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

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

**Agenda item:** 8.15.4

**Source:** Moderator (Samsung)

**Title:** Summary#2 for 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 relates to HARQ operation.

*The second objective is, for the above identified scenarios, to Study and recommend necessary changes to support NB-IoT and eMTC over satellite, reusing as much as possible the conclusions of the studies performed for NR NTN in TR38.821. This objective will address the following items:*

*- Aspects related to random access procedure/signals*

*- Mechanisms for time/frequency adjustment including Timing Advance, and UL frequency compensation indication*

*- Timing offset related to scheduling and HARQ-ACK feedback*

*- Aspects related to HARQ operation*

This contribution summarizes companies’ views for enhancements on HARQ.

# Discussion

The large round trip delay in NTN of hundreds of milliseconds compared to the 1ms delay in terrestrial networks will cause a considerable reduction in throughput due to HARQ stalling before HARQ-ACK feedback is received. Solutions such as increasing the number of HARQ processes and disabling the HARQ feedback for NTN operation are considered in NR NTN to minimize the throughput loss. In this meeting, contributions in NTN IoT AI discuss such solutions, along with other enhancements.

Regarding enhancements for HARQ operation in NTN IoT, many companies note that for NB-IoT and eMTC, throughput and latency are not the main requirements and the benefits of introducing enhancements on HARQ targeting higher throughput and low latency should be assessed considering UE complexity and power consumption which are the main characteristics of these IoT devices.

Agreements on HARQ enhancements in AI 8.15.3 for NTN IoT are listed in Annex A.

Agreements on HARQ enhancements in AI 8.4.3 for NR NTN are listed in Annex B.

## Issue 1 (increasing the number of HARQ processes)

Increasing the number of HARQ processes is one of the solutions considered in NR NTN. More HARQ processes can be used for data transmission to mitigate the impact of HARQ stalling although it may not be entirely removed for large delay cases, e.g. GEO with RTT above 500ms. This solution has an impact on UE cost and complexity as the UE needs to support more HARQ processes, hence larger buffer and additional HARQ feedback.

Based on contributions submitted in RAN1#104e, companies’ inputs on increasing the number of HARQ processes for NB-IoT and eMTC in NTN are summarized in Table 1.

Table 1 Summary: issue 1

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| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 1 | Consider increasing the number of HARQ processes | * **Yes:** Sierra Wireless (for NB-IoT) * **No:** Oppo, Huawei (for NB-IoT), ZTE, CATT, Vivo, MediaTek, Intel, Lenovo, Spreadtrum (for NB-IoT), Xiaomi, Samsung, Sierra Wireless (for eMTC), Apple, Interdigital * **Further discuss (**Ericsson, Nokia, Sierra Wireless, Qualcomm) |
| Reasons to support |  |
| Reasons not to support | * Target is high throughput/low latency, not a priority for NB-IoT/eMTC (Oppo, Vivo, MediaTek, Intel, Lenovo, Ericsson, Xiaomi, Apple) * UE complexity (Oppo, Huawei, CATT, Vivo, Intel, Spreadtrum, Ericsson, Nokia, Xiaomi, Samsung, Apple, Interdigital) * Not needed for NB-IoT, existing mechanism for aggregating resources can be used (Huawei, Spreadtrum, Nokia) |
| Solutions | Observation 7: In NB-IoT, consider increasing the number of HARQs only in the UL since UE complexity is not a factor. (Sierra Wireless) |

### First round discussion

The majority of companies does not support increasing the maximum number of HARQ processes for NB-IoT and eMTC in NTN.

Proposal 1: Increasing the maximum number of HARQ processes for NB-IoT and eMTC in NTN is not supported in Rel-17.

Table 2 Additional inputs: issue 1

|  |  |
| --- | --- |
| **Company** | **Input** |
| ZTE | Agree with proposal 1. But also fine to further discussion since the key issue is justify the required throughput. If no additional needs are considered, keeping current design is 1st choice. |
| Apple | Agree with the proposal. |
| Huawei | Agree with proposal 1. |
| Ericsson | In principle we agree that increasing the number of HARQ processes is likely not needed for IoT NTN but since this is a study item, it would seem proper to have a thorough investigation before concluding this topic. |
| Sierra Wireless | Although we feel NB-IOT speeds and battery life could be improved by increasing UL HARQs to 4 without increasing UE complexity, we can go with majority view here.  However, we still feel there is unacceptable scheduling overhead for LTE-M because when >=4 repeats are scheduled only one TB per HARQ cycle can be scheduled. This issue should be studied. |
| Lenovo, MotoM | Support proposal 1 |
| vivo | Support the proposal. |
| Spreadtrum | Support the proposal. |
| Xiaomi | Support this proposal |
| CMCC | Support the proposal. |
| Qualcomm | It is a bit premature to make this agreement in this meeting. There may be benefits (which could be studied) of having, for example, additional HARQ process(es) without feedback, to enhance throughput in NTNs. |
| Samsung | Support the proposal. |
| CATT | Support the proposal. |
| SONY | This needs further study. We share the view with Sierra Wireless that increasing the number of HARQ processes in the UL does not impact UE complexity.  We think that HARQ can be stalled in the GEO case, but are not so sure in the LEO case. Whether HARQ is stalled or not depends on the number of repetitions required (if the HARQ transmissions take a longer time to transmit than the RTT, there may not be stalling).  We think that there needs to be study on the link budget in order to determine the number of repetitions required. Once this is determined, we will have a better idea of whether there is a stalling problem. |
| MediaTek | Agree with proposal |
| Nokia, NSB | Same view as Ericsson. We agree in principle. But further study may not be excluded in this early stage of SI. |

Updated Proposal 1

Further study increasing the maximum number of HARQ processes for NB-IoT and eMTC in NTN.

Based on the agreement in Wed GTW to study further the potential benefits and/or drawbacks of increasing the number of HARQ processes on throughput, latency, power consumption and complexity, this issue#1 will be discussed in the 2nd round of discussions.

### Second round discussion

|  |  |
| --- | --- |
| **Company** | **Input** |
| Oppo | Proposal 1: HARQ disabling and increased HARQ process number should NOT be supported for NB-IoT/eMTC over NTN. |
| Huawei, HiSi | Proposal 1: There is no need to extend HARQ process number in IoT-NTN. |
| ZTE | Observation 2: HARQ process number for NB-IoT/eMTC in terrestrial network can be reused for IoT-NTN |
| CATT | Observation 1: Increasing the number of processes will cause additional UE cost, which is critical for NB-IoT case. |
| vivo | Proposal 1: The HARQ process number can be maintained the same as the NB-IoT/eMTC for TN, the extension of maximal HARQ process number is not supported in NB-IoT/eMTC NTN. |
| MediaTek | Observation 4: Doubling the number of HARQ processes from 2 to 4 in NB-IoT is not a priority as it approximately provides a 50% increase in data rates compare to Rel-14 NB-IoT device due to internal scheduling delays and would have high impact on the specifications. By comparison, a Rel-17 NB-IoT device will provide double the data rates compare to rel-14 NB-IoT device. |
| Intel | Proposal 2:  • Increased number of HARQ processes is not considered in NB-IoT/eMTC NTN SI |
| Lenovo, MotoM | Proposal 1: The HARQ process number can be maintained the same as legacy for both eMTC and NBIoT. |
| Spreadtrum | Proposal 1: Number of HARQ process should be kept in IOT NTN. |
| Sony | Observation 4: 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 5: For LEO constellations, the UE processing pipeline can be fully loaded with active PUSCH transmissions when 2 HARQ processes are active. |
| Ericsson | Observation 3 If delay tolerant, small and infrequent data transmissions continue to be the focused use cases for IoT NTN, HARQ enhancements are not foreseen to be needed. |
| Nokia, NSB | Observation 1: repetition for IoT UE will mitigate the impact of HARQ stalling because of long propagation delay in NTN scenario.  Observation 3: more HARQ process with more cost/complexity may not help when repetition number is too large. |
| Xiaomi | Proposal 1: The number of the supported HARQ process should not be increased for IoT NTN. |
| Samsung | Proposal 3: Number of HARQ processes should be kept considering increasing HARQ process number will cause additional UE cost. |
| Sierra W | LTE-M:  Observation 2: A higher TBS increase number of repeats but results in faster speeds, increased spectral efficiency, and lower number of required HARQs.  Observation 3: With TBS = 504, no additional HARQs are needed for LEO and 1 additional HARQs is needed for GEO to fill gaps for LTE-M.  Proposal 1: Do not increase the number of HARQs for LTE-M.  NB-IOT:  Observation 7: In NB-IoT, consider increasing the number of HARQs only in the UL since UE complexity is not a factor.  Observation 8: A higher TBS increases required transmission time but results in faster speed, increased spectral efficiency, and lower number of required HARQs.  Observation 9: With TBS = 504, no additional HARQs are needed for LEO but additional HARQs are needed for GEO to fill gaps for NB-IoT. |
| Apple | Proposal 1: The number of HARQ processes is not increased in IoT over NTN. |
| InterDigital | Proposal 1: Maximum HARQ process number is not increased for NTN NB-IoT/eMTC devices. |

Proposals/observations regarding the increase of number of HARQ processes for NB-IoT/eMTC are listed above.

