**3GPP TSG-RAN WG2 Meeting #116bis electronic R2-22xxxxx**

**Online, Jan. 17th – Jan. 25th, 2022**

**Agenda Item: 8.1.4**

**Source: OPPO**

**Title: [AT116bis-e][028][MBS] MAC Open Issues (OPPO)**

**Document for: Discussion and decision**

# Introduction

This paper is to trigger the following email discussion of MAC open issues in MBS.

* [AT116bis-e][028][MBS] MAC Open Issues (OPPO)

Scope: Address MAC related open issues, as captured in R2-2200022 and R2-2111414 (running CR). Take into account input to this meeting. Identify (easy) agreements, points for discussion etc.

Intended outcome: Report

Deadline: First Deadline Friday W1 (CB online to some important point)

**Contact Information**

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| --- | --- |
| Company | Email |
| OPPO | wangshukun@oppo.com |
| Samsung | sangkyu.baek@samsung.com |
| Ericsson | Henrik.enbuske@ericsson.com |
| CATT | zhourui@catt.cn |
| Nokia | benoist.sebire@nokia.com |
| Lenovo, Motorola Mobility | daimz4@lenovo.com |
| Qualcomm | pkadiri@qti.qualcomm.com |
| LGE | sj117.kim@lge.com |
| TD Tech, Chengdu TD Tech | limei.wei@td-tech.com |
| Fujitsu | [ohta.yoshiaki@fujitsu.com](mailto:ohta.yoshiaki@fujitsu.com) |
| MediaTek | Xiaonan.Zhang@mediatek.com |
| vivo | yitao.mo@vivo.com |
| Xiaomi | wuyumin@xiaomi.com |
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# Discussion

## 2.1 MBS HARQ process

In RAN1#104 meeting, the following agreement is made and it means the MBS and unicast shared the same HARQ process ID space.

PTM transmission + PTM retransmission 🡺 for same TB, same HARQ process id and NDI

PTM transmission +PTP retransmission 🡺 for same TB, same HARQ process id and NDI

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| Agreement:  The same HARQ process ID and NDI are used for PTM scheme 1 (re)transmissions and PTP retransmissions of the same TB.  Conclusion:  The maximum number of HARQ processes per cell, currently supported for unicast, is kept unchanged for UE to support multicast reception.  How to allocate HARQ processes between unicast and multicast is up to gNB. |

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| 5.3.1 DL Assignment reception Downlink assignments received on the PDCCH both indicate that there is a transmission on a DL-SCH for a particular MAC entity and provide the relevant HARQ information.  When the MAC entity has a C-RNTI, Temporary C-RNTI, or CS-RNTI, the MAC entity shall for each PDCCH occasion during which it monitors PDCCH and for each Serving Cell:  1> if a downlink assignment for this PDCCH occasion and this Serving Cell has been received on the PDCCH for the MAC entity's C-RNTI, or Temporary C‑RNTI:  2> if this is the first downlink assignment for this Temporary C-RNTI:  3> consider the NDI to have been toggled.  2> if the downlink assignment is for the MAC entity's C-RNTI, and if the previous downlink assignment indicated to the HARQ entity of the same HARQ process was either a downlink assignment received for the MAC entity's CS-RNTI or a configured downlink assignment:  3> consider the NDI to have been toggled regardless of the value of the NDI. |

In TS 38.321, the yellow highlight part is for the case that SPS HARQ process is previous HARQ process of the dynamic scheduling HARQ process for the same HARQ process id. The NDI will be considered as toggled regardless of the value of the NDI. UE may be configured with unicast including dynamic scheduling and SPS, multicast including dynamic scheduling and MBS SPS. So, the following cases exist:

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| **For the same HARQ process id** | | |
| **Before** | **now** | **Behaviour** |
| MBS SPS | Dynamic scheduling via C-RNTI | consider the NDI to have been toggled regardless of the value of the NDI. |
| Dynamic scheduling via G-RNTI |
| Dynamic scheduling via G-CS-RNTI |
| SPS | Dynamic scheduling via G-RNTI |
| MBS SPS |
| Dynamic scheduling via other G-RNTI |
| Dynamic scheduling via G-CS-RNTI |
| Dynamic scheduling via C-RNTI |

**Proposal:**

* **If the downlink assignment is for C-RNTI, and if the previous downlink assignment indicated to the HARQ entity of the same HARQ process was eithe a downlink assignment received for the MAC entity's G-CS-RNTI or G-RNTI or a configured downlink assignment for MBS, or**
* **if the downlink assignment is for G-RNTI, and if the previous downlink assignment indicated to the HARQ entity of the same HARQ process was either a downlink assignment received for the MAC entity's G-CS-RNTI or other G-RNTI or C-RNTI or a configured downlink assignment for MBS or unicast,**
* **consider the NDI to have been toggled regardless of the value of the NDI.**

**Q1: Do companies agree the above proposal?**

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| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | Partially no | PTM initial Tx (G-RNTI) & PTP retransmission (C-RNTI)  -> NDI value should be compared to the previous value.  **If the downlink assignment is for C-RNTI, and if the previous downlink assignment indicated to the HARQ entity of the same HARQ process was eithe a downlink assignment received for the MAC entity's G-CS-RNTI ~~or G-RNTI~~ or a configured downlink assignment for MBS**  We agree the other cases.  [OPPO] yes, but if the network’s intension of C-RNTI is for a unicast new transmission, not for PTM retranmission, how to capture this case?? |
| Ericsson | Yes | The text should simple follow the logic that e.g. when a G-RNTI (PDCCH DCI) is received for a certain HPID (and NDI), the UE consider this to be new data if the most recent reception for this HPID used a RNTI different from the received RNTI.  It is logically impossible to toggle the NDI in a way (comparing) that would satisfy the toggling rule for a group of UEs with different reception success. This issue is not limited to previous reception via C-RNTI. The same conflict may arise when the earlier RNTIs are different G-RNTIs or G-RNTI and C-RNTI combinations. |
| CATT | Partially no | Agree with the Samsung on the PTP HARQ retransmission of the initial PTM transmission case. |
| Nokia | No | Agree with Samsung: if initial transmission is with PTM (G-RNTI) and retransmission with PTP (C-RNTI), then NDI should be followed.  Also, if we allow initial transmission with PTM (G-RNTI) and retransmit that via PTP (C-RNTI) and then retransmit via PTM (G-RNTI), in this case NDI should be followed (and C-RNTI should be removed from second list) |
| Lenovo, Motorola Mobility | Paritially no | Besides the issue indicated by Samsung, the second bullet has the similar issue:  **if the downlink assignment is for G-RNTI, and if the previous downlink assignment indicated to the HARQ entity of the same HARQ process was either a downlink assignment received for the MAC entity's G-CS-RNTI or other G-RNTI ~~or C-RNTI~~ or a configured downlink assignment for MBS or unicast** |
| Qualcomm | Yes but | Except that PTM G-RNTI initial tx and C-RNTI based re-tx. |
| LGE | Yes except G-RNTI -> C-RNTI | Agree with Samung.  With the above proposal, it is not clear how to indicate PTP retransmission (PTP for PTM retransmission). Need to check RAN1 discussion on PTP retransmission. |
| TD Tech, Chengdu TD Tech | Yes |  |
| Fujitsu | Yes | Similar view with Ericsson.  Having said that, is it better to ask RAN1 by LS on NDI handling? |
| MediaTek | Yes but | Except PTM initial transmission and PTP C-RNTI based retransmission |
| vivo | Partially no | Agree with Samsung’s comment. |
| Xiaomi | Yes, but | We agree with MediaTek and Qualcomm that the above proposal is not applicable for PTM initial transmission and PTP C-RNTI based retransmission. |
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## 2.2 MBS SPS

In RAN2#116 meeting, RAN2 make the following agreement. However, it is not clear whether the below agreement is also valid when MBS SPS is used? In rrapporteur’s understanding, the answer is yes.

