less fluctuated channel due to weak NLOS component (i.e. high K-factor) according to the model in TR38.811. Higher elevation angle (e.g. 70$°$) that has stronger NLOS component could make the result difference. Regarding the 2nd FFS point in Proposal 1, additional restriction due to UE capability would not be needed because it is basically up to UE implementation whether to perform soft combining. Sufficiently good user throughput can be obtained even with a limited UE soft buffer according to our SLS results. |
| Sony | We are neutral on HARQ process number extension. |
| CMCC | Support proposal 1.Extending maximal HARQ process number to 32 is preferred. The extended maximal HARQ process number can be configured by higher layer signalling based on UE capability. |
| Spreadtrum | We support proposal 1. |
|  CATT | Support proposal 1. One simple reason is that in NTN it is no need to support two transport blocks transmission due to poor channel condition. Even if without memory extension, 32 HARQ processes can be supported. |
| Huawei | We support proposal 1.We prefer an extension of maximal HARQ process number to at least 32.Implicit HARQ process ID indication are preferred e.g. slot/SFN-based, combined design of DMRS-based and slot-based solution.  |
| Ericsson | Disagree. We provided simulation results showing no gain is achieved by increasing number of HARQ processes. Simulations from other companies showing gains of increased number of HARQ processes also show inconsistent/unexpected behaviour that requires more thorough analysis before conclusions can be drawn. We propose that companies provide simulation results with same set of simulation assumptions.Also, it should be noted that the fundamental NR HARQ design is asynchronous and thus flexible, relaxed from early LTE HARQ design (which is synchronous to some extent). Time window-based method (and its variations) is not aligned with this principle and re-introduces unnecessary restriction from LTE. In addition, Rel-16 already introduces DCI format x\_2, where the size of HARQ field is 0, 1, 2, 3 or 4 bits determined by higher layer configured number of HARQ processes. This design direction is much cleaner. |

# **Disabling/enabling HARQ feedback**

# **Mechanism for disabling/enabling HARQ feedback**

In SI, the discussion on the mechanism for disabling/enabling HARQ feedback is concluded in RAN2 as below:

* HARQ
	+ Enabling / disabling of uplink HARQ feedback for downlink transmission at the UE receiver should be configurable per UE and per HARQ process.
	+ Enabling / disabling of HARQ uplink retransmission should be configurable per UE or per HARQ process. The LCP impact caused by disabling the HARQ uplink retransmission configuration and its impact on UE’s uplink transmission should be discussed in the work item phase.
	+ Multiple transmission of the same TB to lower residual BLER should also be configured.

In this meeting, group based mechanism for HARQ enabling/disabling is proposed by [MTK, Lenovo, CATT, CAICT]. For example, two set of HARQ process can be constructed with enabling and disabling the HARQ feedback, respectively [MTK]. And as highlighted by [CATT, Xiaomi], dynamic HARQ enabling/disabling via DCI should not be supported. But from [OPPO, Apple]’s view, either RRC configured or L1 signaling based enabling/disabling for each HARQ process can be considered. Moreover, for the DL SPS/UL CG case, enabling/disabling of HARQ feedback per configuration is proposed by [CAICT]. And reporting HARQ feedback information for the SPS PDSCH activation by UE is preferred in case of HARQ feedback is disabled for HARQ process of SPS PDSCH [Sony].

In addition, discussion on the different parameters configurations per HARQ with/without feedback is proposed by [QC, Ericsson]. For example, parameters as power control, MCS table and UCI multiplexing parameters are mentioned in [QC].

In addition, for ensuring the efficiency and reliability of transmission carrying the signaling, e.g., RRC configuration/MAC CE command, as highlighted in [Ericsson, ZTE, MTK, Sony, LG, CAICT, Samsung], at least one HARQ process with feedback should be kept. Moreover, the specification impacts (e.g., up to gNB implementation without specification changes) on such restriction should be further discussed [MTK, ZTE].

Based on the above analysis, following proposals are provided according to majority view:

***Proposal 2:*** *Enabling/disabling on HARQ feedback for downlink transmission should be at least configurable per HARQ process via RRC signaling.*

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| **Company** | **Comments and Views** |
| MediaTek | Support proposal 2 |
| Lenovo&MotoM | Support proposal 2 |
| Panasonic | Support proposal 2 |
| Sony | Support proposal 2 |
| CMCC | Support proposal 2 |
| Spreadtrum | Support proposal 2 |
| CATT | Support proposal 2 |
| Huawei | Support proposal 2. |
| Ericsson  | We think RAN2 already agreed this and thus perhaps there is no need to make agreement again in RAN1. In RAN1, we could take this as a common understanding and a basis for further discussion. |

***Proposal 3:*** *At least one HARQ process with feedback for downlink transmission should be kept.*

* *FFS: whether and how to capture it in specification*

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| **Company** | **Comments and Views** |
| MediaTek  | Support proposal 3 |
| Lenovo&MotoM | Support proposal 3 |
| Panasonic | Support proposal 3 in principle, but it would be up to network implementation.  |
| Sony | Support proposal 3On the FFS part, descriptions such as UE is not expected to receive a PDSCH carrying MAC CE via a HARQ process with feedback disabling can be added. If MAC CE is allowed to be scheduled with both HARQ feedback enabled and disabled processes, then two MAC CE action timings may need to be specified for the with and without HARQ feedback cases.In case HARQ feedback is disabled for SPS PDSCH, the DCI for SPS PDSCH activation may need HARQ feedback similar with SPS PDSCH release in Rel.15/16. |
| CMCC | Support proposal 3 |
| Spreadtrum | Support proposal 3 |
| CATT | Support proposal 2 |
| Huawei | Support proposal 3. |
| Ericsson | Support proposal 3. |

