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

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

**Agenda item:** 8.15.4

**Source:** Moderator (Samsung)

**Title:** Summary#1 of enhancements on HARQ

**Document for:** Discussion and Decision

# Introduction

One item of the second objective of the Study on NB-IoT/eMTC support for Non-Terrestrial Network [1] is about studying aspects related to HARQ operation. In RAN#91-e [2] it was discussed the prioritization of enhancements of essential features that can be considered in a potential normative phase in Rel-17.

From [RP-210915](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_91e/Docs/RP-210915.zip):

* *The study on IoT over NTN should target the following by RAN#92*
	+ *Detailed study of solutions addressing essential functionality for GEO and NGSO scenarios, prioritizing at least the use case of intermittent delay-tolerant small packet transmissions*
	+ *Prioritization of potential enhancements for the functionalities needed specifically for IoT over NTN that cannot be translated from the ongoing NR NTN WI for the considered scenarios and use case(s) in the study*
	+ *Recommendations on specification changes needed at least for essential functionality (to be determined by working groups targeting Rel-17), for the considered scenarios and use case(s)*
	+ *Note: Additional enhancements on at least the following can be considered by the working groups as candidates for non-essential functionality in Rel-17.*
		- *HARQ*
		- *Latency*
		- *Power consumption*
		- *Spectral efficiency*
		- *Coverage*
		- *Mobility*
		- *RLF and re-establishment handling*
* *Time permitting, at least a high-level description of the potential solutions for enhancements targeting potential optimization of IoT NTN in later releases can be captured in TR 36.763, when feasible.*

This contribution summarizes companies’ views for enhancements on HARQ.

# Discussion

In RAN1#104-e [3] potential enhancements for HARQ operation for NB-IoT/eMTC in Non-Terrestrial Networks were identified. A RAN discussion in RAN#91-e concluded in [2] that the study on IoT over NTN should target prioritization of potential enhancements for the functionalities needed for IoT over and that the working groups should recommend the specification changes needed at least for essential functionalities. Companies’ views are summarized in Sections 2.1 to 2.9 with respect to what was identified in RAN1#104-e as potential aspects to be studied. For many of the aspects identified in RAN1#104-e only few companies provided an opinion in this meeting. Given the RAN guidance, it can be assumed that most aspects are considered not essential for specification in Rel-17 and can potentially be revisited in Rel-18 and beyond.

## Number of HARQ processes

Increasing the number of HARQ processes and disabling HARQ feedback are the two functionalities that are discussed by almost all companies. These two functionalities have been considered in NR NTN in order to mitigate the impact of HARQ stalling to throughput. Companies’ views are given in Table 1. Few companies did not express an explicit opinion on these two issues while mentioning the RAN#91-e discussion to focus on essential functionalities. In the moderator’s opinion, this can be interpreted that the issue is not considered essential.

**Table 1 - Views on increasing number of HARQ processes**

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| **Company** | **Input** |
| Huawei, HiSilicon | For GEO, the timing between NPUSCH and its corresponding NPDCCH indicating ACK/NACK can already be occupied with 2 HARQ processes for the case of multi-tone transmission with 6 subcarriers and single tone transmission |
| Oppo | Increased HARQ process number for NB-IoT/eMTC over NTN should be studied and specified in later release. |
| Spreadtrum | Reducing processing delay would require more capable DSP which would have significant impact on baseband cost in device. Given that the delay and data rate characteristics of IoT applications, this is not needed. |
| Vivo | Observation 1: The required HARQ process number is less than the subframe number in the RTT latency due to the larger repetition factor of IoT transmission.The objective of extending the HARQ number is to obtain high throughput and low delay for the IoT service - not typical for IoT usage cases which are typically small data size and infrequent data transmission, and delay-tolerant is a key requirement of IoT service. |
| CATT | Observation 1: Increasing the number of processes will cause additional UE cost, which is critical for NB-IoT case.Same applies to eMTC. |
| APT, FGI, ITRI, III | Non-essential functionality for NB-IoT in Rel-17, deprioritize |
| MediaTek | Observation 1: for NB-IoT, HARQ stalling reduces data rates by approximately 95% and 49% for GEO and LEO respectively. Observation 2: With 4 HARQ processes, HARQ stalling reduces data rates by approximately 53% and 22% for GEO and LEO respectively.Observation 3: It is sufficient to use 1 or 2 HARQ processes for NTN NB-IoT and eMTC in LEO and GEO scenarios to support data rates for intermittent delay-tolerant small packet transmissions in typical IoT applications.Proposal 1: Re-use 1 or 2 HARQ processes for NTN NB-IoT and eMTC in LEO and GEO scenarios. |
| Nokia, NSB | • The advantage will be mitigation of HARQ stalling and reducing the loss on throughput/data rate because of large RTT in NTN scenario, • While the disadvantage will be the cost and complexity of UE will increase along with the increased ratio of HARQ process number and one another issue would be the advantage can only exist when there is chance for the increased HARQ processes to be used. As discussed in [2], even with more HARQ process, it may not help, as the repetition may take so long time, e.g. 2048ms for NB-IoT NPDSCH and eMTC PDSCH, and one HARQ process could occupy all the time resource with the repetitions.Observation 2: More HARQ process with more cost/complexity may not help when repetition number is too large.Proposal 1: Both number of HARQ process and number of repetition, which will impact throughput, should be evaluated. |
| ZTE | Proposal 1: HARQ process number for NB-IoT/eMTC in terrestrial network is reused for IoT-NTN. |
| Xiaomi | Proposal 1: The number of the supported HARQ process should not be increased for IoT NTN. |
| Ericsson | Proposal 1 Do not increase the number of HARQ processes for eMTC. |
| Apple | Observation 1: The acquired throughput and latency of IoT over NTN, without increasing the number of HARQ processes, may still be enough to support IoT services.Observation 2: Increasing the number of HARQ processes increases IoT device complexity.  |
| Samsung | Proposal 4: Number of HARQ processes should be kept considering increasing HARQ process number will cause additional UE cost. |
| Interdigital | Observation-1: Only essential enhancement which is required to enable IoT support in NTN system should be considered in Rel-17 to expedite the progress and finish the SI earlier than planned and have a reasonable scope of normative work in Rel-17Proposal-1: Extending maximum HARQ process number is not supported in Rel-17 IoT NTN. |
| Lenovo, MM | Proposal 1: The HARQ process number can be maintained the same as legacy for both eMTC and NBIoT. |

