**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-17  Proposal-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** |
| MediaTek | Support moderator proposal. Description of HARQ stalling could include data rates and reduction in data rates due to HARQ stalling. Support conclusion of not increasing the number of HARQ processes in Rel-17 NTN IoT. |
| vivo | Agree with the Proposal 1-1 and yes to Question 1-1. |
| ZTE | Agree with proposal 1-1 and we can summarize the views to justify the this observation |
| CATT | Support moderator proposal. |
| Huawei, HiSilicon | Considering the limited time we have at hand, it is best to focus what absolutely has to be captured in the TR. There is no need to take the extra effort to draft a text proposal to explain background when the conclusion is that no enhancement is introduced to the existing protocol considering the number of HARQ processes. |
| Apple | We support Proposal 1-1, and neutral whether to describe the HARQ stalling issue in NTN in the TR. |
| Qualcomm | OK with Proposal 1-1. Would be good to have a note in the TR that increasing HARQ processes were discussed, as a solution to precent possible HARQ stalling, but was not prioritized for an *initial* release—however, this may be revisited for future work. |
| SONY | We are OK with capturing the HARQ stalling issue in the TR. If we do this, then a TP should not only consider increasing the number of HARQ processes, but also allowing the UE to go to sleep while stalled.  If the consensus is not to capture anything in the TR, we are also OK with that. |
| Nokia, NSB | We are OK for it. |
| Ericsson | Yes on question 1-1. |
| Lenovo, MotoM | Agree with the Proposal 1-1 and yes to Question 1-1. We can have a note in TR to conclude the issue. |
| Xiaomi | Agree with the proposal. |
| CMCC | We support Proposal 1-1, and neutral whether to describe the HARQ stalling issue in NTN in the TR. |
| Novamint | Support the proposal |
| GateHouse | Agree to P1-1 and Q1-1 |

## 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-17  Proposal-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. |
| GateHouse | We do not see the disabling of HARQ feedback as essential for Rel-17. |

**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** |
| MediaTek | Re-use HARQ without disabling HARQ feedback for intermittent delay-tolerant small packet transmissions in Rel-17 is reasonable way. The data rates due to HARQ stalling are still sufficiently for typical IoT applications. Disabling HARQ feedback is an enhancement that could be considered in Release 18. |
| vivo | Disabling HARQ feedback is beneficial to the power consumption and resource utilization, and it provides a way to maintain continuous data transmission when HARQ stalling in NTN with few HARQ processes. Meanwhile, disabling HARQ feedback would not increase the device complexity, so we propose to support disabling HARQ in IoT NTN, just like in NR NTN. |
| ZTE | We are supportive to study the disabling of HARQ process, especially for DL. Such solution can deal with the HARQ stalling with limited impacts. It’s a good tradeoff for IoT-NTN case. |
| CATT | For eMTC CEModeA, disabling HARQ feedback is useful since there are sufficient HARQ processes, and disabling partial HARQ process can simplify UE implementation.  For other cases, due to limited HARQ process, disabling HARQ feedback is less beneficial. |
| Huawei, HiSilicon | We prefer not to introduce HARQ feedback disabling as 1) IoT NTN is delay tolerant; 2) there is no higher data rate requirement for IoT NTN. Furthermore, this is not within the scope of essential minimum functionality that we see is needed in Rel-17. |
| Apple | Disabling HARQ feedback could save UE power, at the cost of increased latency (due to RLC retransmission). We are open to consider it in Rel-17 IoT over NTN. |
| Qualcomm | We *strongly propose supporting feedback-disabled processes* to make sure that NB-IoT peak throughput is *not orders of magnitude worse than terrestrial.*  Just to make the case that this has minimal (if any) spec impact, NB-IoT today *already supports feedback-disabled HARQ processes* (e.g., in SC-PTM).  Quoting from 36.212:  ***“When the format N1 CRC is scrambled with a RA-RNTI or a G-RNTI, then the following fields among the fields above are reserved for RA-RNTI and not present for G-RNTI:***  ***- New data indicator***  ***- HARQ-ACK resource”***  Quoting from (corresponding procedure in) 36.213:  ***If a NB-IoT UE receives a NPDSCH transmission ending in subframe n, and if the UE is not required to transmit a corresponding NPUSCH format 2, the UE is not required to monitor NPDCCH in any subframe starting from subframe n+1 to subframe n+12.***  So this hardly needs “novel” specification work, while ensuring that we don’t take unreasonable hits to peak throughput w.r.t terrestrial. |
| SONY | It is likely that there would be a lot of discussion about this issue and we may not have time for this. Furthermore, disabling HARQ feedback is not essential functionality. The system can operate with a lower data rate and accept HARQ stalling. Support of HARQ feedback leads to a decrease in power consumption in our understanding.  Disabling HARQ feedback can be considered as an enhancement in Rel-18. |
| Nokia, NSB | For IoT UE with 1 HARQ process, it will remove all confirmation if disabled HARQ feedback.  While for all IoT UE, when HARQ feedback is disabled it could help reduce HARQ stalling, then it can not confirm whether the packet is correct which may cause less information for link adaptation, so additional other type of feedback should be considered e.g. assistance on requested number of repetition, BLER-based triggering or bundling of feedback, to maximize the performance and resource utilization efficiency. |
| Ericsson | Disabling HARQ feedback should be studied further since it can significantly increase the throughput at a small cost in case of large RTT. |
| Lenovo, MotoM | Due to limited time, we prefer to introduce disabling HARQ feedback to next release for IoT NTN. |
| Xiaomi | HARQ disabling is more like to be a optimization, thus it is not essential for Rel-17. |
| CMCC | Disabling HARQ feedback can be considered as an enhancement in Rel-18.  Furthermore, in our view, disabling HARQ feedback is beneficial to increase the data rate with the cost of reduced reliability.  Nevertheless, the benefit of power saving needs more clarification.  Firstly, if HARQ feedback is disabled, higher repetition number may be configured, which may significantly increase the power consumption for DL data reception.  Secondly, if retransmission at RLC layer (i.e. RLC ARQ) is supported, UE may need to awake for a longer time to wait for the potential retransmission scheduling signaling trigged by RLC layer, which may increase the power consumption for PDCCH monitoring. |
| Novamint | Agree with Mediatek’s comments |
| GateHouse | Agree with Mediatek, that disabling HARQ feedback is not essential (for Rel-17) and can be seen as possible enhancement. |
| InterDigital | We also think it is not an essential issue and possibly discussed in Rel-18 |

