**3GPP TSG RAN WG1 Meeting #110b-e R1-220xxxx**

**e-Meeting, Oct 10th – 19th, 2022**

**Agenda Item: 9.11.3**

**Source: Moderator (Lenovo)**

**Title: FLS#1 on disabling of HARQ feedback for IoT NTN**

**Document for: Discussion and decision**

# Introduction

In the RAN#94 plenary meeting, an enhancement work item for Rel.18 IoT NTN was approved. One of the objectives is to specify the following HARQ enhancements to IoT NTN.

*This work considers Rel-17 IoT-NTN as baseline as well as Rel-17 NR-NTN outcome and the further IoT-NTN performance enhancements objectives are listed below:*

*-* ***Disabling of HARQ feedback to mitigate impact of HARQ stalling on UE data rates [RAN1,RAN2]***

*- Study and specify, if needed, improved GNSS operations for a new position fix for UE pre-compensation during long connection times and for reduced power consumption [RAN1]*

The following agreements on disabling of HARQ feedback for IoT NTN were achieved:

**RAN1-109e**

***Agreement***

*For IoT NTN, to configure/indicate enabling/disabling on HARQ feedback for downlink transmission, one or more of the following options can be considered:*

* *Option 1: per HARQ process via UE specific RRC signaling*
* *Option 2: per HARQ process via SIB signaling*
* *Option 3: explicitly indicated by DCI (e.g., new field or reusing existing field)*
* *Option 4: implicitly determined by existing configured/indicated parameter(s) (e.g., repetition number, TBS)*
* *Option 5: per HARQ process via MAC CE*
* *Other options or combinations are not excluded*

*Note: Option(s) for eMTC and NBIoT can be separately discussed.*

***Agreement***

*For IoT NTN, further study the potential issues due to enabling/disabling on HARQ feedback for downlink transmission*

* *Issue A: SPS PDSCH*
* *Issue B: (N)PDSCH/(N)PDCCH scheduling restriction*
* *Issue C: HARQ feedback for scheduling multiple TB*
* *Issue D: HARQ bundling for eMTC HD-FDD*
* *Issue F: NPRACH capacity*
* *Issue G: Serving cell/satellite change during data transfer (FFS: for eMTC and/or NB-IoT)*
* *Other issues are not excluded*

*Note: The “Issues” in common for eMTC and NB-IoT can be separately discussed.*

**RAN1-110**

Agreement

*For eMTC NTN, to configure/indicate enabling/disabling of HARQ feedback for downlink transmission, down select one or more from the following options:*

* *Option 1: per HARQ process via UE specific RRC signaling.*
* *Option 3: explicitly indicated by DCI (e.g., new field or reusing existing field).*
* *Option 4: implicitly indicated by existing configured/indicated/combined parameter(s) in the DCI (e.g., repetition number, TBS)*
* *Option 6: combinations of some options above.*

Agreement

*For NB-IoT NTN, to configure/indicate enabling/disabling of HARQ feedback for downlink transmission, down select one or more from the following options:*

* *Option 1: per HARQ process via UE specific RRC signaling*
* *Option 3: explicitly indicated by DCI (e.g., new field or reusing existing field)*
* *Option 4: implicitly indicated by existing configured/indicated/combined parameter(s) in the DCI (e.g., repetition number, TBS)*
* *Option 6: combinations of some options above*

Agreement

*For a DL HARQ process with disabled HARQ feedback in NB-IoT, at least the following UE behavior(s) can be considered:*

* *Option 1: UE is not expected to receive another NPDCCH carrying a DCI scheduling a NPDSCH for a given HARQ process that starts until X(ms) after the end of the reception of the last NPDSCH for that HARQ process.*
	+ *X =12*
* *Option 2: UE is not required to monitor NPDCCH in a period of Y(ms) from the end of reception of the last NPDSCH*
	+ *Y=12*

*Note: it may be different UE behaviors for different UE categories (e.g., UE with single/multiple HARQ processes).*

This document provides the proposals and summary of discussions with detailed proposals from each company listed in appendix according to the inputs [4]-[22]. Companies are encouraged to provide the inputs on Issue 1-8 in the discussion.

# Issue-1 Indication/configuration of disabling HARQ feedback

## Background

In NR NTN, disabling HARQ feedback for downlink transmission is semi-static configured by RRC signaling. The configuration is indicated per HARQ process index by a bitmap manner, e.g., 32bit bitmap if the configured HARQ process number is 32.