**Summary of companies’ views:**

* No increase of the number of HARQ processes
	+ Supported by: Huawei, HiSilicon, Oppo, Spreadtrum, Vivo, CATT, APT, FGI, ITRI, III, MediaTek, ZTE, Xiaomi, Ericsson, Apple, Samsung, Interdigital, Lenovo, Motorola Mobility
	+ Not expected to be helpful, evaluate (Nokia, NSB)

**Proposal 1-1:**

**Increasing the number of HARQ processes for NB-IoT and for eMTC in NTN is not supported in Rel-17.**

The issue of HARQ stalling and increase in number of HARQ processes for NB-IoT and eMTC in NTN can be briefly captured in the TR, along with the RAN1 conclusion of not introducing it in Rel-17. If there is an agreement on capturing this in the TR, the next step would be to discuss a text proposal.

**Question 1-1:**

**Should a brief description of HARQ stalling issue in NTN, increasing the number of HARQ processes and RAN1 conclusion of not increasing the number of HARQ processes in Rel-17 NTN IoT be captured in the TR?**

Companies are encouraged to provide feedback on Question 1-1.

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| **Company** | **Comments** |
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## Disabling HARQ feedback

Disabling of HARQ feedback has been agreed in NR NTN: *Enabling/disabling on HARQ feedback for downlink transmission should be at least configurable per HARQ process via UE specific RRC signalling*. With this solution, no explicit UL feedback for DL transmission acknowledges a successful transmission and the HARQ process does not need to wait for the feedback before a new data transmission. This can avoid HARQ stalling and consequently throughput degradation. Correspondingly, retransmission at RLC layer (i.e. RLC ARQ) may be required to meet reliability requirements. Typically, ARQ re-transmissions in RLC can have high latency, which might be acceptable as IoT services are generally delay tolerant.

**Table 2 Views on disabling HARQ feedback**

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| **Company** | **Input** |
| Huawei, HiSilicon | HARQ processes can meet the data rate requirement for both UL and DL, there is no need to disable HARQ feedback for the reason of increasing data rate. IoT NTN is delay tolerant, it is not obvious that there is any need to disable DL HARQ processes. |
| Oppo | HARQ disabling for NB-IoT/eMTC over NTN should be studied and specified in later release. |
| Spreadtrum | Whether to support disabling HARQ feedback for NB-IoT and eMTC can be considered in R18. |
| Vivo | Functionality of disabling HARQ feedback is not necessary from a latency viewpoint. Benefits are power consumption and resource utilization improvement.Observation 2: It is up to network implementation to determine whether to disable HARQ process, the number of disabled HARQ processes and enabling/disabling for one HARQ process.Proposal 3: The functionality of enabling/disabling per HARQ process can be configured in semi-static or dynamic way. |
| CATT | Observation 2: Disabling HARQ feedback doesn’t show clear benefit to NB-IoT use case. Proposal 4: Reuse disabling HARQ feedback mechansim of NR NTN for CEmodeA in eMTC NTN, and no need to disable HARQ feedback for CEmodeB UE. |
| APT, FGI, ITRI, III | Non-essential functionality for NB-IoT in Rel-17, deprioritize |
| MediaTek | Proposal 2: UL HARQ feedback is not disabled for Message 3 during initial access.Observation 4: Allowing HARQ re-transmissions without disabling of UL HARQ feedback is consistent with the requirements for latency and data rates for intermittent delay-tolerant small packet transmissions for LEO and GEO.Observation 5: HARQ stalling has no significant impact on UE power consumption as the active time is highly dependent on the transmit time which is not reduced by removing HARQ stalling.Proposal 3: Re-use HARQ without disabling HARQ feedback for intermittent delay-tolerant small packet transmissions. |
| Nokia, NSB | Observation 3: HARQ feedback disabling is not helpful in some of IoT NTN scenarios.  |
| CMCC | Non-essential functionality for NB-IoT in Rel-17, deprioritize |
| ZTE | Proposal 2: HARQ feedback disabling for DL can be supported in IoT-NTN. |
| Xiaomi | Support of HARQ disabling can have the negative impact on the reliability which in turn can possibly increase the UE’s power consumption. The IoT application is normally target for delay insensitive small data packets, thus, the support of HARQ disabling is not required.Proposal 2: HARQ disabling is not supported for IoT NTN. |
| Ericsson | Proposal 2 Study further the benefits and drawbacks of disabling HARQ feedback. |
| Qualcomm | Proposal 1: RAN1 to support at least one feedback-disabled HARQ process for NB-IoT over NTN. (essential feature for Rel-17) |
| Apple | Observation 3: Disabling HARQ feedback for downlink transmissions may increase the data rate, at the cost of reduced reliability. Observation 4: Disabling HARQ feedback for downlink transmissions does not increase the IoT device complexity and can reduce the power consumption. |
| Samsung | Proposal 1: Disabling of HARQ feedback should be supported as NR NTN.Proposal 2: HARQ feedback can be enabled/disabled per HARQ process via UE specific RRC signaling as NR NTN.Proposal 3: Whether to support disabling of HARQ feedback for all the HARQ processes should be discussed. |
| Interdigital | Observation-1: Only essential enhancement which is required to enable IoT support in NTN system should be considered in Rel-17 to expedite the progress and finish the SI earlier than planned and have a reasonable scope of normative work in Rel-17Proposal-2: Enabling/disabling HARQ feedback is not supported in Rel-17 IoT NTN (not essential in Rel-17) |
| Sony | Observation 1: For GEO, 63% (512ms out of 806ms) of the HARQ cycle time is occupied by active PUSCH transmissions when 2 HARQ processes are active.Observation 2: For LEO constellations, the UE processing pipeline can be fully loaded with active PUSCH transmissions when 2 HARQ processes are active. |
| Lenovo, MM | Proposal 2: At least for NBIoT NTN, disabling HARQ is not supported. |