* one-to-many mapping between G-RNTI and MBS sessions is supported and it is assumed that this does not introduce additional specification work.

**Proposal: one-to-many mapping between G-CS-RNTI and MBS sessions is supported and it is assumed that this does not introduce additional specification work.**

**Q2: Do companies agree the above proposal?**

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| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | Yes | Same as G-RNTI to MBS session mapping |
| Ericsson | Yes |  |
| CATT | Yes |  |
| Nokia | Yes |  |
| Lenovo, Motorola Mobility | Yes |  |
| Qualcomm | Yes |  |
| LGE | Yes |  |
| TD Tech, Chengdu TD Tech | Yes |  |
| Fujitsu | Yes | It was already agreed. |
| MediaTek | Yes |  |
| vivo | Yes | The same logic for mapping between G-RNTI and MBS sessions should be reused for the GC-SPS. |
| Xiaomi | Yes |  |
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In RAN1 meetings, RAN1 made following agreements about SPS. There will be multiple SPS-config for MBS. However, it is not clear the mapping between G-CS-RNTI and SPS-config.

In R16, only one CS-RNTI will be configured for UE to address all SPS and also all CG configuration.

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| Agreement: (RAN1#104)  For RRC\_CONNECTED UEs, more than one SPS group-common PDSCH configuration for MBS can be configured per UE subject to UE capability   * The total number of SPS configurations supported by a UE currently defined for unicast is not increased due to additionally supporting MBS.   Agreement: (RAN1#106)  If a SPS-config for MBS is configured in CFR, one G-CS-RNTI is associated with the SPS-config.   * FFS: Multiple G-CS-RNTIs associated with one SPS-config   Agreement: (RAN1#106bis)  The association between a G-CS-RNTI and a SPS-Config-Multicast is indicated by the activation GC-PDCCH for SPS GC-PDSCH, i.e., a value of the HARQ process number field in a DCI format indicates an activation for a SPS GC-PDSCH configuration for multicast with a same value as provided by *sps-ConfigIndex* in a *SPS-Config-Multicast.* |

Based on RAN1 agreements above, rapporteur made following understanding:

**Rapporteur’s understanding:** There will be multiple MBS SPS-config and there will also be multiple G-CS-RNTI. However, the association between G-CS-RNTI and MBS SPS-config will not be specified in RRC signalling. The DCI scrambled with G-CS-RNTI will indicated which MBS SPS-config will be activated via HARQ process id in this DCI and sps-ConfigIndex in a SPS-Config-Multicast. Then this G-CS-RNTI will be associated with the MBS SPS-config. It is up to network whether support one to multiple or multiple to one maping between G-CS-RNTI and MBS SPS config.

**Q3: Do companies agree the above rapporteur’s understanding? If no, do you agree to send LS to RAN1 for further confirmation?**

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| --- | --- | --- | --- |
| Company | Yes/No?  For understanding | Yes/No?  For LS | Comments |
| OPPO | Yes |  |  |
| Samsung | No |  | We do not agree “It is up to network whether support one to multiple or multiple to one maping between G-CS-RNTI and MBS SPS config.” due to the following FFS points:   * FFS: Multiple G-CS-RNTIs associated with one SPS-config   [OPPO] the latest agreement is in RAN1#106bis. The FFS is not FFS any more in my understanding. |
| Ericsson | comment |  | The FFS does make the question difficult to decide upon. RAN2 should decide what is supported (and why) and then check if RAN1 have concerns. |
| CATT | No |  | Agree with Samsung,we expect there will be a conclusion(either from RAN1 or RAN2) on the mapping between G-CS-RNTI and SPS-config |
| Nokia | No |  | If multiple G-CS-RNTI are mapped to same MBS SPS-config, multiple activations can then refer to the same MBS SPS-config, but how would that work? It would seem more logical to have a single G-CS-RNTI per MBS SPS-config.  If one G-CS-RNTI is mapped to multiple MBS SPS-config, the activation indicates which SPS-config is activated (as was introduced for URLLC earlier). |
| Lenovo, Motorola Mobility | No |  | We tend to agree with CATT and Samsung’s view. |
| Qualcomm | Yes partially |  | Same comment as Samsung. May be we can send LS to RAN1 to clarify this. |
| LGE | No | Yes | It seems that one-to-one mapping and one-to-many mapping seem to be supported, but multiple-to-one mapping is still being discussed in RAN1. We’re ok to send LS to RAN1 for confirmation. |
| TD Tech, Chengdu TD Tech | Comments |  | We think the descriptoni is not clear enough.  We agree that the DCI scrambled with G-CS-RNTI can be used to activate an sps-ConfigIndex in a SPS-Config-Multicast.  More than one G-CS-RNTIs can use a same sps-ConfigIndex in a SPS-Config-Multicast in TDM mode. That is, during the same time interval, an sps-ConfigIndex in a SPS-Config-Multicast can only be activated by one G-CS-RNTI or used by one G-CS-RNTI. When the sps-ConfigIndex is deactivated by the G-CS-RNTI, it can be activated by anothjer G-CS-RNTI.  Furthermore, a G-CS-RNTI can activate different sps-ConfigIndexes if several MBS SPS configurations are applied for the realted MBS session(s) assocated with the G-CS-RNTI.  If “multiple to one maping between G-CS-RNTI and MBS SPS config” is used to indicate that several G-CS-RNTIs can use the same sps-ConfigIndex in a SPS-Config-Multicast in TDM mode as explained above, we think such description is not clear.  If “one to multiple maping between G-CS-RNTI and MBS SPS config” is used to indicate that one G-CS-RNTI can activated different sps-ConfigIndexes in a SPS-Config-Multicast, such description is not clear. |
| Fujitsu | No | Yes | RAN1 can lead this discussion. |
| MediaTek | No | Yes | Agreed with Samsung, multiple to one maping between G-CS-RNTI and MBS SPS config still need discussion from RAN1 |
| vivo | No |  | Agree with Samsung's view that RAN1 has not concluded whether Multiple G-CS-RNTIs associated with one SPS-config is supported or not. |
| Xiaomi | No |  | Agree with the FFS point indicated by Samsung. |
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In RAN1#105 and RAN1#107meeting, RAN1 make following agreements on how to use CS-RNTI for multicast MBS. CS-RNTI will be used in PTP for PTM retransmission when MBS SPS is for PTM transmission and CS-RNTI is also used to deactivate the MBS SPS per UE.

