**3GPP TSG RAN WG1 Meeting #104b-e R1-210xxxx**

e-Meeting, April 12-20, 2021

**Agenda Item: 7.2.2**

**Source: Moderator (Huawei)**

**Title: Feature lead summary#1 on NR-U HARQ maintenance**

**Document for: Discussion and Decision**

# Introduction

Corrections on NR-U HARQ have been submitted at RAN1#104b e-meeting. The preparation phase (April 8th – 9th) determined that corrections labelled Type3CB#1 and Type3CB#1 are deemed as essential corrections, and will be discussed at RAN1#104b-e by email discussion.

[104b-e-NR-NRU-04] Email discussion/approval on HARQ enhancements until Apr-16 – David (Huawei)

* Type3CB#1, Type3CB#2

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| **Issue #** | **Issue summary** | **Contributions** |
| Type3CB#1 | **Type-3 HARQ-ACK codebook size ambiguity** **R1-2102325*****Observation***: in the pseudo-code of section 9.1.4 of TS38.213v16.5.0, in case NDI reporting is not configured for Type-3 HARQ-ACK codebook, if the UE has not yet obtained HARQ-ACK information for a TB corresponding to a scheduled PDSCH reception and the UE has detected a DCI format scheduling a PDSCH reception for the TB, the UE shall not include a bit for the corresponding TB and HARQ process in the Type-3 HARQ-ACK codebook.Whether the UE reports a bit impacts the Type-3 HARQ-ACK codebook size, so if any UE is implemented based on a different understanding than in the observation above, then codebook mismatch will occur when the gNB interpretation is consistent with the observation above, and vice-versa. A safer (and more robust) approach would be to define/reserve a bit to report.***Proposal 1***: in case NDI reporting is not configured for Type-3 HARQ-ACK codebook, if the UE has not yet obtained HARQ-ACK information for a TB corresponding to a scheduled PDSCH reception and the UE has detected a DCI format scheduling a PDSCH reception for the TB, the UE shall report NACK for the corresponding TB and HARQ process in the Type-3 HARQ-ACK codebook. (TP provided in R1-2102325)**R1-2102367*****Observation 1***: Type-3 HARQ-ACK codebook is also applicable to frequency band that does not require shared spectrum access. gNB cannot avoid a SPS PDSCH is transmitted before a type 3 CB without enough processing time when multiple SPS PDSCH configurations or SPS PDSCH configuration with short periodicity is configured to a UE.***Observation 2***: The size of Type-3 HARQ-ACK codebook will be changed when the UE has not obtained HARQ-ACK information for a HARQ process.***Proposal 1***: For a given HARQ process, if the UE has not obtained HARQ-ACK information,  should be reserved in the Type-3 HARQ-ACK codebook. (TP1 provided in R1-2102367) | R1-2102325 R1-2102367  |
| Type3CB#2 | **Correction on multiplexing timeline definition for Type-3 HARQ-ACK codebook*****Reason for change***: In current specification of multiplexing timeline definition in Clause 9.2.5, DCI format 1\_1 indicating a request for a Type-3 HARQ-ACK codebook report without scheduling PDSCH is missing for $T\_{proc,2}^{mux}$ calculation.***Summary of change***: Add the DCI format 1\_1 providing the indication of a request for a Type-3 HARQ-ACK codebook report without scheduling PDSCH in the paragraphs of $T\_{proc,2}^{mux}$ calculation in Clause 9.2.5.**Refer to R1-2102587 for the detailed CR.** | R1-2102587  |
| Type2CB#3 | **Assumption on NFI value for a PDSCH group not received at UE side when the UL DAI indicates a value not equal to 4 for that group*****Proposal #2***: For the case when a PDSCH group is not received at UE side and the UL DAI in UL grant DCI corresponding to the PDSCH group indicates a value not equal to 4, the following behavior is applied.* NFI value for the PDSCH group is assumed to be non-toggled from the latest value.
	+ Payload size of the HARQ-ACK on PUSCH is determined by the indicated UL DAI itself without accumulating the HARQ-ACKs in the previous PUCCH occasion (similarly as for the case when UE only receives DL fallback DCI and the UE would transmit HARQ-ACK on PUCCH).