**Summary of companies’ views:**

* Disabling HARQ feedback

Supported by Vivo, CATT (only for eMTC CEModeA), CMCC, ZTE, Qualcomm, Samsung

* No disabling of HARQ feedback

Supported by: Huawei, HiSilicon, Oppo, CATT (for NB-IoT and eMTC CEModeB), APT, FGI, ITRI, III, MediaTek, Nokia, NSB, CMCC, Xiaomi, Interdigital, Lenovo, Motorola Mobility (for NB-IoT)

* Further study (Ericsson)
* Open to support (Apple)
* Open to study for eMTC only (Lenovo, Motorola Mobility)

Companies have discussed the motivation for disabling HARQ feedback and some companies think that it is not necessary to introduce it in NTN IoT because IoT is delay tolerant. Other companies think that the main motivation for introducing it is power saving, however others mention that the reduced reliability due to disabling HARQ feedback can in turn cause a larger power consumption. Besides the impact on performance, companies have suggested to deprioritize such enhancement in Rel-17 for the purpose of focusing the study only on essential features that can allow NB-IoT and eMTC operation in NTN.

**Further discuss**

Companies are encouraged to provide further comments on disabling HARQ feedback to understand whether consensus could potentially be reached for disabling HARQ feedback only under certain conditions, e.g. number of processes, etc.

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| **Company** | **Comments** |
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## Other HARQ feedback mechanisms

**Table 3 Views on introducing additional HARQ feedback**

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| **Company** | **Input** |
| APT, FGI, ITRI, III | Non-essential functionality for NB-IoT in Rel-17, deprioritize |
| Nokia, NSB | If stalling is to be avoided with one HARQ process without disabling feedback, some other feedback mechanisms should be studied, including their timing. This feedback can include mechanisms from the UE to provide proactive feedback. Similar to Early Termination, where the network informs the UE that is has received sufficient number of uplink repetitions, the UE may be able to provide such information for downlink transmissions when sufficient number of repetitions are received, or even determine it prior to having received the sufficient number. In the latter case, the UE could estimate the expected number of required remaining repetitions prior to actually receiving them and indicate the number to the network, such that the propagation delay impact is minimized.Furthermore, the base stations ability to perform link adaptation is reduced, if the UE does not provide HARQ feedback. The reason is that link adaptation algorithms take into account the ACK/NACK when deciding the MCS for a transmission. Considering that CQI in NTN can be stale some type of feedback may be necessary for link adaptation. Therefore, RAN1 can discuss means to reduce the signaling overhead of HARQ feedback, for example by defining BLER-based triggering or bundling of feedback. Observation 3: HARQ feedback disabling is not helpful in some of IoT NTN scenarios. Proposal 2: Alternative feedback for HARQ, e.g. assistance on requested number of repetition, BLER-based triggering or bundling of feedback, should be considered to maximize the performance of the link. |
| Samsung | In another aspect, a UE is fully aware of the buffer situation in the DL HARQ procedure. If a UE observes the buffer for HARQ operation is full or almost full, it would be beneficial to trigger the HARQ disabling from the UE side, although the final decision of HARQ disabling/enabling is configured from the network side. For example, a UE can report HARQ related information in the RRC parameter UEAssistanceInformation to request for HARQ disabling/enabling, and the HARQ related information could be an explicit indication of HARQ disabling/enabling request, or a buffer condition for HARQ operation for gNB to consider disabling/enabling HARQ. For another example, a UE can report HARQ related information in the RRC parameter UEAssistanceInformation to request for adapting the number of HARQ processes, in an explicit way by requesting the number or an implicit way by reporting the buffer condition. Alternatively, the UE buffer size could be signaled as part of UE capability, then gNB could handle contiguous data transmission, if necessary, by estimating the UE’s soft buffer status.Proposal 5: UE assistance information for HARQ can be supported. |

Two companies discuss introducing other HARQ feedback mechanisms. Various types of feedback are proposed:

* Timing - UE informs the network a sufficient number of repetitions has been transmitted
* UE assistance on requested number of repetition, BLER-based triggering or bundling of feedback, should be considered to maximize the performance of the link
* Report of buffer status
* Request for HARQ disabling/enabling

**Further discuss**

In a first round of discussions, companies are encouraged to provide views on the proposals or other aspects related to additional feedback, however the low interest in this topic may be due to the consideration of only essential features for Rel-17.

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| **Company** | **Comments** |
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## Reduced PDCCH monitoring