***downlinkHARQ-FeedbackDisabled***

Used to disable the DL HARQ feedback, sent in the uplink, per HARQ process ID. The first/leftmost bit corresponds to HARQ process ID 0, the next bit to HARQ process ID 1 and so on. Bits corresponding to HARQ process IDs that are not configured shall be ignored. The bit(s) set to one identify HARQ processes with disabled DL HARQ feedback and the bit(s) set to zero identify HARQ processes with enabled DL HARQ feedback.

Regarding indication/configuration of disabling HARQ feedback for downlink transmission for IoT NTN, several options were discussed in last RAN1 meeting. The following table lists/summarizes the pros and cros for different options from technical aspect.

|  |  |  |
| --- | --- | --- |
| Options | Advantage | Disadvantage |
| Option 1:per HARQ process via UE specific RRC signaling | 🡪reuse HARQ feedback enabling/disabling configuration agreed in NR-NTN and facilitate/ease the discussion and standard effort. [MTK, Huawei, CATT, Samsung, Nordic, CMCC, Sharp, Apple]🡪ensure network flexibility in HARQ feedback enabling/disabling scheduling [ZTE] | 🡪May not be applicable for **NBIoT** with single process since MAC CE relies on HARQ feedback for activation and NW may frequently reconfigure the HARQ feedback configuration (e.g., TAC), resulting in significant overhead signaling and degrading the system performance [Huawei, NEC, Mavenir, Nokia]🡪UE that only supports the Control Plane CIoT EPS optimization or the Control Plane CIoT 5GS optimization, RRC reconfiguration is not applicable. It is impossible for a UE to further switch on/off the HARQ-ACK feedback through RRC reconfiguration once it is configured during RRC connection setup in TS36.300 Sec. 7.3a. [Huawei]🡪For **eMTC**, CE Mode A and CE Mode B support different number of HARQ processes, thus the RRC solution may not be agnostic if there are two RRC fields, one for CE Mode A and another one for CE Mode B.[Ericsson] |
| Option 3:explicitly indicated by DCI (e.g., new field or reusing existing field) | 🡪Provides a more flexible HARQ feedback configuration for IoT devices. [OPPO]🡪 For NBIoT, with dynamic HARQ disabling, the issues on NPRACH capacity starvation and lack of reference for open loop link adaptation can be alleviated by eNB implementation. [Huawei]🡪Dynamic signaling will allow adapting faster to changes/variations in the IoT-NTN scenarios. [Ericsson] | 🡪 more spec efforts [OPPO]🡪additional bit overhead for DCI and increase complexity in PDCCH detection. [Huawei, NEC]🡪causes additional scheduling latency and UE power consumption due to incorrect DRX configuration. [Interdigital]🡪may not easily be adopted in eMTC SPS or multiple TB scheduling scenarios, may need additional SPS configuration for HARQ enabling/disabling. [Lenovo]🡪the channel condition in IoT-NTN is more stable than NR-NTN since most of UEs are stationary. Introducing new dynamic configuration method for HARQ feedback disabling is not needed. [ZTE] |
| Option 4:implicitly determined by existing configured/indicated parameter(s) (e.g., repetition number, TBS) | 🡪dynamic HARQ feedback enabling/disabling is based on MCS and allocated resource for transmission(s) as there is no impact on the existing DCI format N1. [Huawei]🡪 For NBIoT, with dynamic HARQ disabling, the issues on NPRACH capacity starvation and lack of reference for open loop link adaptation can be alleviated by eNB implementation. [Huawei]🡪whether to disable HARQ feedback can be determined by repetition number. [CATT] | 🡪determine the appropriate repetition threshold based on the simulations. [CATT]🡪HARQ feedback disabling should not be applied to HARQ-ACK for PDSCH including MAC CE command. MAC CE command is attached by MAC entity in any TB (i.e., any TBS, any repetition) [Sharp]🡪 Relying on implicit indication via other configurations can limit network flexibility when configuring other parameters (e.g. repetition number) to ensure the correct DL HARQ feedback behavior. [Interdigital] |

In this meeting, preference options from companies are summarized as follow:

**eMTC**

For eMTC NTN, to configure/indicate enabling/disabling of HARQ feedback for downlink transmission, down select one or more from the following options

* Option 1: per HARQ process via UE specific RRC signaling

Supported by: MTK, Huawei, Spreadtrum, ZTE, OPPO(1st), CATT, Nordic, Nokia, CMCC, Apple, InterDigital, Mavenir, Samsung, Sharp, Qualcomm, Lenovo

* Option 3: explicitly indicated by DCI (e.g., new field or reusing existing field)