**FL note: Discussed as issue A9 in the past** | R1-2103336  |

# Type3CB#1: Type-3 HARQ-ACK codebook size ambiguity

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| Type3CB#1 | **Type-3 HARQ-ACK codebook size ambiguity** **R1-2102325*****Observation***: in the pseudo-code of section 9.1.4 of TS38.213v16.5.0, in case NDI reporting is not configured for Type-3 HARQ-ACK codebook, if the UE has not yet obtained HARQ-ACK information for a TB corresponding to a scheduled PDSCH reception and the UE has detected a DCI format scheduling a PDSCH reception for the TB, the UE shall not include a bit for the corresponding TB and HARQ process in the Type-3 HARQ-ACK codebook.Whether the UE reports a bit impacts the Type-3 HARQ-ACK codebook size, so if any UE is implemented based on a different understanding than in the observation above, then codebook mismatch will occur when the gNB interpretation is consistent with the observation above, and vice-versa. A safer (and more robust) approach would be to define/reserve a bit to report.***Proposal 1***: in case NDI reporting is not configured for Type-3 HARQ-ACK codebook, if the UE has not yet obtained HARQ-ACK information for a TB corresponding to a scheduled PDSCH reception and the UE has detected a DCI format scheduling a PDSCH reception for the TB, the UE shall report NACK for the corresponding TB and HARQ process in the Type-3 HARQ-ACK codebook. (TP provided in R1-2102325)**R1-2102367*****Observation 1***: Type-3 HARQ-ACK codebook is also applicable to frequency band that does not require shared spectrum access. gNB cannot avoid a SPS PDSCH is transmitted before a type 3 CB without enough processing time when multiple SPS PDSCH configurations or SPS PDSCH configuration with short periodicity is configured to a UE.***Observation 2***: The size of Type-3 HARQ-ACK codebook will be changed when the UE has not obtained HARQ-ACK information for a HARQ process.An example is provided to illustrate how a missed DCI will result in a codebook size mismatch between the UE and gNB.***Proposal 1***: For a given HARQ process, if the UE has not obtained HARQ-ACK information,  should be reserved in the Type-3 HARQ-ACK codebook. (TP1 provided in R1-2102367) | R1-2102325 R1-2102367  |

Given the various observations and examples in R1-2102325 and R1-2102367, which illustrate various conditions under which a codebook size mismatch may occur between the UE and the gNB, it is proposed to ensure that the codebook size does not depend on whether a UE has obtained or not obtained HARQ-ACK information for a HARQ process.

**Proposal 1**: correct the generation of the Type-3 HARQ-ACK codebook to ensure that HARQ-ACK bit(s) are always included for each of the configured HARQ processes.

* If UE has neither reported nor obtained HARQ-ACK information for a HARQ process, UE reports NACK for the corresponding bit(s).

A corresponding TP1 is provided in Annex 1.

Companies are invited to comment on proposal 1 and TP1 using the table below.