**Table 4 Views on reduced PDCCH monitoring**

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| **Company** | **Input** |
| APT, FGI, ITRI, III | Non-essential functionality for NB-IoT in Rel-17, deprioritize |
| Huawei, HiSilicon | For a NTN UE that is configured with one HARQ process, if the NPUSCH transmission ending in subframe n, due to long RTT, the corresponding NPDCCH which indicated ACK/NACK would not come before RTT, therefore, UE shall skip NPDCCH monitoring to reduce power consumption. When an NTN UE is configured with higher layer parameter *twoHARQ-ProcessesConfig,* NPDCCH candidates from the two HARQ processes can be scheduled together or separately. Obviously, DCI with format N0 which indicates the ACK/NACK information from the same HARQ process will not come within RTT+3 from the ending of the corresponding NPUSCH transmission (NPUSCH0). However, for the “one by one” scheduling, UE needs to monitor the NPDCCH from the other HARQ process, which may come after a short period of NPUSCH0 transmission. Observation 2: The earliest subframe for a UE to receive an NPDCCH with DCI format N0/N1 for the same HARQ process depends on the offset between the UL and DL frame timing at the eNB. |
| ZTE | When HARQ feedback is enabled, the interval between two transmissions of one HARQ process should be longer than RTT. During this interval, UE is not possibly to receive a PDCCH. Hence, the PDCCH monitoring in this waiting time can be skipped to reduce power consumption. In traditional TN, the active time for PDCCH monitoring is controlled by HARQ RTT Timer and UL HARQ RTT timer. By enhancing the timers, e.g., add an additional offset corresponding to RTT, UEs can avoid to monitor PDCCH for a long time.Observation 3: Reduced PDCCH monitoring can be achieved by enhancing HARQ RTT Timer. |
| Sony | Figure 1 shows that for a GEO deployment there are portions of the HARQ cycle in which the UE cannot be scheduled with UL data since there are no available free HARQ processes in the UE. However, the UE needs to monitor MPDCCH during this time period just in case it is going to be scheduled (e.g. with an MPDCCH signaling a DL grant, even though this is unlikely). The requirement to monitor MPDCCH, even though the UE is unlikely to be scheduled, leads to unnecessary and wasteful UE power consumption.It is hence proposed that, in order to reduce power consumption, when a UE is scheduled PUSCH in the UL, it does not need to monitor MPDCCH until the RTT time has elapsed from the end of the PUSCH. This is a form of reduced MPDCCH monitoring, leading to lower UE power consumption, since the UE is able to sleep.Proposal 1: In order to reduce power consumption, when a UE is scheduled PUSCH in the UL, it does not need to monitor MPDCCH until the RTT time has elapsed from the end of the PUSCH. |
| Lenovo, MM | Proposal 3: NB-IoT UE is to skip NPDCCH monitoring for an HARQ process for a longer time interval than the time interval in TN. |

This issue relates to the monitoring of a PDCCH which indicates the ACK/NACK after transmission of a PUSCH. Since the PDCCH would not be received before a RTT after the end of the transmission of the corresponding PUSCH, the UE can skip monitoring PDCCH for a time interval that depends on the RTT. The introduction in NTN of an additional offset to the timing relationships between the end of a PUSCH transmission and the start of the received corresponding PDCCH may be treated in the AI 8.15.3. Further coordination is needed. In order to progress the discussion, the following proposal can be considered.

**Proposal 4-1:**

**For a NTN UE that is configured with one or more HARQ processes, the UE does not monitor PDCCH until the RTT time has elapsed from the end of the PUSCH.**

Companies are encouraged to provide comments on the proposal and/or any other aspect related to reducing PDCCH monitoring.

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| **Company** | **Comments** |
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## Coverage enhancement

**Table 6 Views on coverage enhancement**

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| **Company** | **Input** |
| APT, FGI, ITRI, III | Non-essential functionality for NB-IoT in Rel-17, deprioritize |
| ZTE | Such large coupling loss is not expected by NB-IoT and eMTC devices, and performance enhancement, e.g., higher repetition number or more suitable MCS, on data transmission should be considered if these UEs are supported.**Proposal 3:** Enhancement on coverage should be considered if scenarios beyond exiting system capability are supported. |

Only one company discusses this issue and concludes that it is not applicable to the current use cases for NB-IoT/eMTC.

**Conclusion 5-1:**

**Coverage enhancement is not further discussed in Rel-17 NTN IoT.**

Companies are encouraged to provide comments on the proposed conclusion.

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| **Company** | **Comments** |
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## Serving cell change

**Table 6 Views on enhancements for serving cell change**

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| **Company** | **Input** |
| APT, FGI, ITRI, III | Observation 2 For NTN NB-IoT, considering an earth-moving cell of diameter 50km (set 1) and 90km (set 2) for LEO at 600km, the largest repetition time of 10.24s for 15kHz SCS cannot be supported. |
| Nokia, NSB | For each HARQ process, LTE NB-IoT transmission time will be decided as repetition time \* number of RU \* number of slot in RU. When considering largest repetition time, number of RU, number of slot in RU defined in LTE, the maximum transmission time could be 0.5 ms \* 128 \* 10 \* 16 = 10240 ms for 15kHz SCS or 2 ms \* 128 \* 10 \* 16 = 40960 ms for 3.75kHz SCS. This time length could be larger than the time before UE need to handover or perform a cell reseletion with high speed satellite, resulting that UE can not complete the repetition before change of cell. Repetition continuation for the HARQ process should be considered and it should be guaranteed that the repetition from coverage of two cells should be able to be combined. Therefore, after a handover (eMTC) or RLF+ cell reselection (NB-IoT) the data transfer could continue instead of restarting. This could be studied for both uplink and downlink data transfers. Specifically, RAN1 can consider if such continiuation is feasible on the PHY layer in terms of keeping soft bits/repetition data, while solutions on higher layer RLC can also be envisioned. Proposal 3: Repetition continuation for HARQ process should be studied and repetition from coverage of two cells should be able to be combined, especially for LEO with high speed satellite movement. |
| ZTE | Long UL/DL transmission with larger repetition number is supported in terrestrial IoT system. For IoT over NTN, there may exist corresponding long UL/DL transmission e.g., up to N\*256ms, in a cell/beam. Moreover, the transmission may go through different cells/beams because the lasting time of transmission may surpass the serving time of a satellite beam, especially for LEO satellite scenario. As discussed in [6], as to the mobility of IoT, introducing beam management mechanism is preferable from the perspective of avoid much impact from high layer and much complexity. Therefore, HARQ continuity in beam switch should be considered in priority compared with that in serving cell change since beam switch happens more frequently. To tackle this problem, when a long transmission does not completely end while the UE moving out of a first beam coverage, the gNB may determine to continue the transmission via a different service beam, e.g., via indicating beam switching, and a second beam can be employed for the next repeated transmission.Proposal 4: In IoT over NTN, enhanced repeated transmission to keep HARQ process continuity in beam switch should be studied.  |

Due to the large number of repetitions, an UL/DL transmission in IoT can be longer than the time interval needed by the UE for cell reselection or handover. It is proposed to study the feasibility of combining repetitions on two cells. It is also proposed to study the feasibility of combining repetitions over different beams.