Supported by: NEC, Ericsson

* Option 4: implicitly determined by existing configured/indicated parameter(s) (e.g., repetition number, TBS)

Supported by:

* Option 6: combination

Supported by:

**NBIoT**

For NB-IoT NTN, to configure/indicate enabling/disabling of HARQ feedback for downlink transmission, down select one or more from the following options:

* Option 1: per HARQ process via UE specific RRC signaling

Supported by: MTK, Spreadtrum, ZTE, OPPO(1st), CATT(1st), CMCC, Apple, InterDigital, Mavenir, Samsung, Sharp, Qualcomm, Lenovo

* Option 3: explicitly indicated by DCI (e.g., new field or reusing existing field)

Supported by: OPPO (2nd), CATT (2nd), NEC, Nordic, Nokia(1st), Xiaomi, Apple, InterDigital, Mavenir, Ericsson

* Option 4: implicitly determined by existing configured/indicated parameter(s) (e.g., repetition number, TBS)

Supported by: Huawei, CATT (2nd), Nokia(2nd),

* Option 6: combination

Supported by: InterDigital, Mavenir

Along with RAN1 discussion, in RAN2-119 meeting, the following agreement has been achieved that from RAN2 perspective, at least eMTC, enabling/disabling HARQ feedback can be configured per DL HARQ process at least via UE specific RRC signaling. FFS for NB-IoT (and especially for CP solution for NB-IOT).

Agreements:

1. Disabling DL HARQ feedback is supported for NB-IoT and eMTC NTN. FFS on UE capability.
2. For UL HARQ operation, introduce two HARQ modes, i.e., HARQ mode A and HARQ mode B in IoT NTN (both NB-IoT and eMTC NTN), similarly to NR NTN.
3. From RAN2 perspective, at least for eMTC, enabling/disabling HARQ feedback can be configured per DL HARQ process at least via UE specific RRC signalling. FFS for NB-IoT (and especially for CP solution for NB-IOT).

## Company views

In summary, from moderator’s perspective, NR NTN disabling HARQ feedback configuration can be a starting point for IoT NTN, especially for eMTC with more than one HARQ processes.

For eMTC, as RAN2 has agreed to take Option 1 as the baseline solution, in order to align the understanding with RAN2, the following proposals are listed as majority views:

**[Proposal 1-1a]:**

For eMTC NTN, to configure/indicate enabling/disabling of HARQ feedback for downlink transmission, at least Option 1 (e.g., per HARQ process via UE specific RRC signaling) is supported.

* FFS: Option 3 (e.g., explicitly indicated by DCI).
* FFS: Criteria on switching of different options

For NBIoT, companies still have concerns that if disabling HARQ feedback for single HARQ process is supported and it is disabled by RRC configuration, the issue related to any impact on the MAC CE activation and overhead of RRC configuration/reconfiguration back-and-forth needs further study.

Based on that, potential solutions are listed for further study based on IoT specific feature (e.g., NBIoT support single HARQ process case, NBIoT with large repetition number). Regarding Option 6a and Option 6b, two options (e.g., one by RRC signaling, one by DCI based) are considered to overcome the potential drawback of single solution if any, and the corresponding switching mechanism should be further discussed if supported.

Note: NBIoT with single HARQ process, NBIoT with more than one HARQ process and eMTC HARQ feedback enabling/disabling indication/configuration are separately discussed although unified solution is encouraged if necessary/possible.

**[Proposal 1-2a]:**

For NB-IoT NTN, to configure/indicate enabling/disabling of HARQ feedback for downlink transmission, down select **ONE** from the following options in [RAN1-110b-e, RAN1-111]:

* Option 1: per HARQ process via UE specific RRC signaling
* Option 3: explicitly indicated by DCI (e.g., new field or reusing existing field)
* Option 4: implicitly indicated by existing configured/indicated/combined parameter(s) in the DCI (e.g., repetition number, TBS)
* Option 6a: Option 1+ Option 3
	+ FFS: Criteria on switching of different options
* Option 6b: Option 1+ Option 4
	+ FFS: Criteria on switching of different options

Please provide your views and comments.

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| **Company** | **Comments and Views** |
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# Issue-2 SPS PDSCH

## Background

Since SPS is only supported in CE mode A and the corresponding SPS period can be configured from 10ms to 640ms. While the reference value of RTT for LEO and GEO are 25.77ms and 541.46ms respectively. The HARQ stalling issue is not obvious in LEO scenario but do exist in GEO scenarios. Based on that, it is beneficial to configure HARQ disabling at least for GEO scenarios in eMTC. Similarly, for NR NTN SPS, the SPS period can also be configured from 10ms to 640ms, and the supported HARQ process is even larger than that of eMTC, the SPS HARQ disabling was introduced in Rel.17 NR NTN.