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| **Company** | **Comment** |
| OPPO | We support this TP, without this TP, the type 3 CB size is dynamically determined. This problem should be corrected.  |
| QC | Support in principle, but we think the TP can be simplified:The condition ”if UE has obtained HARQ-ACK information for TB $t$ for HARQ process number $h$ on serving cell $c$ corresponding to a PDSCH reception and has not reported the HARQ-ACK information corresponding to the PDSCH reception” can be mentioned first, and then one “else” condition can capture all other cases. With this, the existing condition “if UE has reported HARQ-ACK information for TB $t$ for HARQ process number $h$ on serving cell $c$, and has not subsequently detected a DCI format scheduling a PDSCH reception, or received a SPS PDSCH, with TB $t$ for HARQ process number $h$ on serving cell $c$” is also not needed (can be captured as part of “else”). |
| ZTE | We support the proposal 1. And for the TP we share the same view as QC that the conditions can be combined for simplicity. |
| Intel | The sub-bullet of the proposal is a bit confusing to me. The intention should be to let UE report NACK for the two cases: 1) UE already reported HARQ-ACK information; 2) UE didn’t obtain HARQ-ACK information. We are fine with the TP and support the simplification by QC.  |
| Samsung  | We share the same understanding with Intel for the proposal, i.e. UE reports NACK for two cases as Intel explained. We support the simplification TP by QC.  |
| vivo | We share similar view as QC, i.e. support the proposal 1, but the TP can be simplified further. |
| Sharp | We agree with the method in proposal 1.Sharing the same view as QC and companies, we also think that improvement from QC makes the logic simpler and clearer. |
| Nokia, NSB | We support the proposa, as well as the TP modified according to the Qualcomm comment. |
| Lenovo, Motorola Mobility | We are fine with the TP and support the simplification by QC. |
| LG | We also think some correction is necessary to address the concern raised from OPPO and Huawei, and for this, we prefer to keep the previous text which was made based on the agreement in WI phase unless there is problem with it. Thus, we propose to simply add the following to the pseudo code part in current spec:else ~~if UE has not obtained HARQ-ACK information for TB~~ $t$ ~~for HARQ process number~~ $h$ ~~on serving cell~~ $c$= NACK$j=j+1$ $t=t+1$ end if |

# Type3CB#2: Correction on multiplexing timeline definition for Type-3 HARQ-ACK codebook

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| Type3CB#2 | **Correction on multiplexing timeline definition for Type-3 HARQ-ACK codebook*****Reason for change***: In current specification of multiplexing timeline definition in Clause 9.2.5, DCI format 1\_1 indicating a request for a Type-3 HARQ-ACK codebook report without scheduling PDSCH is missing for $T\_{proc,2}^{mux}$ calculation.***Summary of change***: Add the DCI format 1\_1 providing the indication of a request for a Type-3 HARQ-ACK codebook report without scheduling PDSCH in the paragraphs of $T\_{proc,2}^{mux}$ calculation in Clause 9.2.5.**Refer to R1-2102587 for the detailed CR.** | R1-2102587  |

**Proposal 2**: agree on the CR in R1-2102587

Companies are invited to comment on proposal 2 using the table below.

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| **Company** | **Comment** |
| OPPO | We support this TP.  |
| QC | Support the proposal and the CR. |
| ZTE | We support the proposal 2. |
| Intel | We support this TP |
| Samsung  | We support the TP |
| vivo | Support the proposal 2 and corresponding CR. |
| Sharp | We support this proposal. |
| Nokia, NSB | We support this TP. |
| Lenovo, Motorola Mobility | We support this TP. |
| LG | We support this TP. |

# References

[R1-2102325](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102325.zip) Maintenance on channel access and HARQ procedures for NR Unlicensed Huawei, HiSilicon

[R1-2102367](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102367.zip) Discussion on the remaining issues of HARQ enhancements OPPO

[R1-2102587](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2102587.zip) Correction on multiplexing timeline definition for Type-3 HARQ-ACK codebook CATT, Huawei, HiSilicon, OPPO

[R1-2103336](file:///C%3A%5CUsers%5Cwanshic%5COneDrive%20-%20Qualcomm%5CDocuments%5CStandards%5C3GPP%20Standards%5CMeeting%20Documents%5CTSGR1_104b%5CDocs%5CR1-2103336.zip) Remaining issues of UL channels and HARQ procedure for NR-U LG Electronics

# Annex 1: TP1

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| ***Reason for change:*** | The construction of the Type-3 HARQ-ACK codebook may result in a codebook size mismatch between UE and gNB, if the UE determined that it has not yet obtained HARQ-ACK information for a TB corresponding to a scheduled PDSCH reception, but the gNB determined otherwise. |
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| ***Summary of change:*** | Specify that if the UE has not yet obtained HARQ-ACK information for a TB and a HARQ process, the UE shall report NACK for the corresponding TB and HARQ process in the Type-3 HARQ-ACK codebook. |
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| ***Consequences if not approved:*** | UE and gNB may have a different assumptions on the size (number of bits) reported by the UE in the Type-3 HARQ-ACK codebook, leading to HARQ failure. |

================== Start of TP#1 for TS 38.213 v16.5.0 ===================

**9.1.4 Type-3 HARQ-ACK codebook determination**

If a UE is provided *pdsch-HARQ-ACK-OneShotFeedback*, the UE determines $\tilde{o}\_{0}^{ACK},\tilde{o}\_{1}^{ACK},…,\tilde{o}\_{O\_{ACK}-1}^{ACK}$ HARQ-ACK information bits, for a total number of $O\_{ACK}$ HARQ-ACK information bits, of a Type-3 HARQ-ACK codebook according to the following procedure.

