**3GPP TSG-RAN2 #114e R2-** **210xxxx**

**Electronic meeting, May 19 – May 27, 2021 revision of R2-** **2104501**

**Agenda item:**8.1.2.1 (NR\_MBS-Core)

**Source:** LG Electronics Inc.

**Title:** [Pre114-e][001][MBS] Summary 8.1.2.1 MBS Connected mode Reliability (LGE)

**Document for:** Discussion and Decision

# 1. Introduction

This document summarizes the issues identified by documents submitted to A.I. 8.1.2.1 in RAN2-114e meeting.

The issues are categorized into two types:

- Category 1: Essential issues related to three options for L2 reliability

- Category 2: Other issues

Also, this document summarizes contributions which expresses theirs views on options for L2 reliability and the essential issues to be supported in each option.

# 2. Discussion

## 2.1 Essential issues related to three options for L2 reliability

At RAN2-113e meeting RAN2 discussed followings and Proposal 1 is agreed.

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| --- |
| **Proposal 1: A1+B1, No L2 ARQ with PDCP anchored PTM – PTP switching shall be supported, at least for the case that both PTM and PTP are RLC-UM.**  **Proposal 2: Discuss whether to support any of:  - A1+B1 for PTM RLC-UM + PTP RLC-AM, possibly with some kind of data recovery in the switching procedure.**  **- A2+B1 for PTM RLC-UM + PTP RLC-AM**  **- A3+B2(+B1) For PTM RLC-AM + PTP RLC-AM**  A1. No L2 ARQ for PTM  A2. L2 ARQ by PDCP for PTM  A3. L2 ARQ by RLC-AM for PTM  B1. PDCP anchored PTM/PTP switch  B2. RLC anchored PTM/PTP Switch |

As noted above, three options are still on the table, and RAN2 should discuss whether to support any of three options.

As companies have different level of acceptance for each option, it is not worth to discuss unmeasurable aspects, e.g. whether option X is feasible or not, whether spec impact of option X is big or small, whether option X supports required level of reliability or not, etc.

Instead, this document summarizes the essential technical issues of each option brought up by the companies. Whether the brought up issues are real issues or not need to be verified by RAN2.

### 2.1.1 Option 1 - A1+B1 for PTM RLC-UM + PTP RLC-AM

**PDCP data recovery**

According to current specification, PDCP PDU is retransmitted at PDCP data recovery. The PDCP data recovery is supported for AM DRBs, and when upper layers request a PDCP data recovery for an AM DRB the transmitting PDCP entity shall perform retransmission of all the PDCP Data PDUs previously submitted to re-established or released AM RLC entities. However, for option 1, PDCP data recovery should be supported for UM DRB [2][11].

**PDCP status report**

According to current specification, PDCP status report is transmitted at specific events, i.e. PDCP re-establishment, PDCP data recovery, UL data switching, and DAPS release. However, for option 1, PDCP status report should be triggered at PTM/PTP switch. The new triggering condition may be not exactly at switching, but at the first packet received via the activated leg, e.g., PTP leg in case of switching from PTM to PTP. The PDCP status reporting can be supported to improve the reliability of the MBS session reception and ensure the data lossless reception during the PTM/PTP switch. In addition for lossless switching, PDCP status reporting would also be useful to avoid duplicate reception of PDCP PDUs [2][3][9][11][19].

### 2.1.2 Option 2 - A2+B1 for PTM RLC-UM + PTP RLC-AM

**PDCP status report**

In current specs, PDCP status report is triggered by upper layers. For option 2, PDCP-based ARQ in MBS services can be implemented by adding new triggers for PDCP status report. New triggers for PDCP status report can be specified based on polling or loss detection. Number of missing SNs is also suggested for a trigger for PDCP status report [1][2][11][17].

When *t-reordering* timer expiry is used as a trigger for PDCP status report, the lower edge of PDCP reception buffer RX\_DELIV is moved forward when *t-reordering* expires and any retransmission of missing PDCP PDU would fall out of reception buffer. There is a need of modified window management similar to RLC AM to prevent loss of PDCP PDUs. The change is that SDU will not be delivered to upper layer after *t-reordering* expires, and RX\_DELIV remains unchanged [3][17].