In NR NTN, it was agreed that for HARQ feedback of each PDSCH, UE follows the per-process HARQ feedback enabled/disabled configuration for the associated HARQ process except for the first SPS PDSCH after activation if additionally enabled, where ACK/NACK is always reported by UE for the first SPS PDSCH.

For IoT NTN, As highlighted by [Spreadtrum, ZTE, OPPO, CATT, Nokia, Xiaomi, CMCC, Apple, Qualcomm, Lenovo], that the same mechanism for NR NTN could be applied to IoT NTN. UE follows the per-process HARQ feedback enabled/disabled configuration for the associated HARQ process except for the first SPS PDSCH after activation. For SPS PDSCH, ACK/NACK is reported by UE for the first SPS PDSCH regardless of network configuration of enabled/disabled for this HARQ process if additional signal indicated. However, As proposed by [Nokia, NEC], HARQ feedback should be always enabled for the first SPS PDSCH after activation to avoid the repetition resource wasted, [NEC] further propose that HARQ feedback enabled/disabled for the first SPS PDSCH after activation is indicated by DCI. [Nokia] further propose that the configuration allows a process to report one HARQ-ACK for every n TBs received in SPS. As mentioned by [Samsung], for IoT NTN, the considered scenarios are not latency sensitive. The gNB can activate at a time where the first SPS PDSCH has a HARQ process with enabled HARQ-ACK report, so the additional HARQ feedback for SPS activation is not needed.

As highlighted by [Spreadtrum, Lenovo, Apple], for DCI indicating SPS PDSCH release, HARQ-ACK report is performed as legacy.

## Company views

From moderator’s perspective, if the indication/configuration of disabling HARQ feedback in eMTC follows that of NR NTN in previous section, the NR configuration of HARQ feedback enabling/disabling for SPS PDSCH can be the starting point for eMTC NTN.

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

**[Proposal 2-1a]:**

For HARQ feedback for eMTC SPS PDSCH, UE follows the per-process HARQ feedback enabled/disabled configuration for the associated HARQ process except for the first SPS PDSCH after activation

* for the first SPS PDSCH after activation,
	+ Option 1: If HARQ feedback for SPS activation is additionally enabled, ACK/NACK is reported by UE for the first SPS PDSCH after activation regardless of network configuration of enabled/disabled for this HARQ process, and follow per-process HARQ feedback enabled/disabled configuration otherwise.
	+ Option 2: ACK/NACK is always reported by UE for the first SPS PDSCH after activation regardless of network configuration of enabled/disabled for this HARQ process.
	+ Option 3: follow the per-process HARQ feedback enabled/disabled configuration for the associated HARQ process.

**[Proposal 2-2a]:**

For DCI indicating SPS PDSCH release, HARQ-ACK report is performed as legacy in eMTC.

Please provide your views and comments.

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| **Company** | **Comments and Views** |
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# Issue-3 (N)PDSCH/(N)PDCCH scheduling restriction

## Background

In NR NTN, additional gap is considered to avoid the continuous reception of PDSCH with same HARQ process at UE side as specified in TS38.214.

**TS38.214 Section 5.1**

When HARQ feedback for the HARQ process ID is disabled, the UE is not expected to receive another PDCCH carrying a DCI scheduling a PDSCH or set of slot-aggregated PDSCH scheduled for the given HARQ process or to receive another PDSCH without corresponding PDCCH for the given HARQ process that starts until Tproc,1 after the end of the reception of the last PDSCH or slot-aggregated PDSCH for that HARQ process.

For eMTC, as proposed by [ZTE, CATT, Nordic, Apple, Qualcomm, Lenovo], following NR PDSCH/PDCCH scheduling restriction, the similar mechanism should be introduced to eMTC NTN. However, as mentioned by [Ericsson] that there is a delay between the “MPDCCH and the scheduled PDSCH”, afterwards there is at least a 3 ms delay between the end of PDSCH and the start of PUCCH which accounts for sufficient PDSCH decoding time at the devices, and further propose that UE is not required to monitor PDCCH in a period of Y(ms) from the end of reception of the last PDSCH.

The minimum gap between the end of PDSCH and the start of corresponding HARQ-ACK is 3ms for eMTC defined in 36.213, which accounts for PDSCH decoding time and corresponding uplink data preparation at the devices. Furthermore, eMTC UE has the ability to decode MPDCCH and PDSCH in the same subframe and there is NO MPDCCH monitoring restriction in legacy eMTC shown in Figure 1 (e.g., UE has the ability to decode PDSCH and monitor/decode MPDCCH simultanously even for the PDSCH with HARQ enabling/disabling, as subframe #2 in Figure 1).