**Further discuss**

In a first round of discussions, companies are encouraged to provide views on the proposals or other aspects related to serving cell change issues, however the low interest in this topic may be due to the consideration of only essential features for Rel-17.

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| **Company** | **Comments** |
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## Multi-TB scheduling

Two companies propose to support multi-TB scheduling in Rel-17 NTN-IoT. In a first round of discussions, companies can provide views on the proposal, however it is noticed the low interest in this aspect as companies that haven’t expressed a view may consider it not essential for Rel-17. Alternatively, since it has not been identified any issue related to the operation in NTN, whether Rel-17 NTN IoT supports Multi-TB scheduling can be part of a discussion on UE features.

**Table 7 Views on supporting multi-TB scheduling**

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| **Company** | **Input** |
| APT, FGI, ITRI, III | Non-essential functionality for NB-IoT in Rel-17, deprioritize |
| CMCC | Proposal 2: Support multiple transport blocks scheduling. |
| ZTE | Proposal 5: Multiple TBs scheduling is supported in IoT-NTN as in traditional TN. |

**Proposal 7-1:**

**Whether to support multi-TB scheduling in Rel-17 NTN IoT is decided in the UE features discussion.**

Companies are encouraged to provide feedback on the proposal

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| **Company** | **Comments** |
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## Throughput enhancements

**Table 8 Views on throughput enhancements**

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| **Company** | **Input** |
| APT, FGI, ITRI, III | Non-essential functionality for NB-IoT in Rel-17, deprioritize  |
| CMCC | Proposal 3: The study of throughput enhancements to be de-prioritized. |
| Qualcomm | In an NTN, a UE may have to wait for a considerable period after receiving a DL transmission before it transmits the corresponding UL. This is especially true for “near UEs” if the “scheduling offsets” (K\_offset) are cell-specific, and hence, cater to UEs with the worst round-trip time. According to current specifications, in many such would-be “waiting periods”, the UE is “not required to monitor NPDCCH”. To mitigate this loss in throughput, we can enable PDCCH monitoring for at least a subset of the “waiting period”.Proposal 2: RAN1 to consider enabling PDCCH monitoring in “waiting periods”—for example, between receiving NPDSCH and transmitting HARQ ACK in NB-IoT—to mitigate suboptimal throughput. (recommended to be captured, additionally to the essential features, in the TR) |

One company proposes to enable PDCCH monitoring during the time period between receiving NPDSCH and transmitting HARQ ACK in NB-IoT to increase throughput. Two companies propose to deprioritize throughput enhancements. It is noticed the low interest in this aspect as companies that haven’t expressed a view may consider it not essential for Rel-17.

**Further discuss**

In a first round of discussions, companies are encouraged to provide views on the proposals or other aspects related to throughput enhancements, however the low interest in this topic may be due to the consideration of only essential features for Rel-17.

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| **Company** | **Comments** |
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## Other

**Timing relationship between reception of PDSCH and transmission of HARQ-ACK feedback**

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| **Company** | **Input** |
| Oppo | In NR-NTN, an offset, i.e., K\_offset is introduced to enhance the timing relationship for HARQ-ACK transmission. For HARQ-ACK transmission on a PUCCH, if UE is scheduled with a PDSCH reception ending in slot n, the UE should provide corresponding HARQ-ACK information in a PUCCH transmission within slot n+K1+K\_offset, where K1 is a number of slots and is indicated by the PDSCH-to-HARQ-timing-indicator field in the DCI format, if present, or provided by dl-DataToUL-ACK.For HARQ-ACK feedback in IoT-NTN, similar to NR-NTN, the timing relationship between PDSCH reception and HARQ-ACK feedback should be enhanced with the K\_offset at least in the large propagation delay scenarios, e.g., GEO. Otherwise, the IoT devices will be unable to transmit the corresponding HARQ-ACKs for PDSCH receptions in such scenarios and the systems will be broken. Proposal 1: K\_offset is introduced to enhance the timing relationship for HARQ-ACK transmission for NB-IoT/eMTC over NTN in Rel-17.  |

The timing relationship between reception of PDSCH and transmission of HARQ-ACK feedback may be studied in AI 8.15.3. Further coordination is needed.

**Support of some NB-IoT functionalities in NTN**

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| **Company** | **Input** |
| APT, FGI, ITRI, III | To support complete NB-IoT features for NTN given a limited time might be unrealistic, e.g., PUR, EDT, NPUSCH format 2, or 3.75KHz SCS. However, at least some notes shall be taken in the TR |

The discussion of which NB-IoT features to support in Rel-17 NTN IoT can happen at a later stage in the UE features discussion. The same applies to eMTC in NTN.

**Conclusion 9-1:**

**Support of NB-IoT/eMTC features from up to Rel-16 in NTN is decided in the UE features discussion.**

Companies are encouraged to provide views on the above conclusion.

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| **Company** | **Comments** |
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# Companies’ proposals and observations