**PDCP PDU retransmission**

When L2 ARQ is implemented by PDCP retransmission, it can use PDCP status report to inform missing packets. Then lost PDUs stored in PDCP transmission buffer will be retransmitted through PTP leg. According to current specification, PDCP PDU is retransmitted at PDCP data recovery. The PDCP data recovery is supported for AM DRBs, and when upper layers request a PDCP data recovery for an AM DRB, the transmitting PDCP entity shall perform retransmission of all the PDCP Data PDUs previously submitted to re-established or released AM RLC entities. However, for option 2, PDCP PDU retransmission should be triggered by PDCP status report [1][2][3][11][17][23].

### 2.1.3 Option 3 - A3+B2(+B1) For PTM RLC-AM + PTP RLC-AM

**Reception window maintenance with two logical channels**

In option 3, both PTM and PTP are supported by a single RLC entity. A PTM AM RLC entity at UE side needs to be associated to two kinds of logical channels, one for reception of group common packets, one for reception and transmission of UE-specific packets (such as acknowledgments and re-transmission data packets) [2].

The AM RLC entity has two legs, i.e. PTP leg and PTM leg. If gNB performs RLC retransmission in PTP leg, it has to be discussed how to maintain RLC AM reception window and how to perform RLC reordering with the two RLC legs [1]. RLC AM reception is suggested to be handled in a single RLC entity. ARQ of PTM transmission and RLC-AM on PTM transmission are supported through logical channel aggregation [6].

**RLC SDU segmentation for UEs in PTP**

Option 3 supports retransmission of RLC segments, which is different from option 2 that performs per-PDCP SDU retransmissions. So, option 3 could be considered as the best performance among the three options in terms of spectral efficiency [2][11]. However, RLC segmentations for different UEs may be different even for the same MBS packet in retransmission using PTP transmissions. It means that on the network side separate tx RLC buffer managements and separate RLC tx operations are required for logical channels of PTP transmission for different UEs [24].

**gNB PTM RLC Tx window handling**

For option 3, RLC AM needs to be enhanced to support point to multipoint (PTM) transmissions and re-transmissions. gNB is expected to receive RLC status report from multiple UEs. gNB should be able to handle RLC Tx window movement based on feedback from multiple multicast UEs’ RLC status reports. There can be instances where some of the UEs are not able to successfully receive a RLC SN. This might result in PTM RLC Tx Window stall at gNB side. It is required to allow the movement of the PTM RLC Tx Window lower edge even when not all the UEs have acknowledged the RLC Tx window lower edge. gNB PTM RLC Tx entity can inform the RLC Tx window lower edge movement to all the participating UEs. The left edge of Rx window (of UEs in poor conditions) may be forced to moved forward without successful reception [1][2][3][5][15][17][20][23].

### 2.1.4 Selection of option(s) for L2 reliability

The essential technical issues that may need to be supported in each option are discussed in the previous sections. As companies have different view, it is proposed to verify the listed essential issues. Then, we can focus on the same essential issues of each option and make better common understanding for further discussion.

**Proposal 1. RAN2 discuss and verify essential issues for each option based on the summarized issues in Section 2.1.**

* Option 1 - A1+B1 for PTM RLC-UM + PTP RLC-AM
  + PDCP data recovery
  + PDCP status report
* Option 2 - A2+B1 for PTM RLC-UM + PTP RLC-AM
  + PDCP status report
  + PDCP PDU retransmission
* Option 3 - A3+B2(+B1) For PTM RLC-AM + PTP RLC-AM
  + Reception window maintenance with two logical channels
  + RLC SDU segmentation for UEs in PTP
  + gNB PTM RLC Tx window handling

Although the above proposal 1 has not been discussed in RAN2-113bis-e meeting, many contributions to this meeting (RAN2-114e meeting) express their views on options for L2 reliability and the essential issues to be supported in each option. It is tried to summarize those contributions for essential issues related to three options for L2 reliability.

For option 3, there are 12 contributions which express their views. Seven contributions (out of 12) do not support option 3 or RLC AM for PTM [1][2][3][15][18][20][24], and five contributions (out of 12) support option 3 [5][6][11][17][21]. It needs to be noted that [15] is co-signed by 26 companies and [5][17] are co-signed by 5 companies.