The motivation for introducing HARQ enhancements in NR is to recover the throughput loss due to HARQ stalling. Throughput is a critical characteristic for MBB traffic and increasing the number of HARQ processes is adopted in NR NTN. For NTN IoT, companies question the adoption of this solution due to the nature of IoT devices (low complexity, low cost, low power consumption) and the requirements of IoT services (low throughput, delay-tolerant, infrequent data transmissions, extended coverage and support of massive connections).

Several companies observed that the requirement of high throughput/low latency is not a priority for NB-IoT/eMTC.

One company (MediaTek) observed that the impact of the satellite RTT delay on the NB-IoT data rates in LEO satellite is about a 50% reduction in throughput for a Rel-14 NB-IoT due to the large processing scheduling delays in such devices. By doubling the number of HARQ processes from 2 to 4, approximately a 50% increase on DL and UL throughput was observed for Rel-14 NB-IoT device. It is also observed that with Rel-17 NB-IoT the data rates will be double than the one in Rel-14 and this loss in throughput would be offset.

One company (Sony) observed that, for eMTC in CE Mode B, if more than 2 HARQ processes were supported, the UE could be transmitting PUSCH during the round trip time, increasing the sustained data rate. It is also observed that in an HARQ cycle for eMTC operation over LEO-600, the round trip time occurs wholly within the transmission time of a PUSCH and hence the UE processing pipeline can be fully loaded in a LEO-600 constellation.

Some companies (Huawei, CATT, Vivo) observed that the large RTT delays can be covered by resource aggregation since a large number of repetitions can be used for IoT applications. For NB-IoT a maximum of 128 repetitions in UL and 2048 in DL can be used.

Almost all companies observe that the major drawback of increasing the number of HARQ processes is the added complexity / cost / power consumption for an IoT device which is intended to be a low complexity / low cost / low power consumption device.

Increased HARQ soft buffer size, larger memory, higher computing capabilities are mentioned by several companies (CATT, ZTE, Vivo, Lenovo, Apple, Samsung, Interdigital) as major impacts to UE complexity. At most two HARQ processes are sufficient for NB-IoT use cases (CATT). For eMTC case, the number of HARQ processes in Rel-17 is increased (from 8 to 14), and further optimization can be deprioritized if no new requirements of data are defined (ZTE).

Companies (Oppo, Huawei (for NB-IoT), ZTE, CATT, Vivo, MediaTek, Intel, Lenovo, Spreadtrum (for NB-IoT), Xiaomi, Samsung, Sierra Wireless (for eMTC), Apple, Interdigital) suggested not to consider increasing the number of HARQ processes.

**Proposed observations**

General observation for HARQ enhancements in NTN IoT.

**Observation 1-1:** The motivation for introducing HARQ enhancements in NR NTN needs further consideration for HARQ enhancements in NTN IoT.

* For NR NTN, the main reasons for enhancing HARQ operation are to recover the throughput loss due to HARQ stalling and UE power saving. Throughput is a fundamental requirement of MBB services, hence solutions as increasing the number of HARQ processes and disabling HARQ feedback are beneficial to satisfy key requirements in NTN. Disabling HARQ feedback enables UE power saving.
* For NTN IoT, potential HARQ enhancements need to consider the main characteristics of an IoT device, which are low complexity, low cost and low power consumption, and key requirements of IoT services which are extended coverage, low throughput, delay-tolerant and infrequent data transmissions and support of massive communications. Increasing complexity and power consumption of NB-IoT and eMTC UEs that operates in NTN compared to UEs operating in TN to increase throughput may not be viewed as an acceptable trade-off for IoT deployments in NTN.

**Question 1 – Any views on observations 1-1?**

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| --- | --- |
| **Company** | **Input** |
| Qualcomm | The note for NTN IoT is not acceptable to us. There may be ways in which throughput can be enhanced from a barebones baseline in NTN IoT (which, we may add, may be *significantly lower* than terrestrial IoT, in the most barebones solution) *without* significantly increasing UE complexity. |
| Huawei | In general the observation looks fine, but what is the next step forward here? Is this something that could be developed into a Text Proposal for the SI TR? |
| MediaTek | We agree with observation. The target for first release is to make sure there is a specified solution to support HARQ or support HARQ disabling. Further enhancements of HARQ can be in later releases if needed and beneficial. It could be included in some form in the SI TR |
| Ericsson | The observation looks fine in general. |
| Apple | Agree with the observations. |
| Spreadtrum | The observation is fine. |

Observations on increasing number of HARQ processes.

**Observation 1-2:** The advantage of increasing the number of HARQ processes for NTN IoT is enhanced throughput.

* For a Rel-14 NB-IoT UE operating in LEO satellite, it is observed a 50% reduction in throughput due to the large scheduling delay respect to operation in TN, which can be recovered by increasing the number of HARQ processes from 2 to 4.
* For eMTC in CE Mode B, if more than 2 HARQ processes were supported, the UE could be transmitting data during the round trip time, increasing the sustained data rate.

**Observation 1-3:** The drawbacks of increasing the number of HARQ processes for NTN IoT are increased complexity, cost and power consumption. Specifically, a NB-IoT UE or eMTC UE that supports a larger number of HARQ processes compared to a Rel-16 NB-IoT UE or eMTC UE,

* needs to implement a larger HARQ soft buffer size,
* needs higher computing capability, and
* consumes more power.

**Question 2 – Any views on the observations 1-2 and 1-3?**

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| --- | --- |
| **Company** | **Input** |
| Huawei | We do not agree with the proposed observation 1-2 in absence of any evidence as of now whether the listed bullets indeed are advantages. The baseline for comparisons needs to be agreed upon. |
| Spreadtrum | For observation 1-2, without rigorous evaluation, we cannot be sure that increasing the number of HARQ will bring such a gain in IOT NTN. |
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## Issue 2 (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 3 Summary: issue 2

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| --- | --- | --- |
| **#** | **Issue** | **Companies’ views** |
| 2 | Consider disabling HARQ feedback | * **Yes:** CATT (for eMTC CEModeA), Vivo, Intel, Spreadtrum, Samsung, Apple, Qualcomm * **No:** Oppo, Huawei (for NB-IoT), ZTE, CATT (for NB-IoT, eMTC CEModeB), MediaTek, Lenovo (at least for NB-IoT), Xiaomi, Interdigital * **Further discuss (**Ericsson, Nokia, Sony) |
| Reasons to support | * Throughput requirement for eMTC CEModeA is higher (CATT, Intel) * Optimize throughput for NB-IoT (Qualcomm) * Disabling HARQ feedback benefits UE power consumption (Vivo, Spreadtrum, Samsung) * Allows the prompt release of HARQ soft buffer to facilitate the reception of new data (Apple) |
| Reasons not to support | * Target is high throughput/low latency, not a priority for NB-IoT/eMTC (Oppo, MediaTek, Ericsson, Xiaomi) * UE complexity (Oppo) * Not necessary - due to the higher number of repetitions, and low number of HARQ processes in NB-IoT (Huawei, ZTE, CATT, MediaTek, Lenovo, Spreadtrum) * It can be done by implementation (MediaTek) * It may not be helpful to save the time for HARQ feedback as the main issue is the time resource occupied by repetitions (Nokia) * It can’t be applied to NB-IoT with 1 HARQ process (Nokia) |

### First round discussion

Companies’ views are not aligned and valid reasons for either supporting or not supporting this feature are provided. Since NTN IoT is in study phase, it is suggested to further study disabling HARQ feedback for NB-IoT and eMTC in NTN. Whether to support it or not will be the outcome of further discussions.