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| Agreement:  For PTP retransmission of SPS group-common PDSCH, CS-RNTI is used for CRC scrambling of PDCCH with the NDI bit set to 1. |
| **Agreement**  For multicast in RRC\_CONNECTED state,   * Only SPS-Config-Multicast(s) configured in CFR for multicast can be activated/deactivated by GC-PDCCH with G-CS-RNTI. * SPS-Config-Multicast(s) configured in CFR for multicast cannot be activated by unicast PDCCH with CS-RNTI, but can be deactivated by unicast PDCCH with CS-RNTI. |

**Q4: Do companies agree to capture the CS-RNTI usage in table, i.e. for PTP for PTM retransmission and MBS SPS deactivation when MBS SPS is configured, for MBS in section 7.1 in MBS MAC running CR?**

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| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | Yes | We do not see any issues in MAC. |
| Ericsson | Yes, comment | How to capture and if best in table can be discussed with running CR. |
| CATT | Yes |  |
| Nokia | ? | For information, deactivation by unicast was justified in RAN1 by having a single UE moving out from PTM.  Is it correct to understand the RAN1 agreement such that a single CS-RNTI is used for PTP retransmissions of all G-CS-RNTIs ? |
| Lenovo, Motorola Mobility | Yes |  |
| Qualcomm | Yes |  |
| LGE | Yes |  |
| TD Tech, Chengdu TD Tech | Yes |  |
| Fujitsu | Yes | The exact TP can be further checked later. |
| MediaTek | Yes |  |
| vivo | Yes |  |
| Xiaomi | Yes |  |
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The CS-RNTI will be used for MBS, e.g. MBS SPS deactivation, PTM retransmission via PTP leg. The next question is what is the UE behaviour when CS-RNTI is not configured for one UE? E.g. there is no requirement to configure CG and/or SPS for unicast for this UE.

**Option 1**: If MBS SPS is configured, the CS-RNTI must be configured.

**Option 2**: If MBS SPS is configured and CS-RNTI is not configured, the retransmission of SPS via PTP is not supported and MBS SPS deactivation via CS-RNTI is not supported.

**Q5: Which option do companies prefer?**

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| Company | Option 1/2? | Comments |
| OPPO | Option 2 | It is simple. MBS SPS and unicast SPS are decoupled. |
| Samsung | Option 2 | Can be up to NW whether to config CS-RNTI |
| Ericsson | Option 2 | The RAN1 agreement leads to deactivation(/activation) only by GC-PDCCH with G-CS-RNTI if CS-RNTI is not configured. |
| CATT | Option 2 | From the network perspective, if retransmission of SPS via PTP is supported, CS-RNTI should be configured. Otherwise, it is simple to apply G-CS-RNTI based retransmission/deactivation. |
| Nokia | Option 2 |  |
| Lenovo, Motorola Mobility | Option 2 |  |
| Qualcomm | Option 2 |  |
| LGE | Option 2 |  |
| TD Tech, Chengdu TD Tech | Option 2 |  |
| Fujitsu | Option 2 | CS-RNTI configuration can be up to NW implementation. |
| MediaTek | Option 2 |  |
| vivo | Option 2 | It is purely an NW implementation issue. |
| Xiaomi | Option 2 |  |
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The CS-RNTI will be used for MBS SPS deactivation and HARQ process id filed in DCI will be indicated which MBS SPS will be deactivated according to the sps-ConfigIndex in a SPS-Config-Multicast. In order to address the target SPS for deactivation, the sps-ConfigIndex should unique between uncast SPS and MBS SPS.

**Q6: Do companies agree that the sps-ConfigIndex should unique in UE no matter the SPS is for unicast or multicast?**

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| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | Yes |  |
| Ericsson | Yes |  |
| CATT | Yes |  |
| Nokia | Yes | Logical consequence of what RAN1 has agreed (see background info for Q4). |
| Lenovo, Motorola Mobility | Yes |  |
| Qualcomm | Yes |  |
| LGE | Yes |  |
| TD Tech, Chengdu TD Tech | Yes |  |
| Fujitsu | Yes |  |
| MediaTek | Yes |  |
| vivo | Yes |  |
| Xiaomi | Yes |  |
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## 2.3 MBS DRX

### 2.3.1 MBS DRX command MAC CE

In MAC running CR for MBS, there is an editor note about DRX command for MBS DRX.

Editor’s note: FFS to support DRX Command MAC CE for MBS DRX.

In rapporteur’s understanding, DRX command MAC CE can make UE enter DRX more quickly to achieve more power saving for UE.

In R16, dual DRX is introduced for unicast and common DRX command will be applied to two DRX. In MBS, the multiple DRX are configured per G-RNTI except unicast DRX. It is clear whether apply DRX command and how to apply DRX command.

**Option 1**: Any DRX command MAC CE will not impact MBS DRX.

**Option 2**: legacy DRX command MAC CE will also be used for MBS DRX.

**Option 3.1:** MBS specific DRX command MAC CE is defind, and the MBS specific DRX command MAC CE is common for all MBS DRX associated different G-RNTI, and one new LCID is defined to identify the MBS spefic DRX command MAC CE.

**Option 3.2:** MBS specific DRX command MAC CE is defind, and the MBS specific DRX command MAC CE is common for all MBS DRX associated different G-RNTI, and R bit in MAC subheader for DRX command MAC CE is used to indicate the DRX command MAC CE is for MBS or unicast.

**Option 4:** MBS specific DRX command MAC CE is defind per G-RNTI, i.e. if the PDCCH for TB including DRX command MAC CE is scrambled by a G-RNTI, the DRX command MAC CE is for MBS DRX corresponding to this G-RNTI.