## 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. |
| GateHouse | Not-essential for IoT NTN Rel-17. |

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** |
| MediaTek | Early Termination is not new idea as it was considered for cellular IoT specification. The effectiveness of early termination will be reduced due to long RTT in satellites.  Discussions of the scenarios for buffer for HARQ operation is full or almost full would help understanding of potential issue. |
| vivo | Not essential in Rel-17. |
| ZTE | Can be postponed and not essential. |
| CATT | Not needed due to unconvinced benefit |
| Huawei, HiSilicon | Other HARQ feedback mechanisms are not within the scope of essential minimum functionality that we see is needed in Rel-17. |
| Apple | We consider these topics as non-essential features for Rel-17. The system can work without the corresponding enhancement. |
| SONY | Not essential functionality. |
| Nokia, NSB | To maximize UE performance and resource utilization efficiency, the first two items should be utilized to for a better link adaptation.  For buffer status, the operation of decoding will complete whether HARQ feedback will be disabled. As in NR NTN, if only enough time is reserved for decoding, no need for buffer status report. |
| Ericsson | These enhancements are non-essential. |
| Lenovo, MotoM | This is not essential in Rel.17 |
| CMCC | These enhancements are non-essential. |
| Novamint | Not essential in Rel.17 |
| GateHouse | Not essential functionality for Rel-17. |
| InterDigital | Not essential in Rel-17 |