Proposal 2

Further study disabling HARQ feedback for NB-IoT and eMTC in NTN.

Table 4 Additional inputs: issue 2

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| --- | --- |
| **Company** | **Input** |
| ZTE | Support |
| Apple | Support |
| Huawei | In principle agree with proposal 2, but possibly we can consider the necessity separately for NB-IoT and eMTC because company comments also depend on which one is in question |
| Ericsson | We are fine with the proposal. |
| Sierra Wireless | Support |
| Lenovo, MotoM | Support the proposal. For NBIoT, we are OK not to support the HARQ disabling, but for eMTC, especially for CE mode A, we are still open to identify the penitential benefit of throughput and transmission delay with HARQ disabling. |
| vivo | Support the proposal. |
| Spreadtrum | Support the proposal. |
| Xiaomi | Although we don’t see the benefit to support HARQ disabling, we are OK to study it. |
| CMCC | Support the proposal. |
| Qualcomm | Support (we also support this in our contribution; our position on supporting at least HARQ process without feedback is missing from the table) |
| Samsung | Support the proposal. |
| CATT | Support the proposal. |
| SONY | Support. Whether there is a need to disable HARQ will partly depend on whether there is otherwise a stalling problem, which depends on the link budget. Further progress on this topic can be made once we have made progress on the link budget. |
| MediaTek | Support proposal. Disabling HARQ feedback for LEO is not necessary. HARQ feedback can be disabled for GEO. |
| Nokia, NSB | Agree to the proposal. Additionally, if HARQ feedback is disabled, how to ensure e.g. link adaptation work well should also be studied. |

Based on the above inputs, proposal 2 is support by all companies.

### Second round discussion

Some companies (Vivo, Spreadtrum, Samsung) observe that the main benefit of disabling HARQ feedback is UE power saving. One company (Apple) thinks that introducing disabling of HARQ feedback is beneficial as trade-off between increasing the data rate and the cost of reduced reliability and increased latency. One company (CATT) thinks that it is beneficial to increase the peak rate without increasing the complexity so that the existing number of HARQ processes can be kept. One company (Qualcomm) proposes to study supporting at least a single feedback-less HARQ process that can enable pipelined transmissions and increase throughput

Some other companies (Huawei, ZTE, CATT, MediaTek, Lenovo, Spreadtrum) think that it is not necessary to disable the HARQ feedback due to the high number of repetitions and low number of HARQ processes, or in general not needed to design for higher throughput especially for NB-IoT and eMTC CEModeB.

One company (Huawei) discussed that when disabling HARQ feedback, retransmission at RLC layer (i.e. RLC ARQ) may be required to meet reliability requirements. Typically, ARQ re-transmissions in RLC AM can have high latency, but it can be acceptable as IoT services are generally delay-insensitive. Another company (MediaTek) discussed that the reliability of Message 3 in RACH procedure cannot be based on RLC ARQ as RLC AM is not possible before contention resolution has completed and the simplest way to ensure reliability is not to disable UL HARQ retransmissions before contention resolution in random access procedure has completed.

One company (Sony) observed that whether there is a need to disable HARQ will partly depend on whether there is otherwise a stalling problem, which depends on the link budget. Link budget analysis is needed.

Some companies (Vivo, Spreadtrum, Samsung, Apple, Intel, CATT (for eMTC CEModeB)) propose to introduce disabling HARQ feedback for NTN IoT, while others (Oppo, Huawei (for NB-IoT), ZTE, CATT (for NB-IoT, eMTC CEModeB), MediaTek, Lenovo (at least for NB-IoT), Xiaomi, Interdigital) propose not to introduce it. Others are open to discuss (Sony, Ericsson, Nokia).

Some companies (CATT, Samsung, Apple, Intel) propose enabling/disabling of HARQ feedback for downlink transmission per HARQ process via UE specific RRC signaling as in NR NTN.

**Proposed observations**

**Observation 2-1:** The advantages of disabling HARQ feedback are

* UE power saving
* Throughput increase without increasing UE complexity
* Improved resource utilization

**Observation 2-2:** The drawback of disabling HARQ feedback is

* Reduced reliability

**Observation 2-3:** When the number of HARQ processes is small (e.g. 2) and the number of repetitions is large (e.g. on the order of hundreds), disabling HARQ for NB-IoT and eMTC CEModeB reduces UE power consumption but the benefit is not expected to be large.

**Question 3 – Any views on the observations 2-1 to 2-3?**

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| --- | --- |
| **Company** | **Input** |
| Qualcomm | Not sure of the value-add here; 2-1 and 2-2 seem to be OK. |
| Huawei | The observations 2-1 and 2-2 are interrelated and whilst they are in principle correct, there is so far no evidence that they necessarily follow. The baseline for comparisons needs to be agreed upon. |
| MediaTek | Agree with 2-1 (avoid longer transmission time, HARQ stalling, HARQ buffer increase) and 2-3 (reduced reliability at MAC layer, RLC ARQ can still be used). |
| Ericsson | Further studies are needed to determine and quantify the mentioned advantages/disadvantages. |
| Apple | We are not sure what “improved resource utilization” in observation 2-1 refers to? Does it mean no HARQ feedback could leave more resources for other transmissions?  In Observation 2-2, we may want to mention the drawback of “reduced reliability” may be addressed by some enhancement solutions, e.g., increased repetition number, etc. |

## Other issues – first round discussion

Table 5 is a summary of other proposals on HARQ enhancements. An initial categorization of issues based on companies’ proposals and observations is provided.

Table 5 Summary: issues 3 to 10

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| --- | --- |
| **#** | Issue |
| 3 | **HARQ feedback**   * Companies’ proposals   Proposal 3: RAN1 should study alternative feedback for HARQ maximizing the performance of the link, incl for UEs with 1 or 2 HARQ processes. (Nokia)  Proposal 2: RAN1 to study support for at least one feedback-disabled HARQ process for NB-IoT over NTN. (Qualcomm)  Proposal 2: RAN1 to consider disabling HARQ feedback for downlink transmissions, which is configurable per HARQ process via UE specific RRC signaling (Apple)  Proposal 2: HARQ feedback can be enabled/disabled per HARQ process via UE specific RRC signaling as NR (Samsung)   * Moderator’s note   Pending agreement of the moderator’s Proposal 2, issue 3 would include the discussion of disabling HARQ feedback, along with other proposals on HARQ feedback. |
| 4 | **PDCCH monitoring**   * Companies’ proposals:   NPDCCH  Proposal 1: UE shall skip NPDCCH monitoring for the same HARQ process within a given RTT (Asia Pacific Telecom, FGI)  NPDCCH  Proposal 1: RAN1 to study enabling PDCCH monitoring in “waiting periods”—for example, between receiving NPDSCH and transmitting HARQ ACK in NB-IoT—to mitigate suboptimal throughput. (Qualcomm)  MPDCCH  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. (Sony)   * Moderator’s note   This discussion would be to study mechanisms to reduce PDCCH monitoring related to the HARQ operation. Based on companies’ proposals, the scope would be to reduce UE power consumption. |
| 5 | **Coverage enhancements**   * Companies’ proposals   Proposal 2: Enhancement on data transmission should be considered if scenarios with too large coupling loss and too low CNR are supported. (ZTE)  Proposal 4: Study performance improvement of repetition transmission for satellite NB-IoT in the presence of synchronization error (CATT)  Proposal 1: it should be evaluated whether current LTE NB-IoT/eMTC HARQ and repetition number can support the max coupling loss as requirement and agreed data rate, in NTN scenarios with different satellite obit. (Nokia)   * Moderator’s note   Analysis/evaluation in AI 8.15.1 would assess the performance of the existing transmission schemes (including number of repetitions, HARQ parameters) in NTN. The need for further improvements can be discussed based on the findings in AI 8.15.1, and solutions related to HARQ aspects can be studied in this AI. |
| 6 | **Uplink transmission gaps with multiple HARQ processes for NB-IoT** (Asia Pacific)  Observation 1: If an NB-IoT UE detects a DCI ending in subframe n, the UE may not expect to receive another DCI before subframe n+k-2 for which the corresponding NPUSCH transmission ends later than subframe n+k+255.  Proposal 2: Enhancement on two consecutive NPUSCH transmissions might be needed, regarding the existing scheduling restriction on scheduling offset.   * Moderator’s note   It can be first discussed the necessity of addressing this issue. The enhanced timing relationships considered in AI 8.15.2 would need to be taken into account. |
| 7 | **UE assistance** (Samsung)  Proposal 4: UE assistance information for HARQ can be supported.   * Moderator’s note   It can be also discussed how gNB would use the UE assistance information. |
| 8 | **Serving cell change** (Nokia)  Proposal 4: 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.   * Moderator’s note   It can be first discussed the necessity/scenario for maintaining the continuity for the HARQ process when changing cell in NTN. |
| 9 | **Multiple Transport Blocks per HARQ Cycle (MTBHC)** (Sierra Wireless)  eMTC  Observation 5: Scheduling multiple TBs per HARQ cycle increases UL speeds by 28% for LEO600.  Proposal 2: Study how the variable PDSCH to ACK mechanism for ACK-Bundling can be adjusted to support scheduling more than one TBs per HARQ cycle.  Observation 6: To support multiple TBs scheduled in one HARQ cycle for UL, a variable delay between the UL grant and PUSCH would need to be specified.  Proposal 3: Specify a variable UL grant to PUSCH delay to support scheduling more than one TBs per HARQ cycle.  NB-IoT  Observation 10: Scheduling multiple TBs per HARQ cycle increases UL speeds by 31.4% for LEO600.  Proposal 4: To support scheduling multiple TBs per HARQ cycle, increase the number of HARQs to 4 in the uplink for NB-IoT.   * Moderator’s note   The need/benefit of enhancing timing relationships should consider the time offsets discussed in AI 8.15.2. Pending agreement of the moderator’s Proposal 1, increasing of HARQ processes for NB-IoT may not be considered. |
| 10 | **TP for TR** (Sony)  The IoT-NTN TR captures observations on:  • The fraction of the HARQ cycle that is occupied by active PUSCH / PDSCH transmissions  • The number of HARQ processes that are supportable in IoT-NTN   * Moderator’s note   It can be revisited in a later meeting. |