Regarding reception window maintenance with two logical channels in section 2.1.3, it is pointed out that complexity and specification impacts would be high because a PTM RLC entity needs to be associated with two logical channels, one for reception of group-common packets, one for reception and transmission of UE-specific packets (such as acknowledgments and re-transmission data packets). Considering PDCP anchored structure is required for mobility and switching, the overall structure for option 3 seems heavier than other options [1][2][24]. On the other hand, companies supporting option 3 indicates that with logical channel aggregation applied to the split bearer like framework, RLC-AM can be supported on PTM transmission without increasing UE complexity [6].

Regarding RLC SDU segmentation for UEs in PTP in section 2.1.3, option 3 supports retransmission of RLC segments. A company which does not support option 3 indicates that the efficiency is achieved at the cost of introducing great complexity at gNB by computing the optimal joint policy of segmenting, TB size for PTM transmission and TB size of PTP transmission for each UE [2]. On the other hand, a company supporting RLC AM for PTM points out that option 3 could be considered as the best performance among the three options in terms of spectral efficiency and the complexity is low [11][17].

Regarding gNB PTM RLC Tx window handling in section 2.1.3, it is indicated that it has considerable complexity at network side for Tx window management and it also has considerable specification impacts for the corresponding Rx window management [1][2][3][15][20]. In addition, the left edge of Rx window (of UEs in poor conditions) may be forced to moved forward without successful reception. So retransmission in PTM leg cannot be as reliable as RLC-AM in unicast services [3]. On the other hand, companies supporting option 3 indicate that RLC transmitter is always at network for MRB and there’d be no extra specification work for the transmit operation of an MRB RLC AM entity. Some additional enhancements are required for UEs repeatedly reporting RLC NACKs for a specific RLC SN. This method provides high radio efficiency for PTM leg and has limited specification impact [5][11][17][21].

Although a number of companies support RLC AM for PTM, the following proposal is proposed considering majority companies’ views and the working assumption (i.e. RLC-AM for PTM is not supported.) agreed in RAN2-112e meeting.

**Proposal 2. RAN2 to confirm that PTM does not support RLC-AM. Option 3 (A3+B2(+B1) For PTM RLC-AM + PTP RLC-AM) is not supported.**

For option 1, option 1 seems supported in [1][9][11][13][15][19][20][24]. Although some companies prioritizes L2 ARQ, they also considers switching to PTP for the UE which is in a bad channel condition [2][3][23]. In RAN2-113bis-e meeting, it is also agreed that for a given UE, if the MRB’s QoS requirements are not met via PTM, switching to PTP with RLC-AM shall be supported. So, the following proposal is proposed.

**Proposal 3. Support option 1 (A1+B1 for PTM RLC-UM + PTP RLC-AM, possibly with some kind of data recovery in the switching procedure)**

For option 2, there are 9 contributions which express their views. Three contributions (out of 9) do not support option 2 or RLC AM for PTM [5][17][21], and six contributions (out of 9) support option 2 [1][2][3][20][23][24].

Regarding PDCP status report in section 2.1.2, the triggers for PDCP status report is different from existing triggers for PDCP status report. To support PDCP based retransmission for PTM, similar mechanisms as RLC status report needs to be introduced. Retransmission of lost PDCP PDU without RRC involvement requires significant changes on both gNB and UE sides to introduce similar mechanisms as in RLC sublayer for handling of reception buffer and status report, effectively replicating an Acknowledged Mode at PDCP sublayer [5][11][17][21]. On the other hand, companies supporting PDCP ARQ points out that implementation complexity is low and specification impact is not high because PDCP status report might be needed and it is done in a more relaxed manner compared to RLC statue report. Other behaviors can be same with current PDCP mechanisms. In addition PDCP status reporting needs to be supported for MBS UE at least in handover case. Therefore, option 2 only needs a new trigger for PDCP status reporting during normal data reception [2][3][20].