## 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 process~~es~~, 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** |
| MediaTek | The proposal seems reasonable optimization to save UE power consumption, but it should be further clarified that the UE configured with more than one HARQ processes can monitor PDCCH before the PUSCH starts if it has only received UL grant for one HARQ process. It is then not clear how the UL grant for other HARQ processes can be indicated to UE via DCI, which seems a major deviation for HARQ functionality. |
| vivo | We think the PDCCH monitoring reduction is not necessary.  According to TS 36.213, section 16.6:  *If a NB-IoT UE is configured with higher layer parameter twoHARQ-ProcessesConfig*  *- and if the UE has a NPUSCH transmission ending in subframe n,*  *- the UE is not required to receive transmissions in the Type B half-duplex guard periods as specified in [3] for FDD; and*  *- the UE is not expected to receive an NPDCCH with DCI format N0/N1 for the same HARQ process ID as the NPUSCH transmission in any subframe starting from subframe n+1 to subframe n+3;*  The actual time gap from the **uplink** subframe n to **downlink** subframe n+3 has already been included in the RTT time if a timing offset is considered in AI 8.15.3. |
| ZTE | We can discuss this issue later once the enhancement on timing is done. |
| CATT | This proposal is confusing. If more one HARQ process is supported, UE should monitor PDCCH for new HARQ process. |
| Huawei, HiSilicon | For one HARQ process, we agree with FL proposal. For two HARQ processes, PDCCH monitoring cannot be reduced at the UE side when the DCI from the second HARQ process comes after the transmission of the PUSCH from the first HARQ process. |
| Apple | If more than 1 HARQ process is used, then the proposal is not proper. |
| Moderator | Proposal 4-1 is updated – it should apply only to single HARQ process.  For a NB-IoT UE configured with 2 HARQ processes, companies are encouraged to also comment on the reuse of the existing specifications TS 36.213, section 16.6 (as in Vivo comment). |
| SONY | The proposal as it stands works well for 1 HARQ process.  The point of the proposal is that the UE can go to sleep (not monitor PDCCH and hence save power) if it cannot be scheduled due to HARQ processes being full. The first time that the UE can be scheduled again is following a time equal to the RTT beyond the end of the earliest HARQ process that was filled. This is described in Figure 3 in [20].  In the TR, we should be capturing the outcomes of studies and not necessarily agreeing to proposed enhancements. This comment applies to other FL proposals too.  Further studies, according to company contribution, can capture how to apply the proposal to more than one HARQ process.  In terms of the comment from vivo, we think that the timing relationship enhancements in AI8.15.3 are considering extending DL to UL timing relationships, rather than UL to DL timing relationships. |
| Nokia, NSB | We suggest for further study. One possible way may be UE does not monitor PDCCH for another PUSCH for the same HARQ process until the RTT time has elapsed from the end of the PUSCH, but PDCCH for other purpose should still be monitored. |
| Ericsson | This is DRX behavior and should be decided by RAN2. |
| Lenovo, MotoM | If the HARQ process number is configured to 1, the proposal is OK. For the HARQ process number is configured to 2, further study is needed. Besides the comment from vivo, please also note the following NPDCCH monitoring reduction🡪 not required to monitor only from subframe *n+k-2* to subframe *n+k-1*.  TS36.213 f70 section 16.6  For a NPDCCH UE-specific search space, if a NB-IoT UE is configured with higher layer parameter *twoHARQ-ProcessesConfig* and if the NB-IoT UE detects NPDCCH with DCI Format N0 ending in subframe *n*, and if the corresponding NPUSCH format 1 transmission starts from *n+k,*  - the UE is not required to monitor an NPDCCH candidate in any subframe starting from subframe *n+k-2* to subframe *n+k-1*; and   * - the UE does not expect to receive a DCI Format N0 before subframe *n*+*k*-2 for which the corresponding NPUSCH format 1 transmission ends later than subframe *n*+*k*+255.   - for TDD, and if the corresponding NPUSCH format1 transmission ends in subframe *n+m*, the UE is not required to monitor NPDCCH in any subframe starting from subframe *n+ k* to subframe *n+m-1*.  If a NB-IoT UE is configured with higher layer parameter *twoHARQ-ProcessesConfig*  - and if the UE has a NPUSCH transmission ending in subframe *n*,  - the UE is not required to receive transmissions in the Type B half-duplex guard periods as specified in [3]for FDD ; and  - the UE is not expected to receive an NPDCCH with DCI format N0/N1 for the same HARQ process ID as the NPUSCH transmission in any subframe starting from subframe n+1 to subframe n+3*;* |
| CMCC | We support for the updated Proposal 4-1.  *For a NTN UE that is configured with one HARQ process, the UE does not monitor PDCCH until the RTT time has elapsed from the end of the PUSCH.* |
| Novamint | Agree with CMCC’s views |
| GateHouse | Agree to CMCC/Novamint. |
| InterDigital | We prefer to further study together with more than one HARQ process case |