***Proposal 4：****Different parameters configuration for each HARQ process with/without feedback can be further discussed.*

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| **Company** | **Comments and Views** |
| MediaTek  | Support proposal 4 |
| Lenovo&MotoM | Not support. Hope unified parameter configuration for case with/without HARQ feedback, and the detail MCS is flexibly indicated per HARQ process (with/without feedback) |
| Panasonic | Support proposal 4 |
| Sony | Support proposal 4 |
| CMCC | Support proposal 4 |
| CATT | Not support. No clear reason to configure different parameters for with and without feedback. |
| Huawei | It is not clear to us whether different parameters are actually needed for HARQ processes with and without feedback. |
| Ericsson | Support the proposal. In addition, we think that it would be beneficial to identify the set of parameters that needs to be discussed at this stage. In our view following parameters could be a starting point.- Aggregation factor- MCS table- Time domain resource allocation table- Frequency resource allocation type 0 and type 1- Block error rate target- Physical resource block (PRB) bundling configuration- PDSCH mapping type A and type B |

# **Enhancement on the HARQ-ACK codebook**

In case of HARQ feedback enabling/disabling on a per HARQ process basis, necessity on enhancement for HARQ-ACK codebook is identified in [Huawei, Ericsson, Sony, LG, Asia Pacific Telecom]. For example, as mentioned in by [Ericsson], enhancement on Type-1 can be done by inserting the NACK directly. For Type-2, ignoring the counter DAI from PDCCH associated with a feedback disabled HARQ process can be considered. And w.r.t the Type-3, determination of codebook size can be up to the HARQ process with enabled feedback. Meanwhile, optimization on the HARQ process scheduling to reduce the Type-1 HARQ-ACK codebook redundancy is also mentioned in [Huawei].

Based on the above analysis, following proposal is provided according to majority view:

***Proposal 5****: Optimization on the HARQ-ACK codebook is needed.*

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| **Company** | **Comments and Views** |
| Lenovo&MotoM | Support proposal 5 |
| Panasonic | We prefer a straightforward solution (e.g. insert NACK for type1 and ignore DAI for type2 as proposed by Ericsson). Optimization might not be needed.  |
| Sony | Support proposal 5Type-1 and Type-2 HARQ codebook should be supported in NTN with minor spec. change. For Type-1, consider how to reduce the codebook redundancy. For Type-2, ignore to feedback on disabled HARQ processes when counting DAI. The feedback for SPS PDSCH activation is counted in DAI when HARQ feedback is disabled for HARQ process of SPS PDSCH. |
| CATT | Similar view with Panasonic. We prefer very simple solution. For example, for type 1 codebook, just insert a fixed value ‘0’ or ‘1’, no need special optimization. |
| Huawei | Support proposal 5 |
| Ericsson | We support this proposal. This is not an optimization. It is an essential design piece for enabling / disabling HARQ feedback. UE behaviours for HARQ codebooks should be discussed and specified to support enabling / disabling HARQ. |

# **Enhancement on the transmission**

For enhancing the performance of transmission, especially for the scheduling with disabled feedback for corresponding HARQ process, following aspects are highlighted:

1. Blind retransmission

As highlighted by [Nomor Research GmbH, Thales], supports on blind PDSCH (re)transmission of the same packet by MAC scheduling without waiting for the transmission of the HARQ feedback can be considered.

1. Larger aggregation/repetition factor

Supports on the larger aggregation number is proposed by [CATT, ETRI] with the time-interleaved transmission [CMCC, CATT, Lenovo]. Indication of repetition-related parameters via DCI is also highlighted in [Huawei, Lenovo]. In addition, reduced DM-RS density in both time and frequency domain is also proposed for such case in [ZTE]. Meanwhile, as highlighted in [Nokia], RAN1 to discuss and decide on whether automatic repetitions can solve HARQ stalling in NTN.

1. CQI table with new BLER target

As mentioned in [Nomor Research GmbH, Thales, Qualcomm], introduction on the new CQI table with different BLER target seems to be beneficial. For example, the new table can be developed by assuming BLER equaling to 1% [Nomor Research GmbH, Thales].

1. UCI

As highlighted in [Xiaomi, Qualcomm, ETRI], in case of scheduling with disabled HARQ feedback, additional new UCI feedback, e.g., to report the decoding statistic or reporting DL transmission disruption and/or requesting DL scheduling changes, can be considered to improve the scheduling configuration from gNB side. Meanwhile, reporting of such information via MAC CE is also acceptable by [ETRI].

1. UE assistance information

As mentioned in [Samsung], with additional information from UE side, e.g., the buffer situation in the DL HARQ procedure, the decision for HARQ scheduling with enabled/disabled feedback can be optimized.

Moreover, as highlighted in [CAICT], for performance improvements with disabled HARQ-ACK, solutions with less speciation impacts should be considered firstly. For the solutions with much standardization work, the benefits should be justified.