**Q7: Which option do companies prefer?**

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| Company | Option 1/2? | Comments |
| OPPO | Option 3.2,  Option 4 is acceptable | First, DRX command MAC CE should be supported for MBS.  At least, the DRX command MAC CE should be separate from unicast DRX command MAC CE.  Both option 3.2 and option 4 can be agreed for different purpose. |
| Samsung | Option 1 | In MBS with multiple MBS flows, MAC CE-based immediate sleep is not so beneficial but complicated. Also, it is not clear how gNB deduces the exact data arrival time. |
| Ericsson | Option 4 | As activity is service specific, and G-RNTI maps to a MRB or set of MRBs reflecting this activity (qos etc), it seems natural to have a possible MAC-CE DRX command per G-RNTI. Text for 3.x is somewhat difficult to follow, but seems also 3.2 is ok..  Better proposal would be to state e.g.:  When the UE receives a DRX command MAC CE with DCI scrambled with G-RNTI then the UE stops drx-onDurationTimerPTM and drx-InactivityTimerPTM timer for that G-RNTI. |
| CATT | Option 1 | We think the benefits may be marginal considering there are multiple DRX configurations for MBS. |
| Nokia | Option 1  Option 2+4 | Option 1 if short DRX is not agreed.  Option 2+4 otherwise (similarly as Ericsson) |
| Lenovo, Motorola Mobility | Option 1 |  |
| Qualcomm |  | Same view as Ericsson.  DRX command MAC-CE for Multicat DRX has to be per G-RNTI based.  We prefer a new LCID specified for MBS DRX command MAC-CE. |
| LGE | Option 1 | The gain of MBS DRX command MAC CE seems not much. UEs in a multicast group are in different reception condition and it is not guaranteed for each UE to successfully receive MBS DRX command MAC CE and power saving gain is not guaranteed for all UEs of the multicast group. |
| TD Tech, Chengdu TD Tech | Option 4 | We think the DRX mode is configured per G-RNTI. Different G-RNTIs generally have different DRX modes.  MAC CE can be used to update the DRX mode per G-RNTI.  A new MAC CE can be used for the update of the DRX mode for a G-RNTI.  We think the new MAC CE can be used to send the new parametgers of a new DRX mode associated with a G-RNTI.  Just to use a new MAC CE for the start/stop of a DRX mode associated with a G-RNTI is not enough. |
| Fujitsu | Option 1 > Option 4 | Our preferene is Option 1. If some new mechanism is neede, our preference is Option 4. |
| MediaTek | Option 3.2 | Prefer option 3.2 and it is up to network implememtation to indicate DRX command MAC CE if UE join multiple MBS sessions |
| vivo | Option 4 | We share the same view with OPPO that DRX Command MAC CE should be supported for MBS.  As different MBSs may have different characteristics of data transmission, it is reasonable to apply common DRX command MAC CE per G-RNTI. |
| Xiaomi | Option 3.1, 3.2, 4 | We slightly prefer Option 4, but also ok with Option 3.1 or 3.2. |
| SJTU | Option 4 | Considering the different traffic pattens between unicast services and multicast services, new DRX command MAC CE for multicast DRX operations independent of lagency DRX command MAC CE for unicast DRX operation should be introduced.  Futhermore, new DRX command MAC CE can be introduced per multicast DRX operation (i.e. per G-RNTI basis), considering the different traffic pattens between different multicast services. |
| NERCDTV | Option 4 | Considering that different multicast services may go to sleep at different times due to the different traffic pattens between different multicast services, new DRX command MAC CE should be introduced per G-RNTI basis.  And also, as it has been agreed that multicast DRX pattern is configured on a per G-RNTI basis, it is reasonable to use different Multicast DRX Commond MAC-CE for different Multicast services. |
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### 2.3.2 Short DRX

In MAC running CR for MBS, there is an editor note about short DRX for MBS DRX.

Editor’s note: FFS to support short DRX for MBS.

**Q8: Do companies agree to support short DRX for MBS, and please input the comments?**

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| Company | Yes/No? | Comments |
| OPPO | No, | In our understanding, there is no problem to support short DRX for multicast MBS DRX but it will introduce complexity in MBS DRX operation.  MBS service is not delay sensitive service as URLLC. So no need to use short DRX especially in R17.  If RAN2 cannot reach the consensus for short DRX, RAN2 should send LS to SA2 for confirmation. |
| Samsung | No | Short DRX cycle may also have a mismatch problem among multiple UEs. We do not prefer to have such complexity. |
| Ericsson | Yes | The main use case for Short DRX is that can be used for voice during a talk burst (should be common in public safety), while long DRX is used during silence periods. If some UEs in the PTM group are in short DRX while others are in long DRX, then all UEs in the group anyway wake-up at the same time, but some wake-up more frequent then others. Support for Short DRX cycle is optional with explicit UE capability signalling for unicast in NR and can also be reused for MBS. |
| CATT | No | We think there is no great benefits to support short DRX in MBS. |
| Nokia | Yes | Agree with Ericsson, this is needed for public safety. No need to involve SA2, the characteristics of voice services are well known. |
| Lenovo, Motorola Mobility | No | Introducing short DRX cycles to PTM may cause mismatch between different UEs of a group in case some UEs may fail to decode PTM scheduling and not start inactivity timer and keep using long DRX cycle, while other UE starts inactivity timer and goes to short DRX cycle, and this would cause more problems. |
| Qualcomm | Yes | Agree with Ericsson and Nokia specified use case. All Multicat UEs can support short DRX and it is upto NW whether to configure or not based on type of application used. |
| LGE | No | Short DRX cycle is considered for more power saving gain. However, reception performance may decrease further, particularly, for a UE of a multicast group who is in relatively poor channel condition. So, it seems difficult to generally apply short DRX cycle to multicast scenarios. In addition, compared to unicast traffic, we think that multicat traffic is supported well using long DRX cycle. |
| TD Tech, Chengdu TD Tech | Yes | No strong tendency |
| Fujitsu | Yes | Short DRX configuration can be up to NW implementation. |
| MediaTek | Yes | It can be optional for multicast DRX and up to NW to configure the DRX pattern according to different MBS service type |
| vivo | No | The short cycle DRX mechanism will make UE dynamically switch between long DRX cycle and short DRX cycle, which results in complicated UE behavior. Moreover, if some UEs fail to receive the PDCCH, it will result in the misalignment of DRX Active time between UEs, which does not facilitate the MBS scheduling. |
| Xiaomi |  | We have no strong view. Maybe this can be left to the gNB configuration. |
| SJTU | Yes | It’s useful for some use cases. Since Short DRX is optional, it is up to NW to configure it or not. |
| NERCDTV | Yes | Short DRX can be configured up to NW implementation. |
|  |  |  |

### 2.3.3 DRX operation in PTP for PTM retransmission case

In RAN1#104 meeting, the following agreement is made and it means:

PTM transmission + PTM retransmission 🡺 for same TB, same HARQ process id and NDI

PTM transmission +PTP retransmission 🡺 for same TB, same HARQ process id and NDI

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| Agreement:  The same HARQ process ID and NDI are used for PTM scheme 1 (re)transmissions and PTP retransmissions of the same TB.  Conclusion:  The maximum number of HARQ processes per cell, currently supported for unicast, is kept unchanged for UE to support multicast reception.  How to allocate HARQ processes between unicast and multicast is up to gNB. |

However, it is not clear whether the PTP for PTM retransmission is configured in RRC signalling or can be changed dynamically, e.g. in DCI.

**Option 1**: PTP for PTM retransmission is configured in RRC signalling per G-RNTI.

**Option 2**: PTM retransmission, i.e. via PTM or PTP, can be changed per TB or per TB per transmission.

Option 1 is simple, but RAN1 did not conclude the configuration in RRC for option 1 and this is not discussed in RAN1 yet. It is also not clear whether PTP for PTM retransmission is mandatory for UE who support multicast or it is optional even if the UE support multicast.