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| **Company** | **Input** |
| [R1-2102346](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102346.zip)Huawei, HiSilicon  | Observation 1: In case of GEO, the timing between NPUSCH and its corresponding NPDCCH indicating ACK/NACK can already be occupied with 2 HARQ processes for the case of multi-tone transmission with 6 subcarriers and single tone transmission.Observation 2: The earliest subframe for an UE to receive an NPDCCH with DCI format N0/N1 for the same HARQ process depends on the offset between the UL and DL frame timing at the eNB.Proposal 1: There is no need to extend the HARQ process number for IoT-NTN.Proposal 2: Disabling HARQ processes is not necessary for IoT-NTN. |
| [R1-2102425](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102425.zip)Oppo | Proposal 1: K\_offset is introduced to enhance the timing relationship for HARQ-ACK transmission for NB-IoT/eMTC over NTN in Rel-17. Proposal 2: HARQ disabling and increased HARQ process number for NB-IoT/eMTC over NTN should NOT be specified in Rel-17. Proposal 3: HARQ disabling and increased HARQ process number for NB-IoT/eMTC over NTN should be studied and specified in later release. |
| [R1-2102475](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102475.zip)Spreadtrum | Proposal 1: Number of HARQ process should be kept in IOT NTN.Proposal 2: Whether to support disabling HARQ feedback for NB-IoT and eMTC can be considered in R18. |
| [R1-2102551](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102551.zip)Vivo | Observation 1: The required HARQ process number is less than the subframe number in the RTT latency due to the larger repetition factor of IoT transmission.Observation 2: It is up to network implementation to determine whether to disable HARQ process, the number of disabled HARQ processes and enabling/disabling for one HARQ process.Observation 3: There is a timing misalignment between UE and eNB if the corresponding DCI of one of two HARQs is missing.Observation 4: The total continuous transmission duration of 2 HARQ processes may exceed 256ms according to the current specifications.Observation 5: Due to the round-trip delay of NTN is much large than 3 subframes, the interval of 3 subframes is no longer required.Proposal 1: For NB-IoT/eMTC NTN, the HARQ process number can be maintained the same as the NB-IoT/eMTC for TN, and the extension of maximal HARQ process number is not supported.Proposal 2: Support the functionality of disabling HARQ feedback for downlink transmission for NB-IoT/eMTC NTN.Proposal 3: The functionality of enabling/disabling per HARQ process can be configured in semi-static or dynamic way.Proposal 4: Consider a enhanced gap transmission mechanism to allow repetition continuation when serving cell change.Proposal 5: A enhanced UL gap can be considered as part of the NPUSCH repetition transmission.Proposal 6: The PDCCH monitoring reduction is not necessary. |
| [R1-2102620](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102620.zip)CATT | Observation 1: Increasing the number of processes will cause additional UE cost, which is critical for NB-IoT case.Observation 2: Disabling HARQ feedback doesn’t show clear benefit to NB-IoT use case. Proposal 1: HARQ process number in NB-IoT over satellite should be kept.Proposal 2: There is no need to increase the HARQ process number in eMTC NTN.Proposal 3: No enhancement in disabling HARQ feedback is needed for HARQ in NB-IoT over satellite. Proposal 4: Reuse disabling HARQ feedback mechansim of NR NTN for CEmodeA in eMTC NTN, and no need to disable HARQ feedback for CEmodeB UE.Proposal 5: Enabling/disabling on HARQ feedback for downlink transmission should be at least configurable per HARQ process via UE specific RRC signalling.Proposal 6: “Enabling”/”disabling” HARQ uplink retransmission should be supported. |
| [R1-2102738](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102738.zip)APT, FGI, ITRI, III |  Observation 1 For NTN NB-IoT, HARQ enhancement has been considered by the working groups as candidates for non-essential functionality in Rel-17.Observation 2 For NTN NB-IoT, considering an earth-moving cell of diameter 50km (set 1) and 90km (set 2) for LEO at 600km, the largest repetition time of 10.24s for 15kHz SCS cannot be supported.Proposal 1: For NTN NB-IoT, deprioritize the following study agreed in RAN#104-e: 1) increasing the number of HARQ processes; 2) of disabling HARQ feedback; 3) any other potential HARQ feedback mechanisms; 4) reduced PDCCH monitoring; 5) coverage enhancements; 6) multiple Transport Blocks scheduling; 7) throughput enhancements; 8) HARQ stalling.Proposal 2: For NTN NB-IoT, the study of uplink transmission gaps with multiple HARQ processes shall move to agenda item 8.15.2 enhancements to time and frequency synchronization.Proposal 3: For NTN NB-IoT, confirm that some repetition numbers cannot be supported by set 1 (50km) and set 2 (km) when earth-moving cells are deployed. Taking notes in the TR if needed. |
| [R1-2102757](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102757.zip)MediaTek | Observation 1: for NB-IoT, HARQ stalling reduces data rates by approximately 95% and 49% for GEO and LEO respectively. Observation 2: With 4 HARQ processes, HARQ stalling reduces data rates by approximately 53% and 22% for GEO and LEO respectively.Observation 3: It is sufficient to use 1 or 2 HARQ processes for NTN NB-IoT and eMTC in LEO and GEO scenarios to support data rates for intermittent delay-tolerant small packet transmissions in typical IoT applications.Proposal 1: Re-use 1 or 2 HARQ processes for NTN NB-IoT and eMTC in LEO and GEO scenarios. Proposal 2: UL HARQ feedback is not disabled for Message 3 during initial access.Observation 4: Allowing HARQ re-transmissions without disabling of UL HARQ feedback is consistent with the requirements for latency and data rates for intermittent delay-tolerant small packet transmissions for LEO and GEO.Observation 5: HARQ stalling has no significant impact on UE power consumption as the active time is highly dependent on the transmit time which is not reduced by removing HARQ stalling.Proposal 3: Re-use HARQ without disabling HARQ feedback for intermittent delay-tolerant small packet transmissions |
| [R1-2102834](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102834.zip)Nokia, NSB | Observation 1: repetition for IoT UE will mitigate the impact of HARQ stalling because of long propagation delay in NTN scenario.Observation 2: More HARQ process with more cost/complexity may not help when repetition number is too large.Observation 3: HARQ feedback disabling is not helpful in some of IoT NTN scenarios. Proposal 1: Both number of HARQ process and number of repetition, which will impact throughput, should be evaluated. Proposal 2: Alternative feedback for HARQ, e.g. assistance on requested number of repetition, BLER-based triggering or bundling of feedback, should be considered to maximize the performance of the link.Proposal 3: Repetition continuation for HARQ process should be studied and repetition from coverage of two cells should be able to be combined, especially for LEO with high speed satellite movement. |
| [R1-2102908](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102908.zip)CMCC | Observation 1: Disabling HARQ feedback is beneficial to increase the data rate with the cost of reduced reliability or increased power consumption.Proposal 1: The study of disabling HARQ feedback to be de-prioritized.Proposal 2: Support multiple transport blocks scheduling.Proposal 3: The study of throughput enhancements to be de-prioritized. |
| [R1-2102919](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102919.zip)ZTE | Observation 1: The maximum throughput in DL of IoT-NTN is reduced due to HARQ stalling.Observation 2: The maximum throughput in UL of IoT-NTN will not be significantly affected by HARQ stalling when proper parameter setting is applied.Observation 3: Reduced PDCCH monitoring can be achieved by enhancing HARQ RTT Timer.Proposal 1: HARQ process number for NB-IoT/eMTC in terrestrial network is reused for IoT-NTN.Proposal 2: HARQ feedback disabling for DL can be supported in IoT-NTN.Proposal 3: Enhancement on coverage should be considered if scenarios beyond exiting system capability are supported.Proposal 4: In IoT over NTN, enhanced repeated transmission to keep HARQ process continuity in beam switch should be studied. Proposal 5: Multiple TBs scheduling is supported in IoT-NTN as in traditional TN. |
| [R1-2102975](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102975.zip)Xiaomi | Proposal 1: The number of the supported HARQ process should not be increased for IoT NTN.Proposal 2: HARQ disabling is not supported for IoT NTN. |
| [R1-2103063](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2103063.zip)Ericsson | Observation 1 No HARQ enhancements are necessary to support the required data rates of IoT. However, the reductions in peak data rates due to stalling are substantial, especially for GEO. Therefore, enhancements that do not impose a significant complexity/cost increase could still be considered.Observation 2 Latency should be analyzed for overall delay from application layer including delays introduced in different layers. The general effect of the RTT of the NTN network should be counted to estimate the overall delay of the eMTC for NTN.Observation 3 Battery lifetime calculation requires more details to be considered than the effect of HARQ operation.Proposal 1 Do not increase the number of HARQ processes for eMTC.Proposal 2 Study further the benefits and drawbacks of disabling HARQ feedback. |
| [R1-2103073](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2103073.zip)Qualcomm | Proposal 1: RAN1 to support at least one feedback-disabled HARQ process for NB-IoT over NTN. Proposal 2: RAN1 to consider enabling PDCCH monitoring in “waiting periods”—for example, between receiving NPDSCH and transmitting HARQ ACK in NB-IoT—to mitigate suboptimal throughput. |
| [R1-2103135](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2103135.zip)Apple | Observation 1: The acquired throughput and latency of IoT over NTN, without increasing the number of HARQ processes, may still be enough to support IoT services.Observation 2: Increasing the number of HARQ processes increases IoT device complexity. Observation 3: Disabling HARQ feedback for downlink transmissions may increase the data rate, at the cost of reduced reliability. Observation 4: Disabling HARQ feedback for downlink transmissions does not increase the IoT device complexity and can reduce the power consumption. |
| [R1-2103269](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2103269.zip)Samsung | Proposal 1: Disabling of HARQ feedback should be supported as NR NTN.Proposal 2: HARQ feedback can be enabled/disabled per HARQ process via UE specific RRC signaling as NR NTN.Proposal 3: Whether to support disabling of HARQ feedback for all the HARQ processes should be discussed.Proposal 4: Number of HARQ processes should be kept considering increasing HARQ process number will cause additional UE cost. Proposal 5: UE assistance information for HARQ can be supported. |
| [R1-2103275](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2103275.zip)Interdigital | Observation-1: Only essential enhancement which is required to enable IoT support in NTN system should be considered in Rel-17 to expedite the progress and finish the SI earlier than planned and have a reasonable scope of normative work in Rel-17Proposal-1: Extending maximum HARQ process number is not supported in Rel-17 IoT NTNProposal-2: Enabling/disabling HARQ feedback is not supported in Rel-17 IoT NTN  |
| [R1-2103321](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2103321.zip)Sony | Observation 1: For GEO, 63% (512ms out of 806ms) of the HARQ cycle time is occupied by active PUSCH transmissions when 2 HARQ processes are active.Observation 2: For LEO constellations, the UE processing pipeline can be fully loaded with active PUSCH transmissions when 2 HARQ processes are active.Proposal 1: In order to reduce power consumption, when a UE is scheduled PUSCH in the UL, it does not need to monitor MPDCCH until the RTT time has elapsed from the end of the PUSCH. |
| [R1-2103530](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2103530.zip)Lenovo, Motorola Mobility | Proposal 1: The HARQ process number can be maintained the same as legacy for both eMTC and NBIoT.Proposal 2: At least for NBIoT NTN, disabling HARQ is not supported.Proposal 3: NB-IoT UE is to skip NPDCCH monitoring for an HARQ process for a longer time interval than the time interval in TN. |