Based on the above analysis, following proposal is provided according to majority view:

***Proposal 6****: Enhancements on PDSCH/PUSCH transmission can be considered.*

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| **Company** | **Comments and Views** |
| MediaTek | Support proposal 6 |
| Lenovo &MotoM | Support proposal 6 |
| Panasonic | Support proposal 6. In addition to above list, we propose to discuss an indication to recommend soft buffer usage (store or not) in DCI, as proposed in R1-2006327.  |
| Sony  | Support proposal 6, we prefer aspects 1&3. |
| CMCC | Support proposal 6.Nevertheless, solutions with less spec impacts (e.g., aspects 1&2) may be considered firstly. |
| Spreadtrum | We shared the same view with CMCC |
| CATT | Support proposal 6. More specifically, larger aggregation factor can be supported. |
| Huawei | We propose to add a new bullet:1. Enhancement for HARQ feedback

For handling the larger RTT for ACK/NACK feedback, enhancement as pre-active feedback [Huawei] is proposed. And in this way, the ACK/NACK will be feedback to gNB prior to the reception of re-transmission.With this addition Huawei would support Proposal 6. |
| Ericsson | The necessity of proposed enhancements should come with at least simulation results. Then companies could check the results and discuss whether a specific enhancement is needed. |

# **Others**

# **Extension of K1 value**

For enabling the scheduling with larger HARQ process number and potential ATG usage with TDD configuration, the extension of K1 value for scheduling is proposed in [ZTE, MTK]. Similar discussion is also conducted in AI 8.4.1.

***Proposal 7****: Extension of K1 value can be discussed in AI 8.4.1.*

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| **Company** | **Comments and Views** |
| MediaTek | Support proposal 7 |
| Lenovo &MotoM | Support proposal 7 |
| CMCC | Support proposal 7.In our understanding, extending K1 value range is not a specific requirement of ATG, actually it is beneficial for both LEO and ATG scenario.For example in LEO scenario, enlarge K1/K2 value range is beneficial to enable flexibly changing of timing relationship via DCI, which may reduce RRC signaling overhead for frequently updating $K\_{offset}$ to fit rapidly changed RTT.In ATG scenario, enlarge K1 value range is beneficial to reduce GP overhead.  |
| Huawei | We support Proposal 7 to consider the extension under AI 8.4.1 and not in the HARQ topic in order to avoid overlap. |
| Ericsson | Support proposal 7 |

# **Enhancement on the HARQ feedback**

For handling the larger RTT for ACK/NACK feedback, enhancement as pre-active feedback [Huawei] is proposed. And in this way, the ACK/NACK will be feedback to gNB prior to the reception of re-transmission.

***Proposal 8****: Further discussion and evaluation on the enhancement for HARQ feedback can be considered.*

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| **Company** | **Comments and Views** |
| Lenovo &MotoM | Not support. We don’t see the benefit of pre-active feedback. |
| CMCC | Support proposal 8 with lower priority.If repetition with large transmission interval (e.g., in granularity of RTD) is supported, pre-active feedback may be beneficial to reduce re-transmission overhead. |
| CATT | Not support. If any, the application scenarios and benefits should be justified. |
| Huawei | This issue on ACK/NACK feedback relates more generally to section 3.3 on enhancing the performance of transmission. We propose to move Proposal 8 and merge it with Proposal 6. |
| Ericsson | There are many problems with the “pre-active” feedback. Feedback in current NR is under network control. Such UE initiated “pre-active” feedback is against the basic design principle.  |

# **Misc.**

Additionally, following enhancements are also proposed by corresponding proponent, further discussion on these issues is expected:

* Introduce the larger CSI-Report periodicity [Nomor Research GmbH, Thales]
* Define a minimum time gap for both two PDSCHs of a HARQ process without feedbacks and two PUSCHs of a HARQ process [QC]
* Signalling of the HARQ enabling by the source satellite gNB before the completion of the handover should be studied [Samsung]

***Proposal 9****: Further discussion on the enhancements below can be considered:*

* *Larger CSI-Report periodicity*
* *Define a minimum time gap for both two PDSCHs of a HARQ process without feedbacks and two PUSCHs of a HARQ process*
* *Signalling of the HARQ enabling information by the source satellite gNB*

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| **Company** | **Comments and Views** |
| Lenovo &MotoM | Not support. These issues are not essential and can be discussed in later release. |
| CMCC | Support proposal 9 with lower priority. |
| CATT | Not support. No clear reason to justify these enhancements. |
| Huawei | Further enhancements can be considered if the benefits are obvious. |
| Ericsson | On larger CSI-report periodicity: The necessity would need to be further justified.On minimum gap of 2 feedback disabled PDSCHs/PUSCHs: This is a valid issue related to UE processing time discussion. It is worth further discussionOn HARQ info for handover: This belongs to RAN2 discussion. |

# **Conclusion**

In this summary, following proposals are made according to the contribution submitted in AI 8.4.3:

# **Appendix**

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| Contribution | Observation/Proposals |
| R1-2005267Huawei, HiSilicon | Observation 1: HARQ ID can be implicitly indicated via slot index at the cost of scheduling flexibility.Observation 2: HARQ ID can be implicitly indicated via DMRS at the cost of detection complexity.Observation 3: The pre-active HARQ feedback scheme can improve overall HARQ latency in NTN with multiple retransmission.Proposal 1: More than 16 HARQ process can be considered for higher throughput.Proposal 2: HARQ process number field in DCI shall not be extended to ensure the compatibility with existing NR protocols.Proposal 3: Part of HARQ process ID can be implicitly obtained by slot index and/or DMRS sequence while the rest are indicated from DCI. Proposal 4: Optimization on HAR Q processes scheduling can be considered for reducing HARQ-ACK codebook redundancy.Proposal 5: The pre-active HARQ feedback scheme can be considered as enhancement when enabling HARQ in NTN.Proposal 6: Reinterpreting bits in DCI for indicating repetition-related parameters shall be considered for disabled HARQ process. |
| R1-2005312 Nomor Research GmbH, Thales | Observation 1: For 15UEs per cell, the DL UE throughput is similar for 16 and 32 HARQ processes except when scheduling up to 4 UEs per TTI.Observation 2: For 15UEs per cell and a restriction to schedule up to 4UEs per TTI, the 50%-tile DL UE throughput is 7% higher, if up to 32 instead of 16 HARQ processes can be configured per UE.Observation 3: For 15UEs per cell and a restriction to schedule up to 2UEs or only 1UE per TTI, the 50%-tile DL UE throughput is the same independent if up to 32 or 16 HARQ processes can be configured per UE.Observation 4: For 20UEs per cell, the DL UE throughput is similar for 16 and 32 HARQ processes. Observation 5: The largest difference between the usage of 16 and 32 HARQ processes per UE can be observed for the 5%-tile DL UE throughput.Observation 6: Increasing the number of UEs per cell from 15 to 20, the difference of the DL UE throughput between systems where up to 16 or 32 HARQ processes per UE can be configured disappears.Observation 7: If the propagation delay decreases, e.g. for a system using a lower orbit, the round trip time decreases and 16 HARQ processes per UE will be sufficient. Observation 8: The main purpose of NTN is to provide coverage everywhere and to support high mobility. In real NTN scenarios, there is no need to schedule a UE in each TTI.Observation 9: UL resources utilization decreases with 3 or less UEs scheduled in one TTI.Observation 10: For 16 HARQ processes per cell, the UL UE throughput is maximized for a maximum of 3 UEs per TTI.Observation 11: For 15UEs per cell and a scheduling of 3UEs per TTI, the 50%-tile UL UE throughput is 11% higher, if up to 32 instead of 16 HARQ processes per UE are used.Observation 12: For 15UEs per cell, the difference of the UL UE throughput for the cases with 16 and 32 HARQ processes per UE decreases if the number of UEs scheduled per TTI decreases down to 3. Observation 13: Considering a LEO-1200 S-Band scenario with 20UEs per cell with a restriction to schedule up to 3UEs per TTI, the 50%-tile UL UE throughput is 9% higher, if up to 32 instead of 16 HARQ processes can be configured per UE.Observation 14: Considering a LEO-1200 S-Band scenario with 30UEs per cell the with a restriction to schedule up to 3UEs, the CDF of the UL UE throughput is similar if up to 32 or 16 HARQ processes can be configured per UE.Observation 15: Considering a LEO-1200 S-Band scenario with 30UEs per cell with a restriction to schedule up to 3UEs per TTI, the 50%-tile UL UE throughput is 2% higher, if up to 32 instead of 16 HARQ processes can be configured per UE.Observation 16: Considering a GEO Ka-Band scenario with FR3 and 10 LOS UEs per cell, the minimum TP per UE is 4.2Mbit/s.Observation 17: Considering a GEO Ka-Band scenario with FR3 and 10 NLOS UEs per cell, 88% of the UEs have a TP of 0bit/s.Observation 18: Considering a GEO Ka-Band scenario with FR3 and 10 UEs per cell and LOS probability according to TR 38.811, 6% of the UEs have no TP.Observation 19: Considering a GEO Ka-Band scenario with FR3 and 10 UEs per cell and LOS probability according to TR 38.811, 94.8% of the UEs have an RLC packet error rate smaller or equal than 2%.Observation 20: Considering a GEO Ka-Band scenario with FR3 and 10 LOS UEs per cell 99.2% of the UEs have an RLC packet error rate smaller or equal than 2%.Observation 21: Considering a GEO Ka-Band scenario with FR3 and 10 NLOS UEs per cell, 56.7% of the UEs have an RLC packet error rate smaller or equal than 2%.Observation 22: Considering a GEO Ka-Band scenario with FR3, the coupling loss for NLOS UEs is in most of the cases significantly larger than the coupling loss for LOS UEs (99% of LOS UEs have coupling loss smaller or equal 120dB, while only 13% of NLOS UEs have coupling loss smaller or equal 120dB). Observation 23: Considering a GEO Ka-Band scenario with FR3, the geometry SINR for NLOS UEs is in 50% lower than -6.5dB which was the minimum threshold to schedule a UE with lowest MCS in the performed SLS. LOS UEs show all geometry SINR larger than 1.5dB.Observation 24: Considering a GEO Ka-Band scenario with FR3 and 10 LOS UEs per cell, the TP per UE is in average 30% lower (8.8Mbit/s vs. 12.6Mbit/s) if link adaptation is performed based on the instantaneous channel state.Observation 25: Considering a GEO Ka-Band scenario with FR3 and 10 LOS UEs per cell, the probability of an RLC error rates per UE larger than 3% is 4% if link adaptation is performed based on the instantaneous channel state and BLER offset, while it is 0.6% if link adaptation is performed based on initial channel state measurement and BLER offset.Observation 26: Considering a GEO Ka-Band scenario with FR3 and 10 LOS UEs per cell, it is useful to do an averaging in terms of BLER rather than taking into account the instantaneous channel state due to the expiration of the channel state information upon receiving the CQI at the gNB because of the large transmission delay.Observation 27: Applying a CQI feedback with 1% PHY BLER target performs better in terms of TP than applying a CQI feedback with 10% PHY BLER target and an additional offset.Observation 28: The probability of an RLC error rate per UE larger than 2% is 0.8% if a PHY BLER target of 1% is applied and 0.5% if an averaged SINR in dB and an offset of -4.5dB is used for link adaptation. In the other considered cases of averaged SINR the RLC error rate is significantly larger.Observation 29: Considering a GEO Ka-Band scenario with FR3 and 10 LOS UEs per cell, the mean TP per UE increases from 13.2Mbit/s to 14.0Mbit/s if a PHY BLER target of 2% instead of 1% is applied.Observation 30: Considering a GEO Ka-Band scenario with FR3 and 10 LOS UEs per cell, the 5%-tile of the TP per UE increases from 8.4Mbit/s to 9.2Mbit/s if a PHY BLER target of 2% instead of 1% is applied.Observation 31: Considering a GEO Ka-Band scenario with FR3 and 10 LOS UEs per cell, the mean RLC error rate per UE increases from 1.1% to 2.2% if a PHY BLER target of 2% instead of 1% is applied.Observation 32: Considering a GEO Ka-Band scenario with FR3 and 10 LOS UEs per cell, the 5%-tile of the RLC error rate per UE increases from 0.8% to 1.8% if a PHY BLER target of 2% instead of 1% is applied.Observation 33: The specified 5QI match either packet error rate or delay of a GEO scenario but not both. Proposal 1: UEs supporting NTN should not be mandated to support a higher number of HARQ processes than terrestrial UEs. 16 HARQ processes should be the baseline. Proposal 2: RAN1 may consider 32 HARQ processes as optional UE capability for high capability devices supporting NR peak data rates in low load scenarios. .Proposal 3: The enhancement to the number of HARQ processes per UE shall be captured in following specification sections: Section 5.1 and 6.1 in TS 38.214, Section 6.3.2 in TS 38.331 and Section 4.2.7.10 in TS 38.306.Proposal 4: Allow to send blind PDSCH (re)transmission of the same packet by MAC scheduling without waiting for the transmission of the HARQ feedback. Proposal 5: For GEO scenarios change the channel model to a LOS only channel model meaning Table 6.6.1-1 of TR 38.811[5] does not apply.Proposal 6: Introduce larger CSI-Report periodicity values in TS 38.331 [2] to avoid unnecessary overhead in scenarios with large transmission delay.Proposal 7: Introduce a target BLER for CQI-Reporting to support NTN scenarios with HARQ disabled. Proposal 8: RAN1 to discuss reasonable assumptions for operator defined 5QI requirements to support GEO satellite communication in NR. |
| R1-2005497 MTK | Observation 1: Increasing the number of HARQ processes to match satellite round trip delay to avoid stop-and-wait in HARQ procedure results in a very high number of HARQ processes in device and gNB for LEO and GEO.Observation 2: The network can choose to configure shorter RLC window size parameters t-PollRetransmit = {5, 10, 15, 20, 25, …, 400, 450, 500, 800, 1000, 2000, 4000 ms} for UL and t-Reassembly = {5, 10, 15, 20, 25, …, 400, 450, 500, 800, 1000, 2000, 4000 ms} for DL in ul-AM-RLC and dl-AM-RLC configurations to match the satellite RTD without change to specifications. Observation 3: The network can configure shorter RLC window with the RLC status report transmitted by the UE at least once or several times per satellite RTD for LEO and GEO.Observation 4: Disabling UL HARQ feedback per UE per HARQ process and relying on shorter RLC window with RLC ARQ re-transmission for LEO and GEO will have the following benefits* No stop-and-wait due to UL HARQ feedback: this has the advantage of not decreasing the peak throughput even if the number of HARQ processes is kept to 16
* Re-use legacy DCI
* No impact on HARQ soft buffer