**Q9: Which option do companies prefer? If option 1 is chosen, please comment whether the LS to RAN1 is required?**

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| --- | --- | --- |
| Company | Option 1/2? | Comments |
| OPPO | Option 2 | RAN1 did not conclude such RRC signalling for PTP for PTM retransmission. |
| Samsung | Option 1 | Option 1 is simple as the rapporteur mentioned. This is what RAN2 can decide. |
| Ericsson | Option 2 | One could consider on/off signaling by RRC, but do not think that is needed. If the functionality for handling HARQ operation modes and retransmission rely on RRC, the system becomes very inefficient and slow. |
| CATT | Option 2 | PTP for PTM retransmission should only be a RAN1 dynamic scheduling decision. |
| Nokia | Option 2 | No need to restrict the usefulness of PTP; and not sure why this should be discussed in RAN1. |
| Lenovo, Motorola Mobility |  | We would prefer to check with RAN1 firstly. |
| Qualcomm | Option 2 |  |
| LGE | Option 1 | With option 1, UE is explicitly indicated if C-RNTI is used for retransmission(s) of PTM initial transmission. UE may use PTP/unicast DRX for reception of the the retransmissions. With option 2, UE needs to monitor both G-RNTI and C-RNTI for reception of the retransmissions. We slightly prefer option 1. It does not seem necessary to send LS to RAN1. |
| TD Tech, Chengdu TD Tech | Option 2 |  |
| Fujitsu | None | This can be discussed directly in RAN1. Then RAN2 can just wait. |
| MediaTek | Option 2 |  |
| vivo | Option 2 |  |
| Xiaomi | Option 2 |  |
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In RAN2#116 meeting, the following FFS are left and the following FFS is based on above option 1.

* [050] FFS how UE monitors UE specific PDCCH/C-RNTI for possible PTP transmission for PTM HARQ retransmission in active time of multicast DRX, the following alternatives are on the table (one to be selected):

Option 2: the UE monitors UE specific PDCCH/C-RNTI only when drx-RetransmissionTimerDLPTM is running and PTP retransmission is expected.

Option 3: the UE monitors UE specific PDCCH/C-RNTI only during unicast DRX’s active time. Unicast DRX’s RTT timer can be started when PTP retransmission is expected.

In PTP for PTM retransmission case, the UE will receive PTM via PTM leg scheduled in DCI scrambled with G-RNTI and receive PTM retransmission via PTP leg scheduled in DCI scrambled with C-RNTI if NACK.

In PTP for PTM retransmission case, if option 1 is chosen, there are 3 options to fix this issue:

**Option 1**: The per G-RNTI DRX is not configured if PTP for PTM retransmission is configured in RRC, and both PTM reception and PTP reception are controlled by unicast DRX.

**Option 2**: The per G-RNTI DRX is configured if PTP for PTM retransmission is configured in RRC and parameter *drx-RetransmissionTimerDLPTM* is also configured, and the UE monitors UE specific PDCCH/C-RNTI only when drx-RetransmissionTimerDLPTM is running and PTP retransmission is expected.

**Option 3**: The per G-RNTI DRX is configured if PTP for PTM retransmission is configured in RRC and parameter *drx-RetransmissionTimerDLPTM* is not configured, and the UE monitors UE specific PDCCH/C-RNTI only during unicast DRX’s active time. Unicast DRX’s RTT timer can be started when PTP retransmission is expected.

**Option 4:** The per G-RNTI DRX is configured if PTP for PTM retransmission is configured in RRC and parameter *drx-RetransmissionTimerDLPTM* is not configured, it is up to network to schedule PTP for PTM retransmission in active time of unicast DRX.

**Q10: Which option do companies prefer if PTP for PTM retransmission is configured in RRC signalling per G-RNTI?**

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| --- | --- | --- |
| Company | Option 1/2/3/4? | Comments |
| OPPO | Option 4 | For option 1, there is only unicast DRX for both unicast reception and PTM reception. For option 2, UE will monitor UE specific PDCCH/C-RNTI when drx-RetransmissionTimerDLPTM is running. For option 3, PTM NACK will impact unicast DRX, i.e. drx-RetransmissionTimerDL.  For simplicity, we prefer option 4 and ensure the MBS DRX is independent from unicast DRX. So drx-HARQ-RTT-TimerDLPTM and drx-RetransmissionTimerDLPTM are not useful any more for MBS DRX. The multicast DRX operation in PTM leg is similar as broadcast DRX. Furthermore, RAN2 once agreed that MBS DRX operation is independent from unicast DRX. |
| Samsung | Option 3 but | We do not see any problem on “PTM NACK will impact unicast DRX, i.e. drx-RetransmissionTimerDL.” If a retransmission is expected, the corresponding RTT timer should be started.  We are wondering why we do not start the discussion based on original Option 2 and Option 3   * [050] FFS how UE monitors UE specific PDCCH/C-RNTI for possible PTP transmission for PTM HARQ retransmission in active time of multicast DRX, the following alternatives are on the table (one to be selected):   Option 2: the UE monitors UE specific PDCCH/C-RNTI only when drx-RetransmissionTimerDLPTM is running and PTP retransmission is expected.  Option 3: the UE monitors UE specific PDCCH/C-RNTI only during unicast DRX’s active time. Unicast DRX’s RTT timer can be started when PTP retransmission is expected.  Samsung supported original Option 3 above. We think in the new options, the scope is reduced or distorted by limiting conditions such as “PTP for PTM retransmission is configured in RRC” and parameter *drx-RetransmissionTimerDLPTM* is not configured” We think it would be better to select one of original two options. |
| Ericsson | Comment | Agree with Samsung. Unicast DRX is independent, but the UE should monitor for PTP retransmissions when expected (based on HARQ etc). So original Option 2, 3 seems ok.  The listed options are just to convoluted to be agreed as is. |
| CATT | None | See comments to Q9 |
| Nokia | - | Agree with Samsung and Ericsson. The configuration of per G-RNTI DRX should not be subject of PTP for PTM retransmission. DRX for G-RNTI can be configured even if PTP retransmissions are not used/configured.  Our preference is to go with option 3 from the last meeting, assuming that unicast DRX RTT timer starts when PTM transmission fails, i.e., start both PTM and unicast RTT timers simultaneously and when they expire (possibly at different times), they start the corresponding DRX retransmission timers which defines the actual active time. |
| Lenovo, Motorola Mobility | Comments | We share the same view with Samsung. According to the agreement, we need downselect one of the following options:   * [050] FFS how UE monitors UE specific PDCCH/C-RNTI for possible PTP transmission for PTM HARQ retransmission in active time of multicast DRX, the following alternatives are on the table (one to be selected):   Option 2: the UE monitors UE specific PDCCH/C-RNTI only when drx-RetransmissionTimerDLPTM is running and PTP retransmission is expected.  Option 3: the UE monitors UE specific PDCCH/C-RNTI only during unicast DRX’s active time. Unicast DRX’s RTT timer can be started when PTP retransmission is expected.  We would prefer the original option 3. |
| Qualcomm | comments | Agree with Samsung views.  We support original **“Option 3: the UE monitors UE specific PDCCH/C-RNTI only during unicast DRX’s active time. Unicast DRX’s RTT timer can be started when PTP retransmission is expected”.**  In this option 3, bothdrx-RetransmissionTimerDLPTM and drx-RetransmissionTimerDLPTP will be configured for UE.  drx-RetransmissionTimerDLPTP can be reused from unicast DRX as one option or network can also configure drx-RetransmissionTimerDLPTP explicitly as part of MBR DRX configuration.  UE start drx-RetransmissionTimerDLPTP only when C-RNTI based re-tx expected.  drx-RetransmissionTimerDLPTM is always configured and started by UE for monitoring PTM based re-tx. |
| LGE | Option 3 | We agree to what Samsung pointed out: why we do not start the discussion based on original Option 2 and Option 3. We support the original option 3.  Focusing on Q10, the difference of option 3 from option 4 is that PTP/unicast DRX RTT timer starts when PTP retransmission is expected. However, with option 4, gNB should schedule PTP retransmission only when UE becomes active time by unicast DRX. Then, there will be retransmission latency issue with option 4. |
| TD Tech, Chengdu TD Tech | None | We don’t support the PTP for the PTM retransmission is configured by RRC signalling. |
| Fujitsu | None | This can be discussed directly in RAN1. Then RAN2 can just wait. |
| MediaTek |  | See answer to Q9 |
| vivo | Option 2 | Regrading to the support of PTP retransmission for initial PTM transmission, RAN2 has agreed to discuss and select between option 2 and option 3 in the last meeting. Our view is that option 1 and option 4 are already ruled out.  The difference between option 2 and option 3 is whether UE needs to additionally start the unicast Retransmission timer or not. Obviously, Option 3 relies on the configuration of the unicast retransmission timer provided by NW while option 2 does not require it. From the view of the flexibility of NW configuration, Option 2 is preferred. |
| Xiaomi | None |  |
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If PTM retransmission, i.e. via PTM or PTP, can be changed per TB or per TB per transmission and it is up to gNB to decide, i.e. option 2 is chosen. The UE will not know the PTM transmission is from PTM leg or PTP leg. So the gNB will monitor G-RNTI and C-RNTI. So the MBS DRX configuration should include drx-onDurationTimerPTM, drx-InactivityTimerPTM, drx-LongCycleStartOffsetPTM, drx-SlotOffsetPTM and also drx-HARQ-RTT-TimerDLPTM and drx-RetransmissionTimerDLPTM.