Figure 1 Minimal gap between PDSCH and PUSCH

**TS36.213 Section 10.2**

For FDD, a BL/CE UE shall upon detection of a PDSCH intended for the UE and for which an HARQ-ACK shall be provided, transmit the HARQ-ACK response using the same  derived according to Clause 10.1.2.1 in subframe(s) *n+ki* with *i =0,1, …, N-1*, where

- subframe *n-k-K*offset is the last subframe in which the PDSCH is transmitted, where

- if the UE is in half-duplex FDD operation and is not configured with higher layer parameter *ce-PDSCH-14HARQ-Config* and is configured with CEModeA and higher layer parameter *ce-HARQ-AckBundling* and the 'HARQ-ACK bundling flag' in the corresponding DCI is set to 1, or if the UE is configured with higher layer parameter *ce-SchedulingEnhancement*

- $k$ is given by the 'HARQ-ACK delay' field in the corresponding DCI, and the HARQ-ACK delay value $k$ is determined based on the higher layer parameters according to Table 7.3.1-2;

- if the UE is in half-duplex FDD operation and is configured with higher layer parameter *ce-PDSCH-14HARQ-Config* and is configured with CEModeA, and 'PDSCH scheduling delay and HARQ-ACK delay for 14 HARQ' field is present in the corresponding DCI,

- $k$ is given by the HARQ-ACK delay value as defined in [4], in the corresponding DCI,

- otherwise

- $k=4$

*- 0≤k0<k1<…,kN-1* and the value of and  is provided by higher layer parameter *pucch-NumRepetitionCE-format1,* if configured, otherwise it is provided by higher layer parameter *pucch-NumRepetitionCE*-*Msg4-Level0-r13, pucch-NumRepetitionCE-Msg4-Level1-r13, pucch-NumRepetitionCE-Msg4-Level2-r13* or *pucch-NumRepetitionCE-Msg4-Level3-r13* depending on whether the most recent PRACH coverage enhancement level for the UE is 0, 1, 2 or 3, respectively; and

For NBIoT, as highlighted by [MTK, Huawei, Xiaomi, Apple, Mavenir, Qualcomm, Ericsson], legacy mechanism of PDCCH/PDSCH scheduling restriction for NPDSCH without HARQ feedback should be followed. For a DL HARQ process with disabled HARQ feedback in NBIoT, UE is not required to monitor NPDCCH in a period of Y(ms)=[12] from the end of reception of the last NPDSCH. This restriction is usually applied for NPDSCH carrying SIB, RAR and MBS. [Huawei] further mentions that NBIoT UE is usually not capable of decoding NPDSCH and NPDCCH in parallel. The 12 ms scheduling restriction is reserved for UE to decode NPDSCH, and eNB is not expected to transmit a DCI scheduling NPDSCH with any HARQ process. [Lenovo] further mentions the NPDCCH scheduling restriction behavior is imposed to NBIoT UE with single HARQ process.

However, as proposed by [ZTE, OPPO, Nordic, CMCC, Lenovo], following NR PDSCH/PDCCH scheduling restriction, the similar mechanism should be introduced to NBIoT NTN. [ZTE] mentions that option 2 seems to prohibit all PDCCH monitoring. As a result, for a UE with multiple HARQ processes, if one HARQ process is decoding a PDSCH/NPDSCH, the other free HARQ process scheduling data cannot work either, which seems not reasonable and may decrease system data rate because of the missed detection of the other free HARQ process data.[OPPO] proposes that the original motivation of introducing option 2 is to specify the behavior when UE receives a NPDSCH carrying RAR grant, paging, or Rel-14 SC-PTM. Note that those DL transmissions are broadcast transmissions and not associated with a DL HARQ process for retransmission. It is different from a DL HARQ process with disabled HARQ feedback, which is used for unicast transmission. [Ericsson] mentions that to avoid incurring in an Rx/Tx issue, the NPDCCH monitoring restriction duration can optionally add the legacy variable that accounts for NPUSCH Format 2 repetitions and the RU length that depends on the configured SCS, plus 1ms for UL-to-DL switching.

**TS36.213 Section 16.6**

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*.