Observation 5: Reliability of Message 3 in RACH procedure cannot be achieved via RLC ARQ as RLC AM is not possible before contention resolution has completed.Proposal 1: UL HARQ retransmissions is not disabled for Message 3 transmission in RACH procedure.maximum data rates can be scheduled with HARQ feedback enabled. . Proposal 2: Whether UE should expect that at least one HARQ process is configured with UL HARQ feedback for MAC CE activation / de-activation is specified or up to network configuration can be further discussed.Observation 7: The HARQ parameters for each pool can be configured differently to ensure adequate reliability – i.e. Block error rate target, MCS table, aggregation factor, Time Domain and Frequency Domain resource allocation, PRB bundling, etc.Proposal 3: The network can configure one HARQ process pool with UL HARQ feedback enabled and one HARQ process pool with UL HARQ feedback disabled. Whether HARQ process IDs with UL HARQ feedback disabled via RRC can do HARQ soft combining is a UE capability.Observation 8: 16 HARQ processes are sufficient for ATG NR TDD with 20 ms UL-DL switching periodicity.Observation 9: The value range of K1 for the scheduling gap between the DL packet on PDSCH and the corresponding UL HARQ feedback on PUSCH/PUCCH may need to be increased. |
| R1-2005575Sony | Observation 1: The beam switching is a time-sensitive behavior due to the movement of satellite. Waiting for the HARQ feedback for PDSCH carrying MAC CE for beam switching may miss the favorable time.Observation 2: The redundant feedback of Type-1 / semi-static HARQ codebook would be large based on current HARQ codebook design.Proposal 1: Support at least one HARQ process with HARQ feedback enabled.Proposal 2: When the MAC CE for beam switching is carried by PDSCH without HARQ feedback. UE applies the corresponding action with the reference to slots of the end of PDSCH transmission.Proposal 3: When the HARQ process of SPS PDSCH is HARQ feedback disabled, UE reports HARQ feedback information for the SPS PDSCH activation.  |
| R1-2005708CATT | Proposal 1: Keep at least one HARQ process with feedback if UE specific disabling is configured. Proposal 2: Using HARQ process ID subset to differentiate HARQ feedback should be supported, no need DCI change for HARQ disabling.Proposal 3: Support more than 16 process IDs depending on UE capability. Proposal 4: Keep 16 HARQ process number at most in fallback case. Proposal 5: Re-interpreting DCI field to indicate the HARQ index in case of more than 16 HARQ processes configured.Proposal 6: Support time interleaved slot aggregation to improve transmission reliability. Proposal 7: Support more than 8 repetitions in slot-aggreation transmission. |
| R1-2005835Lenovo | Proposal 1: Support more than 16 HARQ process number in NTN to match long RTT delay.Proposal 2: The HARQ process number is tied to SFN/slot index of PDCCH/PUSCH/PDSCH.Proposal 3: Different numbers of HARQ processes is configured based on UE capability.Proposal 4: UE assume the HARQ feedback disabling where HARQ ID belongs to the RRC configured HARQ process disabling subset.Proposal 5: The multiple transmissions of same TBs in consecutive or interlaced slots can be considered when HARQ is disabled.Proposal 6: Repetition transmission number and interlace transmission interval can be indicated in corresponding DCI when HARQ process is disabled. |
| R1-2005875Intel | Proposal 1:* Enabling / disabling of HARQ feedback for DL transmission should be configurable per HARQ process
	+ UE may expect reception of retransmission for HARQ process with enabled or disabled HARQ feedback