## Coverage enhancement

**Table 6 Views on coverage enhancement**

|  |  |
| --- | --- |
| **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.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MediaTek | Support moderator proposals. The number of repetitions specified in cellular IoT is already extremely high. For example, on UL the transmission time can be as long as 40.96 seconds. It seems challenging to consider higher number of repetitions for reasonable capacity and workability of IoT NTN system. |
| vivo | Due to the link budget results, it is necessary to enhance UL coverage for NB-IoT/eMTC over NTN. |
| ZTE | Whether to further extending the coverage capability for IoT over NTN is up to the needs of operator. According to our analysis, from system level simulation results, partial of UE will be out of service based on current specification. So, if these UEs are needed to be covered, corresponding study should be considered. |
| CATT | Support moderator proposals. Not essential issue. |
| Huawei, HiSilicon | Agree. The current maximum repetition number is large enough to compensate the link budget of IoT NTN and it is not within the scope of minimum essential functionality for Rel-17. |
| Apple | Agree with the conclusion. |
| SONY | Whether coverage enhancement is needed depends on the outcome of the link budget discussions in AI 8.15.1. We should only consider straightforward scenarios / constellations for the purposes of essential functionality in any case. Scenarios / constellations that are more constrained by coverage can be considered as Rel-18 enhancements.  We are unlikely to be making large changes in coverage performance in this SI/WI. |
| Nokia, NSB | Repetition for IoT to guarantee coverage is an important function, considering reduced UE cost/complexity.  Coverage is a basic requirement. If coverage is not clear, then the SI can not provide enough information for WI and it is not clear the network coverage/quality for IoT over NTN even deployed, which will be a big issue.  Coverage should studied in SI and WI, in 8.15.1 or 8.15.4. |
| Ericsson | Ok |
| Lenovn, MotoM | Support the proposal |
| CMCC | Same view with Sony.  Whether coverage enhancement is needed depends on the outcome of the link budget discussions in AI 8.15.1. |
| Novamint | We need to tread carefully with this topic. As pointed out by Nokia, coverage is a basic requirement. So, it depends of what means enhancement.  We are aiming to have a first workable version in Release 17 which can meet market adoption which means to be able to be very cost effective and to be competitive as well with non-3GPP proprietary solutions considering the use cases targeted such as Asset tracking, asset monitoring…  In this context, such first version needs to be able to support small constellations of cubsat (in the case of LEO) with progressive deployment while being already offering the service as soon as the first satellite is in orbit which means discontinuous coverage. Similar for GEO, service link discontinuity is seen as very important for cost perspective.  Therefore, it should be very explicit here that it shall not preclude to address and support in release 17 discontinuous coverage or service link discontinuity and the functionalities needed to support it.  We would even propose to have explicit statement such as  **Proposal 5-1:**  **Support of discontinuous coverage is an** **essential minimum functionality of IoT NTN** |
| GateHouse | Fully agree to Novamint. Support of discontinuous coverage is an essential minimum functionality of IoT NTN, and not to be precluded by descoping Rel-17 in relation to coverage enhancements. |
| Sateliot | Tend to disagree with the conclusion.  We think discussion on the need of coverage enhancement should not be precluded and should be connected to the outcomes of the link budget discussions in AI 8.15.1. A different thing is that coverage enhancement solutions, if any proposed, might be deprioritized in Rel-17 but addressed in next releases.  Fully agree on the points made by Novamint about the support of discontinuous coverage. |
| InterDigital | Support the proposal |