In this meeting, preference options from companies are summarized as follow:

For a DL HARQ process with disabled HARQ feedback in NB-IoT, at least the following UE behavior(s) can be considered:

* Option 1: UE is not expected to receive another NPDCCH carrying a DCI scheduling a NPDSCH for a given HARQ process that starts until X=12(ms) after the end of the reception of the last NPDSCH for that HARQ process.

Supported by: ZTE, OPPO, Nordic, CMCC, Lenovo

* Option 2: UE is not required to monitor NPDCCH in a period of Y=12(ms) from the end of reception of the last NPDSCH

Supported by: MTK, Huawei, Xiaomi, Apple, Mavenir, Qualcomm, Ericsson

The main difference between Option 1 and Option 2 is that for option 1, UE needs to monitor NPDCCH after the reception of previous PDSCH, but UE is not expected to be scheduled with new PDSCH of the same HARQ process within a period, while for option 2, UE is not required to monitor NPDCCH at all for a period of 12ms as shown in Figure 2.



Figure 2 PDSCH/NPDCCH scheduling restriction

## Company views

According to the above summary, reusing NR PDSCH scheduling restriction can be a starting point at least for eMTC. For eMTC, regarding the value of X, as the minimum gap is defined as 3ms, the PDSCH scheduling restriction duration should be 3ms. For NBIoT, considering the UE complexity and power saving, the moderator recommends taking NBIoT legacy Option 2 to NPDCCH monitoring restriction in HARQ disabling scenarios, which is a relative conservative and safe way to NBIoT UE and is aligned with slight majorities.

**[Proposal 3-1a]:**

For a DL HARQ process with disabled HARQ feedback in eMTC, UE is not expected to receive another PDCCH carrying a DCI scheduling a PDSCH for a given HARQ process or to receive another PDSCH without corresponding PDCCH for the given HARQ process that starts until X=[3] (ms) after the end of the reception of the last PDSCH for that HARQ process.

**[Proposal 3-2a]:**

For a DL HARQ process with disabled HARQ feedback in NBIoT, UE is not required to monitor NPDCCH in a period of Y=12(ms) from the end of reception of the NPDSCH.

Please provide your views and comments.

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| **Company** | **Comments and Views** |
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# Issue-4 HARQ feedback for scheduling multiple TB

## Background

eMTC/NBIoT multiple TB scheduling with single DCI is introduced in Rel.16. In HARQ feedback disabling for downlink transmission, solutions should be designed for the case of transmitting HARQ feedback for a multi-TB block where some TBs (or TB bundles) have feedback enabled, while some others have feedback disabled.

For NR NTN HARQ disabling, two types of HARQ codebook are enhanced as:

* For Type-1 HARQ codebook in NR NTN, the UE will consistently report NACK-only for the feedback-disabled HARQ process regardless of decoding results of corresponding PDSCH.
* For Type-2 HARQ codebook in NTN:
* Reduce codebook size with HARQ-ACK codebook only including HARQ-ACK of PDSCH with feedback-enabled HARQ processes
* For the DCI of PDSCH with feedback-enabled HARQ processes, the C-DAI and T-DAI are the count of only feedback-enabled processes

Similar as enhancement of NR NTN HARQ codebook Type-1, as proposed by [Spreadtrum, ZTE, CATT], ACK is assumed for a feedback-disabled HARQ process in the HARQ feedback for scheduling multiple TB scenario. While similar as enhancement of NR NTN HARQ codebook Type-2, as proposed by [Xiaomi, Huawei], UE only reports the HARQ information for the HARQ enabled process, corresponding UE behavior and timing relationship as shown in Figure 3. Specially for NBIoT, as proposed by [Huawei], UE do not feedback HARQ-ACK if two TBs are scheduled by single DCI and HARQ feedback is disabled for both processes, and HARQ feedback are assumed enabled for both of the scheduled TBs if the two TBs have different HARQ feedback assumptions for multiple TB scheduling with single DCI. As proposed by [NEC], HARQ feedback enabling/disabling is indicated by NDI field of DCI or a new DCI field. Optionally, the indication of new DCI field can be applied to all scheduled TBs, the first scheduled TB, the last scheduled TB or the middle-scheduled TB.