Regarding PDCP PDU retransmission in section 2.1.2, PDCP PDU re-transmission is based on UE provided PDCP level feedback (i.e., UE indicating which PDCP SNs are missing), so there is a need to implement RLC AM kind of functionality at PDCP level which augments undesirable PDCP complexity, adds additional overhead and provides same lower layer RLC AM functionality at a higher layer. In spite of additional complexity, it does not offer any additional reliability and radio efficiency compared to PTM RLC AM enhancement. Resource efficiency is lower than option 3 due to unicast L2 re-transmission of a whole PDCP PDU [5][11][17][21]. On the other hand, companies supporting option 2 indicates that PDCP retransmission will not reuse the mechanism of RLC AM, such as Tx window left edge movement and L2 ARQ by PDCP share the same architecture with PDCP anchored PTM/PTP dynamic switch. In addition, based on that L2 ARQ for PTM cannot always guarantee high reliability PDCP ARQ for PTM needs not to target lossless delivery and L2 ARQ for PTM needs not to consider reflecting the whole RLC-AM functionality. Therefore, uplink feedback and retransmission mechanism can be simpler than RLC AM ARQ [1][3][24].

Based on the above, the following proposal is given.

**Proposal 4. Discuss whether to support option 2 (A2+B1 for PTM RLC-UM + PTP RLC-AM).**

## 2.2 Other issues

**RLC status report**

RLC status report for PTM RLC AM has a disadvantage in amounts of UL resource consumption for RLC status reports. PTP RLC AM has less resource consumption for RLC status report comparing to PTM RLC AM. Signaling overhead will be high due to frequent/prompt RLC status report, especially in cases of PTM transmission where the channel is more unpredictable and hard to get the same level of channel adaptation for a PTP link [1][2][15]. If the number of UEs configured as PTM RLC AM is huge, the time for the gNB to collect all UEs’ status report will be considerable. With such time delay, the PDB could be exceeded [1][3].

On the other hand, it is pointed out that Multiple UEs in multicast mode send RLC Status PDUs using PUSCH resources should not cause additional UL overhead compared to multiple UEs sending PTP RLC Status reports during unicast PDU data transfer procedure. Because even if any DL RLC re-transmissions are performed through PTP leg, UEs are still required to send RLC Status PDU reports using PUSCH and it uses the same procedure. Even for reporting PDCP Status reporting, UEs are required to use PUSCH [5][17].

**PDCP retransmission without L2 feedback**

The network can improve the reliability by retransmitting a PDCP PDU using RLC-AM and C-RNTI. The trigger to initiate the retransmission is left to network implementation. HARQ feedback would be useful. In option 1, there is no UE PDCP level feedback. So, gNB decides whether to re-transmit a PDCP PDU (via PTP) based on HARQ feedback without UE PDCP level feedback. In addition, purely relying on PDCP retransmission based on HARQ feedback might not support services with high reliability well since there is potential HARQ feedback error (NACK to ACK) [5][13][17].

**PDCP Rx window update to prevent re-ordering window from stalling**

In NR, reordering of PDUs takes place at PDCP. To prevent the receiver from stalling forever in case of gaps, a reordering timer (*t-Reordering*) was introduced. This means that any missing PDCP PDU will stall the re-ordering window. In PTM transmission, when a UE lacks too far behind to catch up with an ongoing PTM transmission. To avoid stalling the re-ordering window when losses occur, it has to be considered to deliver upper layers 1) all stored PDCP SDU(s) with an associated COUNT value less than the COUNT value associated with the received PDCP SDU; and 2) all stored PDCP SDU(s) with consecutively associated COUNT value(s) starting from the COUNT value associated with the received PDCP SDU [8].

**Rx SN indication between PTM RLC UM and PTP RLC AM for improving PTM reliability**

For RLC UM on PTM and RLC AM on PTP where all PDCP PDUs are submitted for transmission to both legs (as in duplication), a PDCP could indicate to the PTM RLC UM entity, in response to receiving a PDCP Data PDU from the PTM RLC UM entity, that all RLC SDUs with SN lower than the SN of the SDU carrying this PDCP Data PDU can be acknowledged to the TX RLC entity when possible. Then, not all PDCP PDUs are actually transmitted on the PTP leg. For each PDCP PDU received by RLC AM on the PTP leg, a status report can be triggered, taking into account PDCP PDUs already indicated as received by the PDCP entity. By acknowledging those PDUs to the transmitter, only the missing PDUs will then follow on the PTP leg [8].