Set $N\_{cells}^{DL}$ to the number of configured serving cells

Set $N\_{HARQ,c}^{DL}$ to the value of *nrofHARQ-ProcessesForPDSCH* for serving cell $c$, if provided; else, set $N\_{HARQ,c}^{DL}=8$

Set $N\_{TB,c}^{DL}$ to the value of *maxNrofCodeWordsScheduledByDCI* for serving cell $c$ if *harq-ACK-SpatialBundlingPUCCH* is provided and $NDI\_{HARQ}=0$, or if *harq-ACK-SpatialBundlingPUCCH* is not provided, or if *maxCodeBlockGroupsPerTransportBlock* is provided for serving cell $c$; else, set $N\_{TB,c}^{DL}=1$

Set $N\_{HARQ-ACK,c}^{CBG/TB,max}$ to the number of HARQ-ACK information bits per TB for PDSCH receptions on serving cell $c$ as described in Clause 9.1.1 if *maxCodeBlockGroupsPerTransportBlock* is provided for serving cell $c$ and *pdsch-HARQ-ACK-OneShotFeedbackCBG* is provided; else, set $N\_{HARQ-ACK,c}^{CBG/TB,max}=0$

Set $NDI\_{HARQ}=0$ if *pdsch-HARQ-ACK-OneShotFeedbackNDI* is provided; else set $NDI\_{HARQ}=1$

Set $c=0$ – serving cell index

Set $h=0$ – HARQ process number

Set $t=0$ – TB index

Set $g=0$ – CBG index

Set $j=0$

while $c<N\_{cells}^{DL}$

while $h<N\_{HARQ,c}^{DL}$

if $NDI\_{HARQ}=0$

if $N\_{HARQ-ACK,c}^{CBG/TB,max}>0$

while $t<N\_{TB,c}^{DL}$

while $g<N\_{HARQ-ACK,c}^{CBG/TB,max}$

= HARQ-ACK information bit for CBG $g$ of TB $t$ for HARQ process number $h$ of serving cell $c$, if any; else, 

$j=j+1$

$g=g+1$

end while

= NDI value indicated in the DCI format corresponding to the HARQ-ACK information bit(s) for TB $t$ for HARQ process number $h$ on serving cell $c$, if any; else, 

$g=0$

$j=j+1$

$t=t+1$

end while

else

while $t<N\_{TB,c}^{DL}$

= HARQ-ACK information bit for TB $t$ for HARQ process $h$ of serving cell $c$, if any; else, 

$j=j+1$

= NDI value indicated in the DCI format corresponding to the HARQ-ACK information bit(s) for TB $t$ for HARQ process number $h$ on serving cell $c$, if any; else, 

$j=j+1$

$t=t+1$

end while

end if

$t=0$

else

if $N\_{HARQ-ACK,c}^{CBG/TB,max}>0$

while $t<N\_{TB,c}^{DL}$

if UE has reported HARQ-ACK information for TB $t$ for HARQ process number $h$ on serving cell $c$, and has not subsequently detected a DCI format scheduling a PDSCH reception, or received a SPS PDSCH, with TB $t$ for HARQ process number $h$ on serving cell $c$

while $g<N\_{HARQ-ACK,c}^{CBG/TB,max}$



$j=j+1$

$g=g+1$

end while

end if

if UE has obtained HARQ-ACK information for TB $t$ for HARQ process number $h$ on serving cell $c$ corresponding to a PDSCH reception and has not reported the HARQ-ACK information corresponding to the PDSCH reception

while $g<N\_{HARQ-ACK,c}^{CBG/TB,max}$

= HARQ-ACK information bit for CBG $g$ of TB $t$ for HARQ process number $h$ of serving cell $c$