## Serving cell change

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

|  |  |
| --- | --- |
| **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.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | As mentioned in our contribution, considering the large repetition and the randomness of traffic data, it is possible that the repetition transmission is not complete when the serving cell need to change due to the mobility of satellites. Additionally, a group of UEs in the coverage of one cell need to change the serving cell due to the mobility of the cell, not the movement of UEs, which is also a major different between TN and NTN. If the transmitted repetitions of the UEs covered by the cell are discarded, there will be a huge waste of resource. Thus, further study to allow repetition continuation when serving cell changes is needed. |
| ZTE | We are supportive to study this issue.  In our view, it’s critical for corresponding service at least via LEO, which can enable the IoT service to fulfill the targeted MCL. If there is potential downselection w.r.t the supportive scenarios, e.g., GEO or LEO with fixed beam, maybe we can deprioritize it. |
| CATT | It is not essential feature at this SI. |
| Huawei, HiSilicon | Not essential for Rel-17, and continuation of HARQ process (which does not exists in terrestrial NB-IoT) would also have big implications on RAN2 specifications. |
| Apple | This scenario may happen due to the long UL/DL transmissions. However, if possible, we prefer to deprioritize it, due to TU limitation. |
| SONY | If the UE is unable to transmit the required number of repetitions before the cell changes, then reliable communications is going to be difficult to achieve for some LEO scenarios, where the cell / beam changes frequently.  Handling the issue of transmitting a large number of repetitions across serving cells for LEO scenarios seems like essential functionality. There may be alternative solutions for some scenarios with less specification impact, such as deferring transmissions (such that the transmission does not start as a beam is going to go out of view) and not flushing HARQ buffers at cell change (such that a retransmission can be performed in the next cell, rather than repeating transmissions between cells). |
| Nokia, NSB | Combination of repetition in two cells should be very important, as if no, then   * For traffic transmission occur before moving to another cell, the repetition may last for long time but not complete, then all the repetition will be wasted if no combination of repetition in two cells, this will cause more power consumption and latency, especially for UE with larger coupling loss. * For cell with limited coverage, the UE with large coupling loss will request large number of repetition, which may not complete in any cell, then it can never have a success transmission.   Based on above, combination of repetition in two cells should be studied and supported in Rel 17 IoT NTN. |
| Ericsson | This enhancement is non-essential. |
| Lenovo, MotoM | It is not essential feature at this SI. |
| CMCC | Same view with Apple.  Due to TU limitation, this enhancement may be deprioritized. |
| Novamint | Not essential for Rel. 17 |
| GateHouse | Not essential for Rel-17. |
| InterDigital | Not essential for Rel-17 |

## 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**

|  |  |
| --- | --- |
| **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. |
| GateHouse | Not necessarily essential for Rel-17 |

**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

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MediaTek | Support moderator proposal. |
| Vivo | Multi-TB transmission is not a unique issue of NTN, so we think it is just suitable to reuse the way as in traditional TN. |
| ZTE | Support |
| CATT | Support moderator proposal. |
| Huawei, HiSilicon | We don’t understand the FL proposal, in SI stage we do not address the UE features yet. Furthermore, this is not within the scope of essential minimum functionality that we see is needed in Rel-17. |
| Apple | Fine with the proposal. |
| Qualcomm | I think RAN2 already agreed to have Rel16 as a baseline (which includes multi-TB scheduling)—with a caveat from our side, that if some feature needs work that is complicated, it may be deferred.  Specifically, for multi-TB, we see no reason for any complications, and recommend that it be supported, in line with the RAN2 agreement to use Rel16 as a baseline.  Not supporting Multi-TB scheduling is another way to “cripple” NB-IoT/eMTC over NTN vs terrestrial—something that we think sets a terrible precedent. |
| SONY | OK with proposal. |
| Nokia, NSB | OK for further discussion in feature discussion. |
| Ericsson | This is non-essential. |
| Lenovo, MotoM | OK for further discussion in feature discussion. |
| CMCC | Support moderator proposal. |
| Novamint | Agree with Huawei |
| GateHouse | Agree to Huawei/Novamint |
| InterDigital | Not essential in Rel-17 |