# References

1. RP-202689 New Study WID on NB-IoT/eTMC support for NTN, MediaTek
2. RP-210915 Moderator's summary for email discussion [91E] [42] [NTN\_IoT\_roadmap], Ericsson
3. R1-2101957 Summary#3 for enhancements on HARQ, Samsung
4. R1-2102346 Discussion on HARQ enhancement for IoT in NTN Huawei, HiSilicon
5. R1-2102425 Discussion on HARQ enhancements OPPO
6. R1-2102475 Consideration on enhancements on HARQ Spreadtrum Communications
7. [R1-2102551](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102551.zip) Discussion on HARQ enhancements on NB-IoT/eMTC for NTN vivo
8. R1-2102620 HARQ operation enhancement for NB-IoT/eMTC CATT
9. R1-2102738 Enhancements on HARQ Asia Pacific Telecom, FGI, ITRI, III
10. R1-2102757 Enhancements on HARQ for IoT NTN MediaTek Inc.
11. R1-2102834 HARQ for NB-IoT/eMTC over NTN Nokia, Nokia Shanghai Bell
12. R1-2102908 Enhancements on HARQ for IoT NTN CMCC
13. R1-2102919 Discussion on HARQ for IoT-NTN ZTE
14. R1-2102975 Discussion on the HARQ enhancement for IoT NTN Xiaomi
15. R1-2103063 On HARQ enhancements for IoT NTN Ericsson
16. R1-2103073 Enhancements on HARQ Qualcomm Incorporated
17. R1-2103135 On HARQ Enhancement in IoT NTN Apple
18. R1-2103269 On enhancements on HARQ Samsung
19. R1-2103275 HARQ enhancement for IoT NTN InterDigital, Inc.
20. R1-2103321 HARQ issues for IoT-NTN Sony
21. R1-2103530 HARQ enhancement for IoT NTN Lenovo, Motorola Mobility