The MBS DRX operation will be same as PTM for PTM retransmission becaue the UE will not know whether there is PTM retranmission or not next. For PTP reception for PTM retransmission, it is also not foreseeable.

**Q11: Which option do companies prefer in above question if PTM retransmission, i.e. via PTM or PTP, can be changed per TB or per TB per transmission?**

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| --- | --- | --- |
| Company | Option 1/2/3/4? | Comments |
| OPPO | Option 4 | For option 1, there is only unicast DRX for both unicast reception and PTM reception. For option 2, UE will monitor UE specific PDCCH/C-RNTI when drx-RetransmissionTimerDLPTM is running. For option 3, PTM NACK will impact unicast DRX, i.e. drx-RetransmissionTimerDL.  For simplicity, we prefer option 4 and ensure the MBS DRX is independent from unicast DRX. So drx-HARQ-RTT-TimerDLPTM and drx-RetransmissionTimerDLPTM are not useful any more for MBS DRX. The multicast DRX operation in PTM leg is similar as broadcast DRX. Furthermore, RAN2 once agreed that MBS DRX operation is independent from unicast DRX. |
| Samsung | Option 3 but | We prefer to decouple unicast DRX and MBS DRX as much as possible. RNTI monitoring is allowed during that RNTI’s Active Time  - UE monitors UE-specific PDCCH by using C-RNTI during unicast DRX Active Time  - UE monitors group-common PDCCH by using G-RNTI during MBS DRX Active Time for the G-RNTI  We think Option 3 is the closest. |
| Ericsson | Comment | See previous input for Q9-10 |
| CATT |  | The UE monitors UE specific PDCCH/C-RNTI only when drx-RetransmissionTimerDLPTM(i.e. the option 2 from last meeting) |
| Nokia | - | See answer to Q10 |
| Lenovo, Motorola Mobility |  | See comments to Q10. |
| Qualcomm | Comment | Same as Q10 comment. |
| LGE | Option 3 | For the above 4 options, it is not clear how to receive retransmissions via PTM. Focusing on PTP retransmission, with option 3 a UE monitors UE specific PDCCH/C-RNTI during unicast DRX’s active time. Unicast DRX’s RTT timer can be started when PTP retransmission is expected. It is also possible that in parallel the UE monitors group common PDCCH/G-RNTI during multicast DRX’s active time if necessary. Multicast DRX’s RTT timer can be started when PTM retransmission is expected. |
| TD Tech, Chengdu TD Tech | Option 2 |  |
| Fujitsu | None | This can be discussed directly in RAN1. Then RAN2 can just wait. |
| MediaTek | Option 2 | We slightly prefer option2.  For option3, It may be difficult to aligned the retx timer with unicast DRX |
| vivo | Option 2 | Same answer as Q10. |
| Xiaomi |  | No strong preference, but we would like to decouple unicast DRX and MBS DRX as much as possible. |
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### 2.3.4 DRX operation in NACK only case

In RAN2#116 meeting, RAN2 made following agreement for DRX operation in NACK only case.

* [050] For group common PTM Multicast HARQ PUCCH resources (NACK only feedback), the same group of UEs have aligned HRAQ RTT and DL Re-Tx timer configuration. HARQ RTT timer counting starts from end of common PUCCH resource based NACK transmission (i.e. same as Unicast DRX behaviour). FFS for case of disabled HARQ FB.

However, this agreement is not captured in MBS MAC running CR because different companies have different understanding.

RAN1 agreed that if NACK only based HARQ feedback is configured but PUCCH resource for NACK only is not configured, then PUCCH resource for unicast is used for NACK only based HARQ feedback.

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| Agreement:  For UE supporting both ACK/NACK based and NACK-only basedfeedback for multicast, for the same G-RNTI, support the following   * UE can be configured with either ACK/NACK based or NACK-only feedback for a single G-RNTI.   + Note: Case1-1: if configured with ACK/NACK based feedback, UE can be optionally configured a separate *PUCCH-Config/PUCCH-ConfigurationList* for multicast. Otherwise, *PUCCH-Config/PUCCH-ConfigurationList* for unicast applies (This has been agreed.)   + Case 1-2: if configured with NACK-only based feedback, when separate *PUCCH-Config/PUCCH-ConfigurationList* for NACK-onlyis not configured, *PUCCH-Config/PUCCH-ConfigurationList* for unicast applies. |

No matter it is NACK only based HARQ feedback or ACK/NACK based HARQ feedback, if there is real HARQ feedback transmission, it is same and the RTT timer will be started in the first symbol after the end of the corresponding transmission carrying the DL multicast HARQ feedback.

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| 2> if the PDCCH indicates a DL multicast transmission:  3> start the *drx-HARQ-RTT-Timer-DL-PTM* for the corresponding multicast HARQ process in the first symbol after the end of the corresponding transmission carrying the DL multicast HARQ feedback. |

If there is no real HARQ feedback transmission due to ACK, it is not clear whether to start RTT timer and what is the time point to start.

In unicast DRX, no matter the HARQ feedback is ACK or NACK, the UE will start the DRX RTT timer for power saving purpose in DRX RTT timer running period. If the MAC PDU is not decoded successfully, the DRX retransmission timer will be started after DRX RTT timer expiries, otherwise, the DRX retransmission timer will be not started.