It is encouraged to provide inputs on the issues listed in Table 5 in order to decide the categorization of the issues and whether or not an issue has to be further discussed.

Table 6 Additional inputs: Issues 3 to 10

|  |  |
| --- | --- |
| **Company** | **Input** |
| ZTE | Issue 3: Agree with FL’s note. it can be postponed and up to decision of issue 2  Issue 4: For this part, the power saving related discussion can be organized together.  Issue 5~6: Agree with FL’s notes  Issue 7: This is also related to issue 2 since the corresponding assistance information is considered to optimize the scheduling with enabled/disabled feedback as discussed in NR.  Issue 8: Agree. This is valid issue, can be treated with higher priority  Issue 9: Agree with FL’s notes  Issue 10: Will be handled later once any agreement is achieved |
| Apple | Issue 3: Agree with FL’s note.  Issue 4: Power saving is not in the scope of SID.  Issue 5: Agree with FL’s note that it can be discussed in AI 8.15.1  Issue 6: Uplink transmission gap is discussed in NR NTN HARQ enhancement. We may wait for the outcome from NR NTN.  Issue 7: Similar discussion is in NR NTN HARQ enhancement. We may wait for the outcome from NR NTN.  Issue 8: Agree with FL’s note.  Issue 9: Agree with FL’s note.  Issue 10: Agree with FL’s note. |
| Huawei | Issue 3: Agree with FL that this issue can wait until the outcome of issue 2.  Issue 4: We don’t see a great urgency for this topic  Issue 5: We agree with moderator’s note that the AI8.15.1 has to be addressed first with its link budget analysis. This would indicate the need (if any) for any coverage enhancement.  Issue 6: It is best to first conclude on the timing relationship discussion in 8.15.3.  Issue 7: Since this is related to the outcome of issue 2, further discussion can wait.  Issue 8: We agree with moderator’s note on first evaluating the necessity of maintaining HARQ process continuity  Issue 9: it is too early to consider adding HARQ processes particularly in light of the majority of company positions in Issue 1. Bit rate increase is not a key design target for NB-IoT.  Issue 10: Agree with FL’s note |
| Ericsson | Issue 3: The need for disabling HARQ feedback for IoT NTN is not clear and needs to be studied before related proposals are considered.  Issue 4: The necessity of these proposals is not clear. It should be first justified there is an issue.  Issue 5: Agree with the FL’s note.  Issue 6: Agree with the FL’s note.  Issue 7: This discussion can wait until issue 2 is concluded. The necessity of this is questionable. This has been discussed under NR NTN WI without consensus. Suggest following the progress in the NR NTN WI.  Issue 8: Agree with the FL’s note.  Issue 9: Agree with the FL’s note.  Issue 10: Agree with the FL’s note. |
| Sierra Wireless | Issue 3: Agree with FL  Issue 4: Given the large specification impact of PDCCH monitoring changes and the brevity of this work item, PDCCH monitoring changes should not be considered.  Issue 5: Desired number of repeats for different SNRs must be studies. This drives the discussion on #HARQ and HARQ feedback and timing aspects  Issue 6: HARQ-ACK timing must be studied, not only for NPUSCH but also for PDSCH and PUSCH in LTE-M  Issue 7: Wait for NR NTN  Issue 8: Agree with FL  Issue 9: Agree with FL. Since LTE-M only allows 1 TB per HARQ cycle when repeats are scheduled, Grant-PUSCH and PDSCH-ACK timing aspects should be studied for LTE-M.  Issue 10: Agree with FL |
| Lenovo, MotoM | For issue 3, we agree with moderator  For issue 4, PDCCH monitoring issue is identified by many companies, so we should get some guideline on which sub-agenda to discuss this issue  For issue 5, enhancement on data transmission needs further study, especially for some scenarios, e.g, cube satellite with limited Tx power and large coverage range for IoT NTN.  For issue 6, agree with moderator  For issue 7, the issue is related to issue 2, and we can trace the progress of NR NTN if necessary  For issue 8, agree with moderator  For issue 9. We can consider the multiple TB transmission with single DCI to reduce the delay, but don’t need to increase the HARQ process number, which is not supported in R.16 NBIoT |
| vivo | Considering the large RTT in NTN, we agree to further study the PDCCH monitoring to reduce UE power and increase throughput performance. |
| Xiaomi | For issue 3, we agree with the note  For issue 4, we don’t see this have strong relevance to HARQ operation.  For issue 5, we are supportive to study enhancement on data transmission.  For issue 6, agree with moderator.  For issue 7, we share similar view with other companies, no need to discuss it at this stage.  For issue 8, agree with the note |
| CMCC | Issue 3: Agree with FL that this issue can wait until the outcome of issue 2.  Issue 4: Power saving is a key feature for NB-IoT/eMTC application. It needs further study. We agree with ZTE that the power saving related discussion can be organized together.  Issue 5: Agree with the FL’s note.  Issue 6: Agree with the FL’s note.  Issue 7: Wait for NR NTN.  Issue 8: Agree with FL’s note.  Issue 9: Agree with FL’s notes  Issue 10: Agree with FL’s note. |
| Qualcomm | The issue we raised with regards to enabling PDCCH monitoring in waiting periods seems to be “misinterpreted” by some as being some sort of “power saving” proposal. It is not. Our proposal (listed under Issue 4) is about “maintaining throughput”.  We actually propose to “enable” NPDCCH monitoring during potentially large “waiting periods”—e.g., when a cell-specific Koffset is configured (according to the worst-case RTT) in a GEO cell, and a UE with a small RTT has to wait a long time between receiving an NPDSCH and transmitting its corresponding HARQ ACK. The large “waiting period” could be “filled” by allowing the network to schedule other DL transmission in that period (e.g., an NPDCCH scheduling a feedback-less HARQ process).  We request to kindly capture this proposal under a separate item such as “Throughput considerations for NB-IoT over NTN”. We believe this is an important issue, since in the absence of this, the system throughput can suffer significantly. |
| Samsung | Issue 3: Agree with FL’s note.  Issue 4: we don’t see this is related to HARQ enhancements.  Issue 5: Agree with FL’s note.  Issue 6: Agree with FL’s note.  Issue 7: Agree with FL’s note.  Issue 8: Agree with FL’s note.  Issue 9: Agree with FL’s note.  Issue 10: Agree with FL’s note. |
| CATT | Issue 3: Agree with FL proposal.  Issue 4: not sure what is the real benefit?  Issue 5: agree FL proposal. This issue is important for study, but actually it is not related to coverage enhancement, which should be evaluated in normal case to check the repletion gain can be obtained in IoT NTN.  Issue 6: It can be discussed in other AI.  Issue 7: Not sure what is detailed solution?  Issue 8: agree FL proposal, firstly we need to evaluate the necessity of maintaining HARQ process continuity  Issue 9: HARQ process enhancement is not justified in this moment.  Issue 10: Agree with FL’s note |
| SONY | Issue 3: agree with FL  Issue 4: scope is to reduce power consumption, which we see as an important KPI for eMTC / NB-IoT. We would be OK to group power consumption issues together  Issue 5: it is important to determine the amount of coverage enhancement that is required for the studied scenarios. This determination will feed into the other issues discussed under this AI and other AIs. We are not sure that further coverage enhancement (relative to Rel-16) is required.  Issue 6: some clarification of this issue is needed  Issue 7: not a priority. We can wait for NR NTN  Issue 8: agree with FL  Issue 9: This could be considered under AI 8.15.3 (is “8.15.2” a typo in the moderator’s note?). The need for MTBHC depends on the link budget and required number of repetitions, as previously suggested in our responses.  Issue 10: agree with FL note |
| MediaTek | Issue 3: Agree with Moderator’s note. Discuss first need for HARQ disabling  Issue 4: Not a first priority. Whether this is an issue and need and potential benefit should be justified.  Issue 5: Agree with Moderator’s note  Issue 6: Agree with Moderator’s note  Issue 7: The issue has been discussed in NR NTN. The necessity and gains should be justified.  Issue 8: Agree with Moderator’s note.  Issue 9: Agree with Moderator’s note. |
| Nokia, NSB | Issue 3: Agree with the FL’s note.  Issue 4: Further study if it is identified to be with IoT NTN scenario.  Issue 5: Agree with the FL’s note.  Issue 6: Agree with the FL’s note.  Issue 7: Further study  Issue 8: Agree for further study on this issue in this early stage of SI.  Issue 9: Agree with the FL’s note.  Issue 10: Agree with the FL’s note. |