Proposal 2: * If more than 16 parallel HARQ processes are supported for NTN,
	+ HARQ process ID is determined based on DCI indication and slot index of the corresponding transmission
		- 4 bits are used for HARQ process ID indication in DCI
	+ Additional constraints on maximum TBS for a HARQ process or maximum total TBS across all parallel HARQ processes are discussed
 |
| R1-2005965ZTE | Observation 1: Existing HARQ process number is not sufficient to support NTN case.Observation 2: Performance gain can be achieved for the results based on enlarged HARQ process number comparing to the scheduling with disabled HARQ feedback and conservative scheduling, e.g., MCS offset and MCS table with LSE.Observation 3: Performance gain can be achieved for the results based on enlarged HARQ process number comparing to the scheduling with disabled HARQ feedback and lower target BLER.Observation 4: Performance gain can be achieved for the results based on enlarged HARQ process number comparing to the scheduling with disabled HARQ feedback and RLC-ARQ.Observation 5: Performance gain can be achieved for the results based on enlarged HARQ process number comparing to the TDM-ed scheduling with less HARQ process number.Observation 6: It’s necessary to support the HARQ procedure with larger process number in NTN case.Observation 7: The impacts on the UE/BS capability with support on extended HARQ process number is affordable.Proposal 1: Extension of the maximum supported HARQ process number, e.g., up to 32, should be supported for NTN.Proposal 2: Re-interpretation of bits in DCI should be considered as the baseline to support the HARQ process indication with extended maximum HARQ process number.Proposal 3: Enabling/disabling of HARQ feedback in per UE, per HARQ process and per LCH should be supported.Proposal 4: As one baseline assumption, at least one HARQ process with HARQ feedback should be kept. * FFS on whether and how to capture it in specification

Proposal 5: Extension of K1 value should be supported.Proposal 6: Additional enhancement to minimize the DM-RS overhead can be considered. |
| R1-2006031OPPO | Proposal 1: RRC configuring or DCI indicating the disabling of HARQ processes for both DL and UL scheduling should be considered.Proposal 2: HARQ-ACK information should be reported for disabled DL HARQ processes.Proposal 3: HARQ process number can be increased for capable UE if it does not increase UE buffer/cost. Proposal 4: Low DCI overhead methods should be considered if the number of HARQ processes is increased. Proposal 5: Enhancements to PDSCH/PUSCH transmission to achieve higher reliability should be considered.  |
| R1-2006146Samsung | Proposal 1: The number of HARQ processes should be increased.Proposal 2: Mechanism to simplify the DCI format should be supported in NTN.Proposal 3: To support more than 16 HARQ process IDs a slot number based HARQ process ID constructor should be supported in NTN.Proposal 4: Further discuss whether to support to disable HARQ feedback for all the HARQ processes.Proposal 5: UE assistance informaiton for HARQ should be studied for NTN.Proposal 6: Signalling of the HARQ enabling by the source satellite gNB before the completion of the handover should be studied. |
| R1-2006212CMCC | Proposal 1: Support greater than 16 HARQ process number in NTN and keep 4-bit HARQ process number field in DCI.Proposal 2: The time domain window based HARQ scheme can be used for greater than 16 HARQ process ID indication.Proposal 3: The multiple transmissions of same TB in in-consecutive slots can be considered when HARQ is disabled. And at least the following parameters should be included for the configuration: * Repetition number
* The slot interval of repetition slots