**Initial value of PDCP / RLC state variables**

In PTP RLC AM, the initial values of some variables, such as RX\_Next, RX\_Highest\_Status should be initialized to 0. For PTM RLC AM, if the UE join the MBS service during PTM transmission, the initial values of the variables can be non-zero. Then, it has to be considered how to initialize the related variables and guarantee consecutive SNs for PTM RLC AM [1].

In order to support PDCP status reporting, COUNT value needs to be maintained properly. If a UE joins an MBS session after the session start time, initial values of PDCP SN and HFN may not be zero. Therefore, HFN needs to be synchronized between UE and the gNB before the UE start receiving data of the MBS session [19].

**Reconfiguring the RB option to PTP RLC-AM for a given problem UE**

When there is a problem UE in PTM, for example a UE that is in poor coverage and unable to correctly receive a PTM transmission, the gNB should be able to reconfigure the RB option for this problem UE – for example reconfiguring to a DRB with RLC-AM [23].

**Enabling/disabling HARQ-ACK feedback**

According to RAN1 agreements in the last meeting (RAN1-104e), NR multicast supports at least ACK/NACK based HARQ feedback for PTM transmission. From configuration perspective, UE shall be indicated whether HARQ-ACK feedback is enabled. According to the progress in RAN1, there are three different ways on the table to enable/disable HARQ-ACK feedback:

* RRC signalling configures whether DCI indicates the enabling/disabling of HARQ-ACK feedback. Then, UE will understand if DCI carries the indication to enable/disable HARQ-ACK feedback, and act accordingly.
* RRC signalling directly configures whether HARQ-ACK feedback is enabled or disabled.
* MAC CE indicates whether HARQ-ACK feedback is enabled or disabled.

Due to the lack of details from RAN1 perspective, RAN2 is suggested to wait for RAN1 progress before discussing whether/how to provide multicast HARQ configuration for enabling/disabling HARQ-ACK feedback [16].

**MBS packet losses due to measurement gap**

When multiple UEs requiring measurement gaps receive the same MBS service via group scheduling (i.e. PTM transmission through G-RNTI) arise the question of how to handle these measurement gaps. We can think of three alternatives: common gap without MBS transmission, common gap with MBS transmission and dedicated gap with MBS transmission. For the second and third alternatives, UEs having to apply measurement gaps will suffer losses unless retransmissions are separately scheduled. For the retransmissions targeting multiple UEs, group scheduling should also be used. The network assumes that the gap was used and schedules retransmissions. Blind PDCP retransmissions to compensate for missed PTM transmissions due to measurement gaps also relies on group scheduling [8].

**FEC and RAN retransmission for MBS**

According to SA2, MBS data provided to the RAN can be protected by Forward Error Correction (FEC). When a FEC is used, not all PDCP SDUs have to be successfully transmitted and losses should be allowed. This is currently not possible since a Radio Bearer is either configured to be tolerate no losses (with RLC AM) or to allow any (with RLC UM). This is especially problematic for PTM transmissions where having all retransmissions individually handled via PTP. By relying on a FEC to recover from (most) errors on the PTM path, retransmissions in the RAN should only be triggered when the FEC is known not to be able to compensate the corresponding losses [8].

**CA and CA based duplication for MBS**

CA and CA based duplication is used to enhance the reliability and data rate for transmission per unicast. For MBS transmission, CA and CA based duplication could be also beneficial for those MBS services demanding high reliability or high data rate. For PTP transmission, it’s similar as unicast transmission, and thus there would be no issue to adopt CA and CA based duplication just like unicast in legacy. For PTM transmission, when applicable, gNB can transmit MBS packet via any common serving cell(s) among the relevant the group of UEs. Similarly, gNB may decide to adopt CA or CA based duplication to transmit packets to the relevant group of UEs. Considering the limited time in WI, RAN2 is suggested to at least support CA and CA-based duplication for PTP mode [16].