Based on companies’ inputs in Table 6, issues#3 to 11 are discussed below.

### Issue 3 (HARQ feedback)

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| **#** | Issue |
| 3 | **HARQ feedback**   * Companies’ proposals   Proposal 3: RAN1 should study alternative feedback for HARQ maximizing the performance of the link, incl for UEs with 1 or 2 HARQ processes. (Nokia)  [Proposal 2: RAN1 to consider disabling HARQ feedback for downlink transmissions, which is configurable per HARQ process via UE specific RRC signaling (Apple)  Proposal 2: HARQ feedback can be enabled/disabled per HARQ process via UE specific RRC signaling as NR (Samsung)  Proposal 2: RAN1 to study support for at least one feedback-disabled HARQ process for NB-IoT over NTN. (Qualcomm)]   * **Moderator’s note**   Disabling HARQ feedback to be studied in issue#2. Study HARQ feedback. |

All proposals related to disabling HARQ feedback can be studied in issue#2, including the proposals in square brackets above. An additional proposal related to feedback is proposal 3

In R1-2101030 (above proposal 3 from Nokia), it is mentioned to consider some feedback. As an alternative to disabling HARQ feedback, which may not always be feasible, for example for NB-IoT UEs supporting a single HARQ process, or for UEs supporting 2 HARQ processes, in order to avoid HARQ stalling in R1-2101030 it is proposed to study other types of feedback. No other details are given in this meeting.

A similar approach is discussed in R1-2101245, where the feedback from the UE (or assistance information) is used to decide whether to disable/enable an HARQ feedback, or adapt the number of HARQ processes. The feedback can be information about the buffer for HARQ operation.

Some companies think that studying these types of feedback is not a priority. However, given that we are at the beginning of the study, we can discuss this topic related to feedback at next meeting if interested companies provide complete proposals and details.

**Conclusion** – Revisit at next meeting as needed.

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| **Company** | **Input** |
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### Issue 4 (reducing PDCCH monitoring)

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| 4 | **Reducing PDCCH monitoring**   * Companies’ proposals:   NPDCCH  Proposal 1: UE shall skip NPDCCH monitoring for the same HARQ process within a given RTT (Asia Pacific Telecom, FGI)  MPDCCH  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. (Sony)   * **Moderator’s note**   This discussion would be to study mechanisms to reduce PDCCH monitoring related to the HARQ operation. Based on companies’ proposals, the scope would be to reduce UE power consumption. |

Companies expressed the opinion that power saving is not the main scope of this SI, some other companies think that this should be studied since low power consumption for IoT devices is one fundamental requirement, and discuss all related proposals under a single issue.

The moderator suggestion is to discuss such proposals on reducing PDCCH monitoring in the 2nd round of discussion and decide at a later stage whether to prioritize potential solutions. If there are other proposal that should be discussed in this same category, companies are encourage to propose that.

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### Issue 5 (coverage enhancements)

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| 5 | **Coverage enhancements**   * Companies’ proposals   Proposal 2: Enhancement on data transmission should be considered if scenarios with too large coupling loss and too low CNR are supported. (ZTE)  Proposal 4: Study performance improvement of repetition transmission for satellite NB-IoT in the presence of synchronization error (CATT)  Proposal 1: it should be evaluated whether current LTE NB-IoT/eMTC HARQ and repetition number can support the max coupling loss as requirement and agreed data rate, in NTN scenarios with different satellite orbit. (Nokia)   * **Moderator’s note**   Analysis/evaluation in AI 8.15.1 would assess the performance of the existing transmission schemes (including number of repetitions, HARQ parameters) in NTN. The need for further improvements can be discussed based on the findings in AI 8.15.1, and solutions related to HARQ aspects can be studied in this AI. |

Based on inputs provided in Table 6, companies agree with the moderator’s note.

### Issue 6 (uplink transmission gaps)

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| 6 | **Uplink transmission gaps with multiple HARQ processes for NB-IoT** (APT, FGI)  Observation 1: If an NB-IoT UE detects a DCI ending in subframe n, the UE may not expect to receive another DCI before subframe n+k-2 for which the corresponding NPUSCH transmission ends later than subframe n+k+255.  Proposal 2: Enhancement on two consecutive NPUSCH transmissions might be needed, regarding the existing scheduling restriction on scheduling offset.   * **Moderator’s note**   It can be first discussed the necessity of addressing this issue. The enhanced timing relationships considered in AI 8.15.2 would need to be taken into account. |

One company suggested to discuss the uplink transmission gaps also for eMTC.

### Issue 7 (UE assistance)

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| 7 | **UE assistance** (Samsung)  Proposal 4: UE assistance information for HARQ can be supported.   * **Moderator’s note**   Discuss in issue#3 or wait for NR NTN progress. |

Discussed together with issue#3.

### Issue 8 (serving cell change)

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| 8 | **Serving cell change** (Nokia)  Proposal 4: 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.   * **Moderator’s note**   It can be first discussed the necessity/scenario for maintaining the continuity for the HARQ process when changing cell in NTN. |

Based on inputs provided in Table 6, companies agree with the moderator’s note.

### Issue 9 (multiple TB scheduling)

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| 9 | **Multiple Transport Blocks per HARQ Cycle (MTBHC)** (Sierra Wireless)  eMTC  Observation 5: Scheduling multiple TBs per HARQ cycle increases UL speeds by 28% for LEO600.  Proposal 2: Study how the variable PDSCH to ACK mechanism for ACK-Bundling can be adjusted to support scheduling more than one TBs per HARQ cycle.  Observation 6: To support multiple TBs scheduled in one HARQ cycle for UL, a variable delay between the UL grant and PUSCH would need to be specified.  Proposal 3: Specify a variable UL grant to PUSCH delay to support scheduling more than one TBs per HARQ cycle.  NB-IoT  Observation 10: Scheduling multiple TBs per HARQ cycle increases UL speeds by 31.4% for LEO600.  Proposal 4: To support scheduling multiple TBs per HARQ cycle, increase the number of HARQs to 4 in the uplink for NB-IoT.   * **Moderator’s note**   The need/benefit of enhancing timing relationships should consider the time offsets discussed in AI 8.15.2. Increasing of HARQ processes for NB-IoT is not a priority, it might be considered at a later stage after issue#1 is concluded. |

Based on inputs provided in Table 6, companies agree with the moderator’s note.