## Throughput enhancements

**Table 8 Views on throughput enhancements**

|  |  |
| --- | --- |
| **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.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MediaTek | The scenario to enable PDCCH monitoring during the time period between receiving NPDSCH and transmitting HARQ ACK in NB-IoT could be further discussed. In particular, whether a UE would receive a DL assignment or UL grant for other packets between receiving a given packet on PDSCH and transmitting corresponding HARQ ACK, and when it can receive and transmit these other packets. Analysis to show the potential throughput gains will also be helpful. |
| Vivo | Not essential in Rel-17 |
| ZTE | It’s fine to discuss the potential solutions in the SI phase. Due to the limited TU, we can focus on the HARQ disabling as listed in section 2.2. |
| CATT | Not essential. |
| Huawei, HiSilicon | Not within the scope of essential minimum functionality that we see is needed in Rel-17. |
| Apple | Throughput enhancements are not essential for IoT service. |
| Qualcomm | We believe that reducing NB-IoT peak throughput in NTN significantly w.r.t terrestrial sets a bad precedent for the future of the technology—at least in the medium to long term.  To clarify any misinterpretation, *we are not proposing “throughput enhancements”* as some companies seem to suggest. Our goal is to *not make eMTC/NB-IoT orders of magnitude worse in terms of throughput than the terrestrial counterpart*!  While we agree that, other than supporting disabling feedback, additional enhancements may be hard to specify in Rel17, we also strongly believe that **the** **TR should not just be a “limited to Rel 17” document**. The **TR should describe reasonable solutions that were brought up, addressing legitimate issues**, and which may be taken up later—e.g., in future releases.  From our point of view, we would strongly recommend that we include in the TR, the idea of allowing enhanced PDCCH monitoring in current “waiting periods”, so that—e.g., in large RTT GEO-type networks—we don’t suffer a significant throughput loss w.r.t terrestrial.  We paste the figures and proposal below, for inclusion in the TR (but not as “essential” for Rel17)  Graphical user interface, application, Teams  Description automatically generated  Figure 1: Illustration of current UE behavior between receiving NPDSCH and transmitting HARQ ACK.  Graphical user interface, application, Teams  Description automatically generated  Figure 2: Illustration of proposed UE behavior between receiving NPDSCH and transmitting HARQ ACK, to increase overall throughput.  ***Proposal (for documenting in TR)*: 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.** |
| SONY | This does not seem essential. We do not expect a large throughput enhancement to be attained. We are OK to capture results of the study in the TR. |
| Nokia, NSB | We agree with CMCC as it is non-essential function. |
| Ericsson | These enhancements are non-essential. |
| Lenovo,MotoM | OK for further discussion in feature discussion. |
| CMCC | These enhancements are non-essential. |
| Novamint | The point made by Qualcomm makes sense and it would be beneficial to identify legitimate issues as the ones raised here. So, we could even agree with the proposal to document in the TR as long as it doesn’t prevent agreements on the essential parts for Release 17. |
| GateHouse | Supportive to QUALCOMM’s proposal for the TR, though touching non-essential functionality for Rel-17. |
| Sateliot | Agree with QC view. We think it adds value to capture in the TR solutions that could lead to potential throughput gains, even those solutions may be not considered as essential under Rel-17 but could be addressed in subsequent releases. |
| InterDigital | Not essential in Rel-17 |

## Other

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

|  |  |
| --- | --- |
| **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**

|  |  |
| --- | --- |
| **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.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| MediaTek | Support moderator proposal |
| vivo | Support the Conclusion 9-1. |
| ZTE | All IoT feature defined in Rel-16 spec is the baseline for Rel-17 SI. For the potential identified issue, it can be fixed in this or following up release. |
| CATT | Support it. |
| Huawei, HiSilicon | Considering that we now have the deadline to include essential Rel-17 features to the TR at the May meeting at latest, RAN1 has to be very careful in selecting those features only from earlier NB-IoT/eMTC releases that really fall within the scope of essential minimum functionality. Spending meeting time in discussing which of these features would be added is only taking time away from concluding the TR by June RAN plenary. |
| Apple | Agree |
| Qualcomm | We think RAN2 already agreed to use Rel16 as a baseline.  If some feature (e.g., PUR over LEO cells with moving beams) becomes extremely complicated, we should be open to deferring the details those things for future releases, while documenting such observations either in the TR and/or as chairman’s notes in the WI process. |
| SONY | A UE features discussion seems to be something that should happen in a WI, rather than an SI.  If there are features from previous releases that are particularly problematic to support, these could potentially be captured in the TR. |
| Nokia, NSB | Agree |
| Ericsson | Ok |
| Lenovo, MotoM | OK |
| CMCC | Agree |
| Novamint | Agree with Huawei and Sony as well. By June, we should focus on selecting the features from earlier NB-IoT/eMTC releases that are part of essential minimum functionality. |
| GateHouse | Agree to Huawei/Sony/Novamint. |

# Companies’ proposals and observations

|  |  |
| --- | --- |
| **Company** | **Input** |
| [R1-2102346](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102346.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102425.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102475.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102551.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102620.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102738.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102757.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102834.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102908.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102919.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102975.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103063.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103073.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103135.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103269.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103275.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-17  Proposal-1: Extending maximum HARQ process number is not supported in Rel-17 IoT NTN  Proposal-2: Enabling/disabling HARQ feedback is not supported in Rel-17 IoT NTN |
| [R1-2103321](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103321.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2103530.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:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_104b\Docs\R1-2102551.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 complexity  Agreement:   * 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. |

# 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 signaling  Agreement:  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 |

**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 |

**RAN1#104e**

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| Agreement: |