Figure 3 HARQ disabling in multiple TB scheduling

## Company views

According to the above summary, similar as discussion in NR HARQ codebook Type 1, Type 2 enhancement, before we conclude the impact of multiple TB scheduling with HARQ disabling, we should firstly achieve the high-level UE behavior for the downlink transmission with the HARQ process disabled no matter what kinds of indication are adopted and the following proposals are listed as majority views:

**[Proposal 4-1a]:**

For multiple TB scheduling with single DCI, the following UE behaviors are considered for the downlink transmission with HARQ process disabled：

* Option 1: ACK is assumed/reported for the downlink transmission with HARQ process disabled regardless of decoding results of corresponding transmission
* Option 2: HARQ feedback is reported only for downlink transmission with HARQ process enabled (e.g., HARQ feedback is not reported for downlink transmission with HARQ process disabled)
* Option 3: HARQ feedback is reported or not depending on the other TBs HARQ-enabled/HARQ-disabling scheduled by single DCI
* Other options are not excluded

Note 1: eMTC and NB-IoT can be separately discussed

Note 2: HARQ feedback bundling and non-bundling can be separately discussed

Please provide your views and comments.

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| **Company** | **Comments and Views** |
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# Issue-5 HARQ bundling for eMTC HD-FDD

## Background

eMTC HD-FDD HARQ bundling is introduced in Rel.14 and enhanced in Rel.17. The design of disablement of HARQ feedback should handle the case where HARQ feedback is bundled, and HARQ feedback is enabled for some HARQ processes and is disabled for others. Similar as enhancement of NR NTN HARQ codebook Type-1, [Speadtrum, ZTE, OPPO, CATT, Apple] proposes that ACK is assumed for a feedback-disabled HARQ process in the logical AND operation. However, [Lenovo]mentions due to PDSCH number restriction (e.g., 10 PDSCH for each scheduling cycle) and PUCCH feedback resource restriction for each scheduling cycle (e.g., 3 for PUCCH resource for each scheduling cycle), if ACK is assumed for HARQ disabling scenarios (e.g., this HARQ feedback of ACK will occupy a PDSCH number and a PUCCH resource of HARQ bundling), there is no available PDSCH and corresponding PUCCH resource in the scheduling cycle and it is equivalent that HARQ disabling feature is not supported in HD-FDD HARQ bundling.

Similar as enhancement of NR NTN HARQ codebook Type-2, [Qualcomm] proposes UE only report the HARQ feedback for HARQ process enabled as shown in Figure 4, and further mentions that the legacy HARQ bundling only includes the bundling of HARQ enabled process in legacy TS36.213.

[NEC] proposes that ACK is assumed for the disabled HARQ process when performing a logical AND operation if not all the bundled TB is disabled HARQ feedback, and if all the bundled TB is disabled HARQ feedback, then HARQ bundling function will not apply even it is configured. As mentioned by [Sharp] that the UE will ignore HARQ feedback for disabled HARQ processes when performing HARQ bundling.



Figure 4 HARQ disabling in HARQ bundling for eMTC HD-FDD

TS36.213 h20

## 10.2 Uplink HARQ-ACK timing

[……]

For FDD, a BL/CE UE shall upon detection of a PDSCH intended for the UE and for which an HARQ-ACK shall be provided, transmit the HARQ-ACK response using the same  derived according to Clause 10.1.2.1 in subframe(s) *n+ki* with *i =0,1, …, N-1*, where

- subframe *n-k**-**K*offset is the last subframe in which the PDSCH is transmitted, where

- if the UE is in half-duplex FDD operation and is not configured with higher layer parameter *ce-PDSCH-14HARQ-Config* and is configured with CEModeA and higher layer parameter *ce-HARQ-AckBundling* and the 'HARQ-ACK bundling flag' in the corresponding DCI is set to 1, or if the UE is configured with higher layer parameter *ce-SchedulingEnhancement*

- $k$ is given by the 'HARQ-ACK delay' field in the corresponding DCI, and the HARQ-ACK delay value $k$ is determined based on the higher layer parameters according to Table 7.3.1-2;

- if the UE is in half-duplex FDD operation and is configured with higher layer parameter *ce-PDSCH-14HARQ-Config* and is configured with CEModeA, and 'PDSCH scheduling delay and HARQ-ACK delay for 14 HARQ' field is present in the corresponding DCI,

- $k$ is given by the HARQ-ACK delay value as defined in [4], in the corresponding DCI,

- otherwise

- $k=4$

[….]

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### 7.3.1 FDD HARQ-ACK reporting procedure

[….]

For a BL/CE UE in half-duplex FDD operation, if the UE is configured with CEModeA, and if the UE is configured with higher layer parameter *ce-HARQ-AckBundling* and the 'HARQ-ACK bundling flag' in the corresponding DCI is set to 1,

- for HARQ-ACK transmission in subframe *n*, the UE shall generate one HARQ-ACK bit by performing a logical AND operation of HARQ-ACKs across all  BL/CE DL subframes for which subframe *n* is the 'HARQ-ACK transmission subframe'.