### Issue 10 (TP)

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| 10 | **TP for TR** (Sony)  The IoT-NTN TR captures observations on:  • The fraction of the HARQ cycle that is occupied by active PUSCH / PDSCH transmissions  • The number of HARQ processes that are supportable in IoT-NTN   * **Moderator’s note**   It can be revisited in a later meeting. |

Based on inputs provided in Table 6, companies agree with the moderator’s note.

### Issue 11 (Throughput enhancements)

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| 11 | Throughput enhancements (Qualcomm)  Proposal 1: RAN1 to study enabling PDCCH monitoring in “waiting periods”—for example, between receiving NPDSCH and transmitting HARQ ACK in NB-IoT—to mitigate suboptimal throughput. (Qualcomm) |

## Issue 3 (HARQ feedback)

### Second round discussion

As summarized in Sec.2.3.1 in the first round of discussions, this issue can be discussed in next meeting if companies provide more concrete proposals.

**Question 4:**

Further comments, if any, can be provided below.

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| **Company** | **Input** |
| MediaTek | HARQ feedback can be discussed in Issue#2 (section 2.2). It is not necessary to consider other types of HARQ feedback. |
| Spreadtrum | We shared the similar views with MTK. |
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## Issue 4 (reducing PDCCH monitoring)

### Second round discussion

Proposal 1 R1-2100978

To reduce UE power consumption, one proposal for FDD NB-IoT is to skip NPDCCH monitoring for an HARQ process for a longer time interval than the time interval in TN.

If an NB-IoT UE is configured with two HARQ processes and if the UE has an NPUSCH transmission ending in subframe n, 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. An NTN NB-IoT UE may experience longer RTT than 3ms, e.g., 541ms of RTT for GEO and 25ms of RTT for LEO. It is proposed that the UE may skip NPDCCH monitoring for the same HARQ process for a longer time interval.

Proposal 2 R1-2100877

A similar solution is proposed for eMTC. 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. The UE can skip monitoring MPDCCH until the RTT time has elapsed from the end of the PUSCH.

**Question 5:**

5-1 What is the feasibility of proposals 1/2?

5-2 Is there any drawback for not monitoring the NPDCCH/MPDCCH for a long time period (e.g. RTT)?

5-3 Any consideration to be different for NB-IoT and eMTC?

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| **Company** | **Input** |
| Huawei | This should be contribution driven and not a commenting box exercise. Both proposal are from a single company and will require further discussion. |
| MediaTek | Proposals 1 / 2 are for solutions that target improved UE power consumption, which is not in scope of Rel-17 IoT NTN SID objectives. It is not necessary enhancement for first release of IoT NTN. |
| Ericsson | It is too early to conclude on the feasibility and drawbacks of these proposals. We suggest agreeing on the goals of the study first. |

## Issue 5 (coverage enhancements)

### Second round discussion

This issue will be discussed in future meeting based on the performance evaluation/analysis in AI 8.15.1.

## Issue 6 (uplink transmission gaps)

### Second round discussion

The discussion on the scheduling limitation for the network when two HARQ processes are configured for NB-IoT in R1-2100978 is summarized below.

A longer scheduling offset, e.g., > 541ms, would be needed to accommodate RTT (it is the moderator’s opinion that this will be taken into account in the timing relationships discussed in 8.15.3), and this would limit the NW scheduling capability. Uplink compensation gaps exist to allow the UE re-synchronize to DL signals during a long UL transmission.

It is then discussed the case of uplink compensation gaps with 2 HARQ processes. In the Figure below, the UL gaps are defined absolutely from the start of the NPUSCH transmission, i.e., gaps are 40ms occurring every 256ms from the start of NPUSCH#0 until the end of NPUSCH#1. The issue is that if DCI#0 is missing, UE will transmit NPUSCH#1 without pending a gap. But eNB will expect to receive NPUSCH#0 and NPUSCH#1 according to the UCG timer with a UL gap in the middle of NPUSCH#1.



This inconsistency issue may exist when 2 HARQ processes are configured and the maximum total transmission duration exceeds 256ms, without any scheduling gap between the two NPUSCHs towards the 256ms. Some enhancement for two consecutive NPUSCH transmissions shall be considered.

In the moderator’s view, the inconsistency mentioned above would apply to NTN and TN. For NTN, the longer RTT needs to be taken into account. To further discuss enhancements for two consecutive NPUSCH transmissions, it should be first clarified the timing relationship between UE receiving NPDCCH format 0 and transmission of NPUSCH (which should be done in AI 8.15.3).

**Question 6:** Any opinion whether it is necessary to change the timing relationship between UE receiving NPDCCH format 0 and transmission of NPUSCH? Should this timing relationship be discussed in AI 8.15.3?

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| **Company** | **Input** |
| Huawei | Yes, this timing relationship needs to be discussed in AI8.15.3. |
| Apple | We prefer to discuss this issue in AI 8.15.3. |
| Srpeadtrum | Timing relationship related issues need to be discussed in AI8.15.3. |

**Question 7:** Any initial opinion on which issues need to be solved for uplink compensation gaps for NB-IoT operation in NTN? Should uplink compensation gaps be discussed in AI 8.15.3?

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| **Company** | **Input** |
| Huawei | Yes, this timing relationship needs to be discussed in AI8.15.3. |
| MediaTek | The UCG for 2 HARQ processes was specified in Rel-14 (Huawei, CR 1071, V14.6.0, R1-1805403), Rel-15 (Huawei, CR 1072, V15.1.0, R1-1805404). The UCG is needed to allow HD-FDD UE to re-acquire synchronization on the DL. We do not see any issue if UCG is used.  We have different understanding for 2 HARQ processes based on reading of the specifications. The maximum total transmission duration cannot exceed 256ms starting from n+k  *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.*    UL transmission gaps can be discussed in 8.15.2 for synchronization aspects and 8.15.3 for timing relationship aspects. |
| Apple | We prefer to discuss uplink compensation gaps in AI 8.15.3. |
| Srpeadtrum | Timing relationship related issues need to be discussed in AI8.15.3. |

## Issue 7 (serving cell change)

### Second round discussion

In R1-2101030, it is proposed to study mechanisms to ensure that the continuity of the HARQ process across cell. 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 RUs, number of slots in RU defined in LTE, the maximum transmission time could be 0.5ms \* 128 \* 10 \* 16 = 10240ms for 15kHz SCS, or 2ms \* 128 \* 10 \* 16 = 40960ms for 3.75kHz SCS. This time interval could be larger than the time a UE needs to handover or perform a cell reselection with high speed satellite, and the UE cannot complete the repetition before changing cell. It is proposed to ensure the continuity of the HARQ across cells so that repetitions in the two cells should combined, especially for LEO with high speed satellite movement.

**Question 8:** In which scenario is necessary to consider HARQ continuity across cells in NTN IoT?

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| **Company** | **Input** |
| Huawei | This should be contribution driven and not a commenting box exercise. |
| MediaTek | It is not necessary to consider HARQ continuity across cells in NTN IoT.  The assumption of very long transmission of 1 seconds 4 seconds seems a corner case. In practical systems, with reasonable C/N dimensioning (based on EIRP, G/T, elevation angle), it is unlikely that all UEs will transmit with 128 repetitions at all times. In practice, the repetitions could be much less and 15 kHz SCS could be used with typically transmission times of several ms or 10s ms. It is reasonable to expect for some UEs that before serving cell change some packet interruption / loss occur.  We have concern that serving cell change seems to suggest a fundamental deviation from specifications.   * In NB-IoT, no support for HO   In eMTC, our understanding is that the MAC layer flushes HARQ buffers during HO |
| Nokia, NSB | Respect to MediaTek’s concern, we would like to mention:  1, actually, if we consider the slot number in each TU, then the very long transmission will be 0.5 ms \* 128 \* 10 \* 16 = 10240 ms for 15kHz SCS or 2 ms \* 128 \* 10 \* 16 = 40960 ms for 3.75kHz SCS, instead of 1s or 4s. For a UE with large coupling loss, we need to also guarantee it can be served by the maximum number of repetition supported by specification.  2, for serving cell changing: as IoT UE may have data to transmit in any time, it is possible that the repetition is not complete in the coverage of one cell of LEO satellite case. How to solve it should be studied. Similar for eMTC UE with even larger data rate. |
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## Issue 8 (multiple TB scheduling)

### Second round discussion

In R1-2101323 it is proposed to schedule more than one TB in a HARQ cycle in order to lower the amount of subframes used for scheduling and switching between TX and RX.