Proposal 4: The following HARQ re-transmission parameters configuration methods can be considered:* Via RRC signaling semi-static configuration
* Reuse and redefine HARQ related DCI fields
* Remove HARQ related DCI fields and introduced some new DCI fields
 |
| R1-2006327Panasonic | Proposal 1: The maximum number of HARQ processes should be increased for NTN. Candidate would be up to 64 for S-band (FR1) and 256 for Ka-band (FR2).Proposal 2: The following implicit indication of HARQ process ID should be discussed to minimize the DCI size.  Option 1: HARQ process is tied to SFN/slot number  Option 2: Reuse HARQ process ID within RTT by time segmentationProposal 3: A flag in DCI to recommend UE to store HARQ buffer should be supported. |
| R1-2006360ETRI | Observation 1 : When HARQ feedback is disabled on a per UE, the ACK/NACK information for gNB to determine whether DL transmission has become reliable or not does not exist.Observation 2 : Without HARQ feedback, it is impossible for gNB to know whether the transmission parameter is appropriate for the current situation or not.Observation 3 : With slot aggregation, the transmission parameter should be determined properly. * Too reliable parameter : throughput loss
* Too un-reliable parameter : reliability loss

Observation 4 : For minimizing RAN1 impact, UL feedback via MAC-CE/RRC is preferred rather than UL feedback via UCI.Observation 5 : slot aggregation factor is unique for either PDSCH or PUSCH.Observation 6 : slot aggregation factor change could lead to both throughput change and reliability change.Observation 7 : Each transmission parameter has its own SAF value for optimal performance.Observation 8 : Transmission parameter changes might lead to SAF change for achieving optimal performance.Observation 9 : Target performance change might result in requiring SAF value change for optimal performance.Observation 10 : Target performance might be defined individually per RNTI and/or per search space and/or per whether HARQ feedback is disabled or not.Observation 11 : Optimal performance can be achieved by introducing separate SAF per each transmission parameter and/or per each required target performance.Observation 12 : In case of NR, because SAF is unique, the change of SAF is required whenever parameter and/or target performance changes for optimal performance.Proposal 1 : Support a new UL feedback via UCI/MAC-CE/RRC for reporting DL status or requesting DL scheduling changes when HARQ feedback is disabled. * UL feedback can include information such as
	+ DL decoding statistics
	+ request for reducing/increasing MCS
	+ request for reducing/increasing pdsch-AggregationFactor
	+ combinations of the above