$j=j+1$

$g=g+1$

end while

end if

if UE has not obtained HARQ-ACK information for TB $t$ for HARQ process number $h$ on serving cell $c$

while $g<N\_{HARQ-ACK,c}^{CBG/TB,max}$



$j=j+1$

$g=g+1$

end while

end if

$g=0$

$t=t+1$

end while

else

while $t<N\_{TB,c}^{DL}$

if UE has reported HARQ-ACK information for TB $t$ for HARQ process number $h$ on serving cell $c$ and has not subsequently detected a DCI format scheduling a PDSCH reception, or received a SPS PDSCH, with TB $t$ for HARQ process number $h$ on serving cell $c$

= NACK

$j=j+1$

$t=t+1$

end if

if UE has obtained HARQ-ACK information for TB $t$ for HARQ process number $h$ on serving cell $c$ corresponding to a PDSCH reception and has not reported the HARQ-ACK information corresponding to the PDSCH reception

if *harq-ACK-SpatialBundlingPUCCH* is not provided

= HARQ-ACK information bit for TB $t$ for HARQ process $h$ of serving cell $c$

else

= binary AND operation of the HARQ-ACK information bits corresponding to first and second transport blocks for HARQ process $h$ of serving cell $c$. If the UE receives one transport block, the UE assumes ACK for the second transport block

end if

$j=j+1$

$t=t+1$

end if

if UE has not obtained HARQ-ACK information for TB $t$ for HARQ process number $h$ on serving cell $c$

= NACK

$j=j+1$

$t=t+1$

end if

end while

end if

$t=0$

end if

$h=h+1$

end while

$h=0$

$c=c+1$

end while

If $N\_{TB,c}^{DL}>1$, when a UE receives a PDSCH with one transport block, the HARQ-ACK information is associated with the first transport block.

If a UE receives a SPS PDSCH, or a PDSCH that is scheduled by a DCI format 1\_0 for a serving cell $c$ and if *maxCodeBlockGroupsPerTransportBlock* is provided for serving cell $c$, and *pdsch-HARQ-ACK-OneShotFeedbackCBG* is provided, the UE repeats $N\_{HARQ-ACK,c}^{CBG/TB,max}$ times the HARQ-ACK information for the transport block in the PDSCH.

If a UE detects a DCI format that includes a One-shot HARQ-ACK request field with value 1, the UE determines a PUCCH or a PUSCH to multiplex a Type-3 HARQ-ACK codebook for transmission in a slot as described in Clauses 9.2.3 and 9.2.5. The UE multiplexes only the Type-3 HARQ-ACK codebook in the PUCCH or the PUSCH for transmission in the slot.

If

- a UE detects a DCI format that includes a One-shot HARQ-ACK request field with value 1, and

- the CRC of the DCI is scrambled by a C-RNTI or an MCS-C-RNTI, and

- *resourceAllocation* = *resourceAllocationType0* and all bits of the frequency domain resource assignment field in the DCI format are equal to 0, or

- *resourceAllocation* = *resourceAllocationType1* and all bits of the frequency domain resource assignment field in the DCI format are equal to 1, or

- *resourceAllocation = dynamicSwitch* and all bits of the frequency domain resource assignment field in the DCI format are equal to 0 or 1

the DCI format provides a request for a Type-3 HARQ-ACK codebook report and does not schedule a PDSCH reception. The UE is expected to provide HARQ-ACK information in response to the request for the Type-3 HARQ-ACK codebook after $N$ symbols from the last symbol of a PDCCH providing the DCI format, where the value of $N$ for $μ=0,1,2$ is provided in Clause 10.2 by replacing "SPS PDSCH release" with "DCI format".

If a UE multiplexes HARQ-ACK information in a PUSCH transmission, the UE generates the HARQ-ACK codebook as described in this Clause except that *harq-ACK-SpatialBundlingPUCCH* is replaced by *harq-ACK-SpatialBundlingPUSCH*.

================== End of TP#1 for TS 38.213 v16.5.0 ===================