MTC

For an RTT = 16ms for LEO600 systems, it is observed that the scheduling of two TBs per HARQ cycle instead of one, results in a 9% increase in UL speeds. However, depending on the RTT even a higher number of TBs can be scheduled in one HARQ cycle such that the total number of HARQs is <=8. With RTT = 16ms, up to 6 TBs can be accommodated in one HARQ cycle. This increases the UL speed by 28% (elevation angle of 30 degrees).

**Question 9 – Any views on the relevance of supporting multiple TB scheduling for eMTC in NTN?**

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| **Company** | **Input** |
| Qualcomm | As such, multi-TB scheduling is a supported feature for terrestrial networks. A priori, we don’t a reason to “preclude” multi-TB scheduling, unless some companies provide any “explicit reasons” to not support the feature.  Moreover, support of “existing terrestrial features” should be discussed in the WI phase, we feel. |
| Huawei | This should be contribution driven and not a commenting box exercise. This proposal is from a single company and will require further discussion. |
| MediaTek | Multi-TB scheduling is Rel-16 cellular NB-IoT / eMTC feature. No need to exclude it. This can be discussed in WI phase. |
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**Question 10 – What are advantages and drawback for supporting multiple TB scheduling for eMTC in NTN? In which scenarios?**

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| **Company** | **Input** |
| Huawei | This should be contribution driven and not a commenting box exercise. This proposal is from a single company and will require further discussion. |
| MediaTek | Support of existing features can be discussed in WI phase. |
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NB-IoT

For the LEO case, 2 HARQs may be enough to fill the gaps. If the number of HARQ processes were increased, scheduling of more than one TB in a HARQ cycle can be supported. Having more than one TB per HARQ cycle splits the scheduling overhead between more TBs. For UL timing diagram for RTT = 16ms with N\_HARQ increased from 2 to 4 where two TBs are scheduled in the HARQ cycle. Increasing the number of HARQs to 4 increases and scheduling two TBs per HARQ cycle, increases the speed from 22 kbps to 29 kbps - a **32%** data rate increase (elevation angle of 30 degrees).

**Question 11 – Any views on the relevance of supporting multiple TB scheduling for NB-IoT?**

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| **Company** | **Input** |
| Huawei | This should be contribution driven and not a commenting box exercise. This proposal is from a single company and will require further discussion. |
| MediaTek | Multi-TB scheduling is Rel-16 cellular NB-IoT / eMTC feature. No need to exclude it. This can be discussed in WI phase. |
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**Question 12– What are advantages and drawbacks for supporting multiple TB scheduling for NB-IoT? In which scenarios?**

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| **Company** | **Input** |
| Huawei | This should be contribution driven and not a commenting box exercise. This proposal is from a single company and will require further discussion. |
| MediaTek | Support of existing features can be discussed in WI phase. |
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## Issue 9 (throughput enhancements)

### Second round discussion

In R1-2101515 [19] it is proposed a solution to optimize the throughput for NB-IoT in 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. After receiving NPDSCH, there are waiting periods, in which the UE is not required to monitor NPDCCH. The proposal is that in such time periods between receiving an NPDSCH and transmitting the corresponding HARQ ACK, UE monitors NPDCCH.

Further details are not provided. To start the discussion in this meeting, the proponent company may provide further details, and other companies may provide initial comments/questions, if any.

**Question 13 – Any views on the solution provided in [19]?**

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| **Company** | **Input** |
| Qualcomm (Proponent) | 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 “**waiting periods**”, the UE is “not required to monitor NPDCCH” (see Fig. 1). An example shown in the figure is the time period between receiving an NPDSCH and transmitting the corresponding HARQ ACK.  Graphical user interface, application, Teams  Description automatically generated  Figure 1: Illustration of current UE behavior between receiving NPDSCH and transmitting HARQ ACK.  The **“orange period”** in Fig. 1 are “*wasted time periods*” without any enhancements. These would lead to a diminished throughput w.r.t terrestrial networks.  In terrestrial networks, these “waiting periods” were designed to give the UE enough time to process the NPDSCH. In NTN, these periods can—without enhancements—be much larger than the time required by the UEs to process NPDSCH.  To mitigate this loss in throughput, we can **enable PDCCH monitoring** for at least a subset of the “waiting period” shown above (shown in Fig. 2).  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. |
| Huawei | Thank you to the proponent for sharing detail, we need to do more analysis. |
| MediaTek | This issue is for enhancement of throughput. It is not clear whether the throughput enhancements will be significant and should be justified with some analysis. |
| Spreadtrum | We need to do more analysis. |