Proposal 2 : Introduce multiple aggregation factors per PDSCH/PUSCH for achieving optimal adaptation* the following components could be considered as the axis of multiple aggregation factors span
	+ MCS index, modulation order, code rate, spectral efficiency, etc
	+ RNTI type, search space type, etc
		- PDSCH related RNTI : {P,SI,RA,MSGB,TC,C,MCS-C,CS}-RNTI
		- PUSCH related RNTI : {TC,C,MCS-C,CS}-RNTI
		- search space type : {Type0,Type0A,Type1,Type2,Type3}-CSS, USS
	+ whether HARQ feedback is disabled or not, etc
	+ combinations of the above
	+ subsets of the above
 |
| R1-2006380LG | Proposal 1: Based on the UE capability, more than 16 HARQ processes are supported in NTN.Proposal 2: Consider CCE index based HARQ process id identification for NTN.Proposal 3: At least one HARQ process is enabled for HARQ feedback.Proposal 4: Discuss on HARQ-ACK codebook enhancement when HARQ feedback is disabled. |
| R1-2006423Nokia | Observation 1: Continuously scheduling a UE under NTN operation may lead to lower link efficiency due to HARQ stalling.Observation 2: Spreading the UE scheduling over time, lowers the likelihood of lower link efficiency due to stalling.Observation 3: Even for a continuously scheduled UE it is important to avoid stalling due to HARQ in order to save UE power and maximize the network usage.Observation 4: Disabling HARQ and relying on higher layer retransmissions reduces the flexibility of the scheduler and may result in lower spectral efficiency. Observation 5: Disabling HARQ and relying on higher layer retransmissions leads to higher latency per retransmitted packet, which may harm certain applications, in special considering the physical latency constraints in NTN environment.Observation 6: Increasing the number of HARQ processes leads to higher UE complexity.Proposal 1: RAN1 to discuss and decide on whether automatic repetitions can solve HARQ stalling in NTN. |
| R1-2006465 Ericsson | Observation 1 The motivation of increasing number of HARQ processes is not clear, as there exist several other ways to address the issue originated from the stop-and-wait HARQ protocol, particularly by enabling / disabling HARQ feedback. In addition, depending on carrier frequency, subcarrier spacing, satellite altitude and elevation, the needed number of HARQ processes will differ. Hence, any increase is likely to be insufficient for many configurations.Observation 2 Evaluation results show that compared to increasing the number of HARQ processes, HARQ without feedback achieves similar throughput performance.Observation 3 The main purpose of NTN is to provide ubiquitous coverage rather than to provide maximum throughput. Considering the negligible performance difference for realistic scenarios and the added UE complexity and specification impact, it is not desirable to increase the number of HARQ processes.Proposal 1 UE expects that at least one HARQ process is configured with UL HARQ feedback.Proposal 2 RAN1 to discuss what parameters need to be configured differently for HARQ processes with feedback and HARQ processes without feedback.Proposal 3 When HARQ processes are enabled/disabled on a per HARQ process basis, in the case of the NR Type-1 HARQ codebook, the UE inserts NACKs in positions corresponding to PDSCHs associated with feedback disabled HARQ processes.Proposal 4 When HARQ processes are enabled/disabled on a per HARQ process basis, in the case of the NR Type-2 HARQ codebook, the UE ignores counter DAI from a PDCCH that is associated with a feedback disabled HARQ process and counter DAI is not incremented for such a PDCCH.Proposal 5 When HARQ processes are enabled/disabled on a per HARQ process basis, in the case of the NR Type-2 HARQ codebook, the total DAI (if present) indicates the sum of all the scheduled PDCCHs associated with feedback enabled HARQ process.Proposal 6 When HARQ processes are enabled/disabled on a per HARQ process basis, in the case of the NR Type-3 HARQ codebook, the codebook size is dimensioned to include ACK/NACK information only for HARQ processes that are enabled.Proposal 7 RAN1 to conclude that there is no need to increase the number of HARQ processes for NTN. |
| R1-2006521Apple | Proposal 1: NTN supports dynamic enabling/disabling of HARQ feedback. The HARQ feedback is disabled if HARQ process number is configured with disabled HARQ feedback or if dynamically indicated by layer-1 signaling.Proposal 2: The maximum number of HARQ processes for NTN is larger than 16, based on UE capability.Proposal 3: The HARQ process number field in DCI is remained to be 4 bits, and DCI fields are re-interpreted to indicate more than 16 HARQ process numbers.  |
| R1-2006604Xiaomi | Proposal 1: The number of supported HARQ processes can be extended in NTN scenarioProposal 2: The number of the HARQ process indicator in the scheduling grant should be kept unchanged. Proposal 3: Dynamic HARQ enabling/disabling is not supported.Proposal 4: Enhancement on the UCI reporting such as the data decoding statistics should be introduced. |
| R1-2006642Asia Pacific Telecom | Observation 1 For Earth fixed cells, UE may experience poor channel quality for a longer time than Earth moving cells due to having low elevation angles during service.Observation 2 Based on TR 38.821, it is unclear whether the legacy HARQ-ACK codebooks are supportedBased on these observations, we have the following proposalsProposal 1 For Earth fixed cells, HARQ enhancement, especially for low elevation angles, may need FFS.Proposal 2 Type-1 and Type-2 HARQ-ACK codebooks shall be supported in Rel-17 NTN.Proposal 3 To support Type-1 HARQ-ACK codebook, minor changes on the scheduling offset shall be FFS.Proposal 4 To support Type-2 HARQ-ACK codebook, minor changes on the scheduling offset shall be FFS. |
| R1-2006806Qualcomm | Proposal 1: For NTN, UE reports the capability on the number of HARQ processes.Proposal 2: For NTN, more than 16 HARQ processes can be configured.Proposal 3: For NTN, support slot number based HARQ process identification when more than 16 HARQ processes are configured to a UE. Proposal 4: Define a minimum time gap between two PDSCHs of a HARQ process without feedbacks * Different numerologies may have different time gaps.
* FFS to introduce virtual k1

Proposal 5: Consider new CQI BLER targets for HARQ processes without feedbacks.Proposal 6: Support a new UCI feedback for reporting DL transmission disruption and/or requesting DL scheduling changes when HARQ feedback is disabled. * To study the new UCI format and associated resource allocation.

Proposal 7: Support different transmit parameters and/or configurations per HARQ process or per HARQ process type (retransmissions is enabled/disabled), including* Power control
* MCS table
* UCI multiplexing parameters
* FFS other parameters

Proposal 9: For NTN, UE may receive a DCI scheduling a PUSCH of a given HARQ process before the end of the transmission of another PUSCH of that HARQ process. Proposal 10: Define a minimum time gap between two PUSCHs of a HARQ process. |
| R1-2006857CAICT | Proposal 1: Decide the maximum supported number of HARQ process number before discussing the indication method. The supported number of HARQ process number is determined by the requirement of peak data rates in NTN.Proposal 2: Basic assumption for supporting HARQ-ACK disable/enable is to configure two subsets of HARQ processes for enabled HARQ processes and disabled HARQ processes respectively via RRC signaling. To decide the HARQ-ACK disable/enable state with HARQ process ID indication in the scheduling DCI.Proposal 3: Enabling/disabling of HARQ feedback for DL SPS/UL CG is configured per configuration.Proposal 4: For performance improvements for disabled HARQ-ACK, solutions with less speciation impacts should be considered firstly. For the solutions with much standardization work, the benefits should be justified. |