- if subframe *n-k1* is the most recent subframe for which subframe *n* is the 'HARQ-ACK transmission subframe', and if the 'Transport blocks in a bundle' field in the corresponding DCI for PDSCH transmission in subframe *n-k1* indicates a number of transport blocks in a bundle other than , the UE shall generate a NACK for HARQ-ACK transmission in subframe *n*.

[…..]

## Company views

According to the above summary, similar as discussion for scheduling multiple TB, before we conclude the impact of HD-FDD HARQ bundling with HARQ disabling, we should firstly achieve the high-level UE behavior for the downlink transmission with the HARQ process disabled no matter what kinds of indication are adopted and the following proposals are listed as majority views:

**[Proposal 5-1a]:**

For eMTC HD-FDD HARQ bundling, the following UE behaviors are considered for the downlink transmission with HARQ process disabled:

* Option 1: ACK is assumed/reported for the downlink transmission with HARQ process disabled regardless of decoding results of corresponding transmission
* Option 2: HARQ feedback is reported only for downlink transmission with HARQ process enabled (e.g., HARQ feedback is not reported for downlink transmission with HARQ process disabled)
* Option 3: HARQ feedback is reported or not depending on the other TBs HARQ-enabled/HARQ-disabling scheduled within a HARQ bundle
* Other options are not excluded

Please provide your views and comments.

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
|  |  |
|  |  |

# Issue-6 NPRACH capacity

## Background

With the support of disabling HARQ feedback, NPRACH capacity issue is raised up by [Nokia] that if HARQ feedback is disabled, NB-IoT UE will need to transmit the SR on NPRACH, while if HARQ feedback is always enabled in legacy, NB-IoT UE can transmit the SR piggyback with HARQ feedback. The impact of NB-IoT scheduling request when HARQ feedback is disabled needs further study. [Nokia] observes that when SR is only indicated by NPRACH, the required NPRACH capacity may be very high for a NTN cell and further proposes that when HARQ feedback is disabled, NPUSCH format 2 resources can be allocated for SR and ACK/NACK transmission to reduce the load requirement on PRACH.

However, as mentioned by [MTK], considering the data capacity is much smaller than RACH capacity, that data capacity will fail before RACH capacity for many UEs. Unless all HARQ processes are disabled and all UEs transmit RACH at the same time, there will be some HARQ feedback to piggyback SR and no RACH capacity issue happens. [Huawei] further mentions that with dynamic HARQ disabling, the issues on NPRACH capacity starvation and lack of reference for open loop link adaptation can be alleviated by eNB implementation.

## Company views

According to the above summary, further studies are needed for companies.

**[Proposal 6-1a]:**

Further study the issue and potential solution of disabling HARQ feedback impact on NPRACH capacity.

Please provide your views and comments.

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
|  |  |
|  |  |

# Issue-7 Serving cell change during data transfer

## Background

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. [Nokia] proposes to address the issue of repetition continuation for a HARQ process between two NTN cells, and further proposes eNB to maintain the soft bit information, from one cell to another internally in the eNB, and inform the UE to continue the transmission in the next (intra-satellite) cell using the same HARQ process.

## Company views

According to the above summary, further studies are needed for companies.

**[Proposal 7-1a]:**

Further study the issue and potential solution on Serving cell change during data.

Please provide your views and comments.

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
|  |  |
|  |  |

# Others

## Background

NOTE: The issues in this section identified by companies are related to HARQ disabling and corresponding standard impact/enhancement. Since the views from companies are still diverged and the necessity for corresponding enhancement is not fully justified. Then, from moderator’s perspective, it is better to discuss these issues more. Companies are encouraged to give comments on these issues and show views in this meeting and even next meeting contributions.

Performance enhancement for disabling HARQ feedback

For enhancing transmission performance, different solutions including potential parameter configurations are proposed by companies. Following aspects are categorized according to the views from each company:

* UCI/UE assistant information
	+ a new CSI reporting method or a one-bit feedback to suggest an increase or decrease in MCS or repetition value of NPDSCH[Nordic], reporting buffer status for HARQ operation, explicit indication to request enabling/disabling HARQ feedback [Samsung].

## Company views

According to the above summary, further studies are needed for companies.

**[Proposal 8-1a]:**

Further study the issue and potential solution on performance enhancement for disabling HARQ feedback.

Please provide your views and comments.

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
|  |  |
|  |  |

# Proposals for discussion at Online sessions

# Contact information

In order to facilitate the contact among the chairman, moderator and delegates, please feel free to add your company/responsible delegates/email information in the following table.

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