**RRC\_CONNECTED state with MBS service**

According to the agreements made in meetings RAN2-112e and RAN2-113e, it is agreed that UE should keep in RRC\_CONNECTED state to receive multicast session which has high QoS requirement of reliability and/or latency. It is also agreed that “When there is no data ongoing for the multicast session, the UE can stay in RRC\_CONNECTED”. However, it is specified in NR RRC specification that “UE shall perform the actions upon going to RRC\_IDLE state upon receiving the expiry of *DataInactivityTimer* from lower layers while in RRC\_CONNECTED state”. By far, the NR MAC specification considers only the DTCH logical channel, DCCH logical channel, or CCCH logical channel as the condition of maintaining the “*dataInactivityTimer*”. If the UE receives the MBS service through PTM transmission scheme, the new radio bear for MBS service (e.g. MRB) may be mapped to new logical channel for MBS traffic channel (e.g. MTCH) and/or MBS control channel (e.g. MCCH). In the use case that the “dataInactivityTimer” is configured and the UE receives a multicast session through PTM transmission scheme, it has to be discussed how to avoid the expiry of *DataInactivityTimer* and RRC state transition from RRC\_CONNECTED to RRC\_IDLE [10].

**Activation and deactivation of PTM leg and PTP leg**

Leaving the PTM leg activated when the UE is receiving the MBS data over the PTP leg will result in unnecessary processing at the UE. It is suggested that PTM leg should be deactivated after a path switch from PTM leg to PTP leg. The UE can autonomously deactivate the PTM leg upon reception of MBS traffic over a PTP leg or explicit signal may be used to notify UE to stop monitoring over PTM transmission leg after switching. A path switch to the PTM leg requires an activation indication from the network. It is for further study if L1 signalling (i.e. DCI) or L2 signalling (e.g. MAC-CE or PDCP Control PDU) should be supported for such notification [3][20][22].

On the other hand, it is pointed out that dynamic activation and deactivation of PTM RLC (or G-RNTI monitoring) is not necessary. The purpose of the deactivation of G-RNTI monitoring could be power saving by skipping of de-scrambling using G-RNTI. However, it can be achieved by bearer type change to a unicast DRB which does not have any PTM RLC. In that sense, dynamic deactivation is a duplicate functionality with the unicast bearer. Moreover, the case of missing deactivation would make another technical issue, e.g. potential packet loss and recovery. Therefore, the RRC based PTP and PTM switching mechanism via RRC signaling can be suggested. NW can use the RRC signaling to keep the same PDCP entity or change to the different PDCP entity during the switching [7][14][20].

In this section, most of other issues are related to optimization and enhancements to Layer 2 reliability. Additionally, some of issues are related to HARQ, CA duplication, transition to RRC\_IDLE by *DataInactivityTimer* expiry during MBS service and activation/deactivation of PTM/PTP leg. The MBS reliability discussion is related to the basic MBS structure and architecture. So, we think that it would be better to discuss other issues based on the decision on option(s) for L2 reliability.

**Proposal 5. RAN2 discuss and verify issues summarized in Section 2.2 after selecting option(s) for L2 reliability.**

# 3. Conclusion

In this contribution, documents submitted to A.I. 8.1.2.1 are summarized.

**Proposal 2. RAN2 to confirm that PTM does not support RLC-AM. Option 3 (A3+B2(+B1) For PTM RLC-AM + PTP RLC-AM) is not supported.**

**Proposal 3. Support option 1 (A1+B1 for PTM RLC-UM + PTP RLC-AM, possibly with some kind of data recovery in the switching procedure).**

**Proposal 4. Discuss whether to support option 2 (A2+B1 for PTM RLC-UM + PTP RLC-AM).**

For essential issues related to three options for L2 reliability,

**Proposal 1. RAN2 discuss and verify essential issues for each option based on the summarized issues in Section 2.1.**

* Option 1 - A1+B1 for PTM RLC-UM + PTP RLC-AM
  + PDCP data recovery
  + PDCP status report
* Option 2 - A2+B1 for PTM RLC-UM + PTP RLC-AM
  + PDCP status report
  + PDCP PDU retransmission
* Option 3 - A3+B2(+B1) For PTM RLC-AM + PTP RLC-AM
  + Reception window maintenance with two logical channels
  + RLC SDU segmentation for UEs in PTP
  + gNB PTM RLC Tx window handling

**Proposal 5. RAN2 discuss and verify issues summarized in Section 2.2 after selecting option(s) for L2 reliability.**

# 4. References

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