In MBS reception, if NACK only based HARQ feedback is configured, the ACK UE does not know if there is other UE feedback NACK and the ACK UE also does not know whether the next transmission in this HARQ process is new transmission or retransmission. No matter the next transmission is new transmission or retransmission, the UE does not need to monitor the PDCCH in the RTT timer period for UE power saving purpose. After DRX RTT timer expiries, the UE can start DRX retransmission timer to receive the new transmission or retransmission. Some companies may think no need to start DRX retransmission timer because there is no need to receive retransmission due to ACK. However, if the UE does not start RTT timer, the UE may keep active and results in power consumption during RTT running period.

**Option 1**: If there is no real HARQ feedback transmission due to ACK in NACK only case, the UE will not start DRX RTT timer.

**Option 2**: If there is no real HARQ feedback transmission due to ACK in NACK only case, the UE start the DRX RTT timer in the first symbol after the end of the corresponding PUCCH resource for NACK only feedback (the PUCCH resource can be NACK only PUCCH resource if configured or unicast PUCCH resource if PUCCH resource for NACK only based HARQ feedback is not configured).

**Q12: Which option do companies support if there is no real HARQ feedback transmission due to ACK in NACK only case?**

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| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Option 2 | If the UE does not start RTT timer due to ACK in NACK only case, the UE may keep active and results in power consumption during RTT running period. |
| Samsung | Option 1 | Option 1 is the same as unicast. There is no need to start the HARQ RTT timer, because DRX Retransmission Timer will not be started. |
| Ericsson | Option 1 | Agree with Samsung. Very unclear what the resulting proposal of specification text into MAC would be if not, especially for Option 2. |
| CATT | Option 1 | We understand it is obvious that RTT timer should not be started if the PDSCH data is decoded correctly. |
| Nokia | - | Not sure why HARQ RTT timer should be started when UE successfully decoded the TB since DRXRetransmission timer is not started in that case. Do not understand the rapporteurs comments on starting RTT timer for power saving: in our understanding if onDuration or inactivity timer is running, UE monitors even if RTT timer were started.  Finally, what would be the difference between options 1 and 2 from a networks’ perspective? |
| Lenovo, Motorola Mobility | Option 1 |  |
| Qualcomm | Option 2 | From MAC spec:  When DRX is configured, the MAC entity shall:   1. if a MAC PDU is received in a configured downlink assignment:   2> start the drx-HARQ-RTT-TimerDL for the corresponding HARQ process in the first symbol after the end of the corresponding transmission carrying the DL HARQ feedback;   1. stop the drx-RetransmissionTimerDL for the corresponding HARQ process. 2. if a drx-HARQ-RTT-TimerDL expires: 3. if the data of the corresponding HARQ process was not successfully decoded: 4. start the drx-RetransmissionTimerDL for the corresponding HARQ process in the first symbol after the expiry of drx-HARQ-RTT-TimerDL.   Our interpretation is, In unicast DRX, UE starts RTT timer when MAC PDU is received independent of ACK or NACK.  If NACK then drx-HARQ-RTT-TimerDL timer will be started.  Same philosophy can be followed for MBS DRX as well. i.e In case of no actual HARQ feedback due to ACK in NACK only case, UE can start RTT timer and if MAC PDU is not successfully decoded then UE can start Re-Transmission timers for PTM and PTP separately. |
| LGE | Option 1 | UE does not need to start DRX RTT timer because DRX Retx timer does not need to start at DRX RTT timer expiry if ACK. |
| TD Tech, Chengdu TD Tech |  | If option 1 is selected, it’s up to gNB implementation to ensure that the inactivity timer is configured big enough to cover the case that some UEs decoded wrongly and some UEs decode correctly for the same TB.  If option 2 is selected, there’s no limitation on the configuration value of the inactivity timer. |
| Fujitsu | Option 1 | No need to starte the timer. |
| MediaTek | Option 2 | Agree with Qualcomm. Op2 has less power consumption and there is no need for UE to keep active if MAC PDU is decoded successfully. |
| vivo | Option 1 | If UE has decoded the MAC PDU successfully, it is not expected to receive redundant retransmission. Thus, it is logical that the HARQ RTT timer and Retransmission timer are not started. |
| Xiaomi | Option 1 |  |
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After DRX RTT timer expiries, whether to start DRX retranmission timer?

**Option 1:** After DRX RTT timer expiries, UE will not start DRX retranmission timer if the corresponding MAC PDU is decoded sucessfully?

**Option 2:** After DRX RTT timer expiries, no matter the MAC PDU is decoded successfully or not, the UE will start DRX retransmission timer, if the HARQ process id and NDI indicate it is a retransmission, the UE can ignore the DCI.

**Q13: Which option do companies support whether to start DRX retranmission timer after DRX RTT timer expiries?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Option 2 | In MBS reception, if NACK only based HARQ feedback is configured, the ACK UE does not know if there is other UE feedback NACK and the ACK UE also does not know whether the next transmission in this HARQ process is new transmission or retransmission. |
| Samsung | Option 1 | Option 1 is the same as unicast. There is no reason to start the Retransmission Timer in case of the successful reception. We do not see any reason to change the unicast behaviour. |
| Ericsson | Option 1 | Agree w Samsung |
| CATT | Option 1 | Follow the same principle as unicast |
| Nokia | Option 1 | Same as unicast. |
| Lenovo, Motorola Mobility | Option 1 |  |
| Qualcomm | Option 1 | Agree with Samsung. |
| LGE | Option 1 | In other words, UE starts DRX ReTx timer if decoding is not successful. |
| TD Tech, Chengdu TD Tech |  | If option 1 is selected, it’s up to gNB implementation to ensure that the inactivity timer is configured big enough to cover the case that some UEs decoded wrongly, some UEs decode correctly and gNB schedule the retransmission over PTP/PTM.  If option 2 is selected, there’s no limitation on the configuration value of the inactivity timer. |
| Fujitsu | Option 1 |  |
| MediaTek | Option 1 |  |
| vivo | Comments | As mentioned in Q12, UE will not start the HARQ RTT timer and Retransmission timer if UE decodes the MAC PDU successfully. |
| Xiaomi | Option 1 |  |
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In RAN1#106 bis, RAN1 made following agreement. UE will Transform NACK-only into ACK/NACK HARQ bits if more than one NACK-only based feedback are available for transmission in the same PUCCH slot and use UE specific PUCCH resource.

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| Agreement:  When more than one NACK-only based feedback are available for transmission in the same PUCCH slot, further decide based on the following subset of alternatives (from previous agreement) with potential further down-selection:   * Alt1: Support UE multiplexing the HARQ-ACK bits by transforming NACK-only into ACK/NACK HARQ bits. |

In my understanding, there will be real HARQ feedback transmission no matter the HARQ feedback is ACK or NACK, so the legacy behaviour can be followed and no spec impact.

**Q14: Do commanies agree that there is no spec impact when more than one NACK-only based feedback are available for transmission in the same PUCCH slot, UE will transform NACK-only into ACK/NACK HARQ bits.**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | Yes |  |
| Ericsson | Yes |  |
| CATT | Yes |  |
| Nokia | Yes | This should remain transparent to 38.321 and can be left to RAN1. |
| Lenovo, Motorola Mobility | Yes |  |
| Qualcomm | Yes |  |
| LGE | Yes | It seems no RAN2 spec. impact. |
| TD Tech, Chengdu TD Tech | Yes |  |
| Fujitsu | Yes |  |
| MediaTek | Yes |  |
| vivo | Yes |  |
| Xiaomi | Yes |  |
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### 2.3.5 DRX operation for HARQ disable case

In RAN1#106bis, RAN1 made following agreement. It means that the HARQ enabling/disabling indication can be indicated in RRC signalling or DCI.