# Companies’ proposals and observations

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| R1-2100163  Oppo | Observation 1: HARQ enhancements in NR-NTN target for achieving higher throughput.  Observation 2: K\_offset is introduced to enhance the timing relationship for HARQ-ACK transmission.  Proposal 1: HARQ disabling and increased HARQ process number should NOT be supported for NB-IoT/eMTC over NTN.  Proposal 2: K\_offset is introduced to enhance the timing relationship for HARQ-ACK transmission for NB-IoT/eMTC over NTN. |
| R1-2100236  Huawei | Observation 1: NB-IoT supports aggregation of transport blocks to cover long RTT delays.  Proposal 1: There is no need to extend HARQ process number in IoT-NTN.  Proposal 2: Disabling HARQ processes is not necessary in IoT-NTN. |
| R1-2100251  ZTE | Observation 1: Disable/enable HARQ-ACK feedback may not needed for IoT-NTN.  Observation 2: HARQ process number for NB-IoT/eMTC in terrestrial network can be reused for IoT-NTN  Proposal 1: HARQ enhancement for IoT-NTN may not be needed unless high requirement on the throughput is defined.  Proposal 2: Enhancement on data transmission should be considered if scenarios with too large coupling loss and too low CNR are supported. |
| R1-2100368  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: No enhancement is needed for HARQ in NB-IoT over satellite.  Proposal 2: Reuse disabling HARQ feedback mechansim of NR NTN for CEmodeA in eMTC NTN, and no need to increase the HARQ process number for CEmodeA UE.  Proposal 3: There is no need for the enhancement on HARQ in CEmodeB of eMTC NTN.  Proposal 4: Study performance improvement of repetition transmission for satellite NB-IoT in the presence of synchronization error. |
| R1-2100483  vivo | Observation 1: The required HARQ process number can be much less than the subframe number in the RTT latency due to the larger repetition factor of IoT transmission.  Proposal 1: The HARQ process number can be maintained the same as the NB-IoT/eMTC for TN, the extension of maximal HARQ process number is not supported in NB-IoT/eMTC NTN.  Proposal 2: The disabling on HARQ feedback for downlink transmission can be applied to the NB-IoT/eMTC NTN. |
| R1-2100603  MediaTeK | Observation 1: NB-IoT and eMTC data rates in LEO and GEO are sufficient to meet typical data rates for IoT applications.  Observation 2: For typical IoT applications, the need to disable HARQ is not high.  Observation 3: It is up to eNB implementation if UL HARQ feedback is not disabled for Message 3 during initial access.  Observation 4: Doubling the number of HARQ processes from 2 to 4 in NB-IoT is not a priority as it approximately provides a 50% increase in data rates compare to Rel-14 NB-IoT device due to internal scheduling delays and would have high impact on the specifications. By comparison, a Rel-17 NB-IoT device will provide double the data rates compare to rel-14 NB-IoT device.  Observation 5: For GEO, the eNB can disable UL HARQ feedback and rely on RLC ARQ to avoid HARQ stalling. It is also up to the eNB implementation to disable UL HARQ feedback in LEO.  Observation 6: NB-IoT supports large number of transmissions on the DL and UL (i.e. up to 2048 repetitions and 128 repetitions respectively). This is sufficient to ensure reliability of the first transmission when HARQ is disabled. |
| R1-2100685  Intel | Proposal 1:  • For NTN the network could disable HARQ feedback for DL transmission for eMTC and NB-IoT with 2 HARQ processes  o The enabling/disabling of HARQ should be configurable on a per UE and per HARQ process basis via RRC signalling  Proposal 2:  • Increased number of HARQ processes is not considered in NB-IoT/eMTC NTN SI |
| R1-2100765  Lenovo | 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. |
| R1-2100812  Spreadtrum | Proposal 1: Number of HARQ process should be kept in IOT NTN.  Proposal 2: Disabling/enabling HARQ feedback should be considered for IOT NTN. |
| R1-2100877  Sony | Observation 1. Significant amounts of coverage enhancement are required to operate eMTC and NB-IoT in IoT-NTN constellations.  Observation 2. The eMTC UL needs to operate in CE Mode B in order to support NTN.  Observation 3. A 500 bit transport block is transmitted in approximately 320ms in the UL for either eMTC or NB-IoT.  Observation 4: 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 5: 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.  It is further proposed that the IoT-NTN study item technical report records the types of observation that have been made in this document.  Proposal 2: The IoT-NTN TR captures observations on:  • The fraction of the HARQ cycle that is occupied by active PUSCH / PDSCH transmissions  • The number of HARQ processes that are supportable in IoT-NTN |
| R1-2100933  Ericsson | Observation 1 The main motivation for introducing HARQ enhancements for NR NTN is to address throughput stalling due to the large HARQ RTT.  Observation 2 The IoT NTN targets delay tolerant applications with low data rates. Therefore, the rationale for enhancing HARQ operation for NR NTN is not applicable to IoT NTN.  Observation 3 If delay tolerant, small and infrequent data transmissions continue to be the focused use cases for IoT NTN, HARQ enhancements are not foreseen to be needed.  Proposal 1 RAN1 to analyze the necessity of HARQ enhancements for IoT NTN. |
| R1-2100978  Asia Pacific | Observation 1 If an NB-IoT UE detects a DCI ending in subframe n, the UE may not expect to receive another DCI before subframe n+k-2 for which the corresponding NPUSCH transmission ends later than subframe n+k+255.  Proposal 1 UE shall skip NPDCCH monitoring for the same HARQ process within a given RTT.  Proposal 2 Enhancement on two consecutive NPUSCH transmissions might be needed, regarding the existing scheduling restriction on scheduling offset. |
| R1-2101030  Nokia | Observation 1: repetition for IoT UE will mitigate the impact of HARQ stalling because of long propagation delay in NTN scenario.  Observation 2: based on current LTE NB-IoT/eMTC design for HARQ and repetition, the max MCL cannot be guaranteed with TN link budget results.  Observation 3: more HARQ process with more cost/complexity may not help when repetition number is too large.  Observation 4: HARQ feedback disabling is not helpful in some of IoT NTN scenarios.  Proposal 1: it should be evaluated whether current LTE NB-IoT/eMTC HARQ and repetition number can support the max coupling loss as requirement and agreed data rate, in NTN scenarios with different satellite obit.  Proposal 2: reducing repetition number and real requested repetition number should be studied for the requirement of data rate in IoT NTN scenarios.  Proposal 3: RAN1 should study alternative feedback for HARQ maximizing the performance of the link, incl for UEs with 1 or 2 HARQ processes.  Proposal 4: 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. |
| R1-2101107  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. |
| R1-2101245  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: Number of HARQ processes should be kept considering increasing HARQ process number will cause additional UE cost.  Proposal 4: UE assistance information for HARQ can be supported. |
| R1-2101323  Sierra W | LTE-M:  Observation 2: A higher TBS increase number of repeats but results in faster speeds, increased spectral efficiency, and lower number of required HARQs.  Observation 3: With TBS = 504, no additional HARQs are needed for LEO and 1 additional HARQs is needed for GEO to fill gaps for LTE-M.  Proposal 1: Do not increase the number of HARQs for LTE-M.  Observation 4: Sending grants before the UE has completed PDSCH or PUSCH can double the data rates for LOE600 LTE-M. Note - this does not require any standard changes.  Observation 5: Scheduling multiple TBs per HARQ cycle increases UL speeds by 28% for LEO600.  Proposal 2: Study how the variable PDSCH to ACK mechanism for ACK-Bundling can be adjusted to support scheduling more than one TBs per HARQ cycle.  Observation 6: To support multiple TBs scheduled in one HARQ cycle for UL, a variable delay between the UL grant and PUSCH would need to be specified.  Proposal 3: Specify a variable UL grant to PUSCH delay to support scheduling more than one TBs per HARQ cycle.  NB-IOT:  Observation 7: In NB-IoT, consider increasing the number of HARQs only in the UL since UE complexity is not a factor.  Observation 8: A higher TBS increases required transmission time but results in faster speed, increased spectral efficiency, and lower number of required HARQs.  Observation 9: With TBS = 504, no additional HARQs are needed for LEO but additional HARQs are needed for GEO to fill gaps for NB-IoT.  Observation 10: Scheduling multiple TBs per HARQ cycle increases UL speeds by 31.4% for LEO600.  Proposal 4: To support scheduling multiple TBs per HARQ cycle, increase the number of HARQs to 4 in the uplink for NB-IoT. |
| R1-2101371  Apple | Proposal 1: The number of HARQ processes is not increased in IoT over NTN.  Proposal 2: RAN1 to consider disabling HARQ feedback for downlink transmissions, which is configurable per HARQ process via UE specific RRC signaling. |
| R1-2101404  IDC | Proposal 1: Maximum HARQ process number is not increased for NTN NB-IoT/eMTC devices.  Proposal 2: Discussion on enhancements to reduce HARQ stalling is deprioritized in NB-IoT/eMTC.  Proposal 3: No discussion on the HARQ enhancement issues for IoT NTN until a sufficient progress is made for that in NTN. |
| R1-2101515  Qualcomm | Proposal 1: RAN1 to study enabling PDCCH monitoring in “waiting periods”—for example, between receiving NPDSCH and transmitting HARQ ACK in NB-IoT—to mitigate suboptimal throughput.  Proposal 2: RAN1 to study support for at least one feedback-disabled HARQ process for NB-IoT over NTN. |

# References

1. R1-2100163 Discussion on HARQ enhancements OPPO
2. R1-2100236 Discussion on HARQ enhancement for IoT in NTN Huawei, HiSilicon
3. R1-2100251 Discussion on HARQ for IoT-NTN ZTE
4. R1-2100368 HARQ operation enhancement for NB-IoT/eMTC CATT
5. R1-2100483 Discussion on HARQ enhancements on NB-IoT/eMTC for NTN vivo
6. R1-2100603 Enhancement on HRQ MediaTek Inc.
7. R1-2100685 On HARQ enhancements for NB-IoT and eMTC NTN Intel Corporation
8. R1-2100765 HARQ enhancement for IoT NTN Lenovo, Motorola Mobility
9. R1-2100812 Consideration on enhancements on HARQ Spreadtrum Communications
10. R1-2100877 HARQ issues for IoT-NTN Sony
11. R1-2100933 On HARQ enhancements for IoT NTN Ericsson
12. R1-2100978 Enhancements on HARQ to NB-IoT in NTN Asia Pacific Telecom, FGI
13. R1-2101030 HARQ for NB-IoT/eMTC over NTN Nokia, Nokia Shanghai Bell
14. R1-2101107 Discussion on the HARQ enhancement for IoT NTN Xiaomi
15. R1-2101245 On enhancements on HARQ Samsung
16. R1-2101323 NTN IoT HARQ Considerations Sierra Wireless, S.A.
17. R1-2101371 Discussion on HARQ Enhancement in IoT NTN Apple
18. R1-2101404 HARQ enhancement for IoT NTN InterDigital, Inc.
19. R1-2101515 Enhancements on HARQ Qualcomm Incorporated

# Annex A - Agreements

## 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 |

# Annex B - Agreements in NTN 8.4.3

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 |