# Annex A – Agreements 8.15.4 Enhancements on HARQ in NTN-IoT

**RAN1#104-e**

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| Agreement:Study further the potential benefits and/or drawbacks of increasing the number of HARQ processes on throughput, latency, power consumption and complexityAgreement:* For NTN, further study potential benefits and/or drawbacks of disabling HARQ feedback for NB-IoT.
* For NTN, further study potential benefits and/or drawbacks of disabling HARQ feedback for eMTC.

Agreement:In relation to HARQ operation in NTN IoT, further study at least * The necessity, potential benefits and drawbacks of any other potential HARQ feedback mechanisms
* The necessity, potential benefits and drawbacks of reduced PDCCH monitoring
* The necessity, potential benefits and drawbacks of coverage enhancements
* The necessity, potential benefits and drawbacks of uplink transmission gaps with multiple HARQ processes
* The necessity, potential benefits and drawbacks of maintaining HARQ process continuity in serving cell change
* The necessity, potential benefits and drawbacks of multiple Transport Blocks scheduling
* The necessity, potential benefits and drawbacks of throughput enhancements
	+ FFS: Whether target throughput in NTN will be the same as target throughput in terrestrial networks

Agreement:The motivation for introducing HARQ enhancements in NR NTN needs further consideration for HARQ enhancements in NTN IoT. Capture the following in the TR:* For NTN IoT, potential HARQ enhancements need to consider the main characteristics of an IoT device, which are low complexity, low cost, low power consumption and low throughput, and key requirements of IoT services which are extended coverage, delay-tolerant and infrequent data transmissions, and support of massive communications.
* The peak throughput of IoT UEs operating over NTN is not expected to be higher than the peak throughput of IoT UEs operating over TN.

Agreement:Further study to identify whether HARQ stalling happens at least in the GEO satellite scenario.Agreement:* Further discuss the potential benefits and/or drawbacks of increasing the number of HARQ processes in the UL for NB-IoT and eMTC, and for the analysis consider at least the following for the number of HARQ processes
	+ NB-IoT: 1,2,4
	+ eMTC: 2,4,8,14
* And discuss at least power consumption and peak data rate as performance metrics
* FFS: Whether to consider DL
* Other values for number of HARQ processes below the maximum value can be discussed

Agreement:* Further discuss the potential benefits and/or drawbacks of disabling HARQ feedback for NB-IoT and eMTC, and consider at least the following number of HARQ processes for the analysis
	+ NB-IoT:
		- Total: 2, disabled: {1,2}
	+ eMTC:
		- Total: 2, disabled: {1,2}
		- Total: 8, disabled: {1,2,7,8}
* Other values for number of HARQ processes below the maximum value can be discussed
* FFS: whether to consider separately LEO and GEO scenarios
* FFS: whether to allow disabling of HARQ feedback in case of single HARQ process
* FFS: whether to allow disabling of all HARQ feedback
* FFS: other details for the evaluation/analysis.
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# Annex B – Agreements 8.4.3 Enhancements on HARQ in NTN

**RAN1#102e**

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| Agreement:Enabling/disabling on HARQ feedback for downlink transmission should be at least configurable per HARQ process via UE specific RRC signalingAgreement:The extension of maximal HARQ process number can be considered with following assumptions:* The maximal supported HARQ process number is up to 32.
* FFS: Support on the maximal HARQ process number is up to UE capability
* Minimizing the impacts on specification and scheduling
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**RAN1#103e**

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| Agreement:For a DL HARQ process with disabled HARQ feedback, the UE is not expected to receive another PDSCH or set of slot-aggregated PDSCH scheduled for the given HARQ process that starts until [X] after the end of the reception of the last PDSCH or slot-aggregated PDSCH for that HARQ process.* FFS: value of X and units in which it is defined.
* FFS: Whether TB of the two PDSCHs needs to be different

**Decision:** As per email decision posted on Nov.13th,Agreement:* Enhanced HARQ process ID indication is supported for DCI 0-2/1-2 and DCI 0-1/1-1 by at least one of following:
	+ Option 1: Slot index as the MSB
	+ Option 1-a:Slot index as the LSB
	+ Option 2: Reusing one bit from other bit field
	+ Option 3: Extending the HARQ process ID field up to 5 bits
* FFS: DCI 0-0/1-0
* Note: 32 is taken as maximal supported HARQ processes number for both UL and DL

Agreement:HARQ codebook enhancement is supported as:* For Type-2 HARQ codebook:
	+ Option-1: Reduce codebook size with:
		- HARQ-ACK codebook only includes HARQ-ACK of PDSCH with feedback-enabled HARQ processes
			* FFS: the details of C-DAI and T-DAI counting for DCI of PDSCH with feedback-enable/disabled HARQ processes
		- FFS: at least DCI for SPS release/SPS PDSCH
	+ Option-2: No enhancement
	+ Other options are not precluded.
* For Type-1 HARQ codebook, further discuss is needed with down selection among following options:
	+ Option-1: No enhancement;
	+ Option-2: Report NACK on disabled process
	+ Option-3: Reduce codebook size with criteria
* FFS: Enhancements for Type-3 HARQ codebook
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**RAN1#104e**

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| Agreement: |