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| Agreement:  If the group-common DCI indicating the enabling/disabling ACK/NACK based HARQ-ACK feedback is not configured, enabling/disabling ACK/NACK based HARQ-ACK feedback is configured per G-RNTI by UE RRC signalling. |

In RAN1#107, RAN1 made following agreement. It means that HARQ enabling/disabling can be changed in each PTM (re)transmission.

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| **Agreement**   * For PTM retransmission,   + if UE is configured to enable/disable HARQ-ACK per group-common DCI indication for initial transmission, whether HARQ-ACK is enabled/disabled for PTM retransmission also follows the indication in the group-common DCI scheduling the PTM retransmission.   + if UE is configured directly whether the HARQ-ACK is enabled/disabled, it applies to both PTM initial transmission and retransmission. * For PTP retransmission, the HARQ-ACK is always enabled. |

If the HARQ is disable for PTM leg via RRC signalling, it means there is no HARQ feedback and no PTM retransmission in PTM leg. So the *drx-HARQ-RTT-TimerDLPTM* and *drx-RetransmissionTimerDLPTM* are not useful any more for MBS DRX. The multicast DRX operation in PTM leg is similar as broadcast DRX.

**Proposal: For ACK/NACK based HARQ feedback, if RRC based HARQ disable/enable is configured in RRC signalling, the MBS DRX configuration for PTM leg only includes *drx-onDurationTimerPTM*, *drx-InactivityTimerPTM*, *drx-LongCycleStartOffsetPTM*, *drx-SlotOffsetPTM*. The multicast DRX operation in this case is similar as broadcast MBS.**

**Q15: Do companies agree the above proposal for HARQ ACK/NACK based feedback?**

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| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | No | Even if HARQ feedback is disabled for a UE, gNB can retransmit the data for other UEs or perform blind retransmission. In this case, UE should be able to receive the retransmission. Especially, cell-edge or poor-coverage UEs without HARQ FB can be benefited.  [OPPO] the key point is how to handle the DRX? |
| Ericsson | No | Agree with Samsung |
| CATT | No | Agree with Samsung |
| Nokia | No | Agree with Samsung. Disabling HARQ feedback for some UEs does not mean disabling HARQ altogether for those UEs, nor disabling HARQ and HARQ feedback for all other UEs. |
| Lenovo, Motorola Mobility | No | Agree with Samsung |
| Qualcomm | Yes | There was similar discussion in NR NTN as well. When HARQ feedback is disabled, in NTN case, UE does not start RTT timer. We prefer to follow same. |
| LGE | No | The proposal is unclear to me. I think that if RRC based HARQ disable/enable is configured and HARQ is configured to be disabled, the MBS DRX configuration only includes drx-onDurationTimerPTM, drx-InactivityTimerPTM, drx-LongCycleStartOffsetPTM, drx-SlotOffsetPTM.  For a UE with HARQ FB disabled, regarding reception of retransmissions, it is up to UE implementation. It does not need to be specified in DRX operation. DRX operation specifies when UE should monitor. It does not prohit monitoring outside the active time. |
| TD Tech, Chengdu TD Tech | No |  |
| Fujitsu | No | Do you mean the case when “HARQ is disable”? |
| MediaTek | No | Agree with Samsung |
| vivo | No | Agree with Samsung. |
| Xiaomi | No | Agree with Samsung. |
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If the HARQ is disable for PTM leg via DCI, the *drx-HARQ-RTT-TimerDLPTM* and *drx-RetransmissionTimerDLPTM* are useful. When HARQ is disable in DCI, there is no HARQ feedback and also no retransmission, so no need to start the *drx-HARQ-RTT-TimerDLPTM* and *drx-RetransmissionTimerDLPTM* timer and should be stopped if running. When HARQ is enable in DCI, there is HARQ feedback and also retransmission, so need to start the *drx-HARQ-RTT-TimerDLPTM* and *drx-RetransmissionTimerDLPTM* timer as legacy behaviour.

**Proposal: For ACK/NACK based HARQ feedback, if DCI based HARQ disable/enable is controlled in DCI, the MBS DRX configuration for PTM leg includes *drx-HARQ-RTT-TimerDLPTM* and *drx-RetransmissionTimerDLPTM and also drx-onDurationTimerPTM*, *drx-InactivityTimerPTM*, *drx-LongCycleStartOffsetPTM*, *drx-SlotOffsetPTM*. When HARQ is disable in DCI, do not start the *drx-HARQ-RTT-TimerDLPTM* and *drx-RetransmissionTimerDLPTM* timer and stop the two timers if running.**

**Q16: Do companies agree the above proposal for HARQ ACK/NACK based feedback?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | No | Even if HARQ feedback is disabled for a UE, gNB can retransmit the data for other UEs or perform blind retransmission. In this case, UE should be able to receive the retransmission. Especially, cell-edge or poor-coverage UEs without HARQ FB can be benefited. |
| Ericsson | No | Again, agree with Samsung |
| CATT | No | Agree with Samsung |
| Nokia | No | Agree with Samsung. Disabling HARQ feedback for some UEs does not mean disabling HARQ altogether for those UEs, nor disabling HARQ and HARQ feedback for all other UEs. |
| Lenovo, Motorola Mobility | No |  |
| Qualcomm | Yes |  |
| LGE | Yes | For a UE with HARQ FB disabled, regarding reception of retransmissions, it is up to UE implementation. It does not need to be specified in DRX operation. DRX operation specifies when UE should monitor. It does not prohit monitoring outside the active time. |
| TD Tech, Chengdu TD Tech | No | Reason: There’s the case that the DCI format is used to diable/enaible the HARQ feedback for some UEs and the HARQ feedback is enabled by RRC signalling for some other UEs. |
| Fujitsu | No | Similar view with Samsung and TD Tech, Chengdu TD Tech. |
| MediaTek | No | See previous question. |
| vivo | No | Agree with Samsung. |
| Xiaomi | No | Agree with Samsung. |
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In RAN1#107 meeting, RAN1 make the following agreement for NACK only based HARQ feedback.

|  |
| --- |
| **Agreement**  Support enabling/disabling HARQ-ACK for NACK-only based feedback.   * The relevant agreements made for ACK/NACK based feedback can be extended for the support of NACK-only, including:   + RRC signalling configures the presence of the field “enabling/disabling HARQ-ACK feedback indication” in the group-common DCI and the configuration is per G-RNTI.   + RRC signalling configures directly whether the HARQ-ACK feedback is enabled or disabled and the configuration is per G-RNTI. |

For the same reason as ACK/NACK based HARQ feedback, the following proposal is for HARQ enable/disable in NACK only case.

**Proposal: For NACK only based HARQ feedback, it is same as ACK/NACK based feedback:**

* **If RRC based HARQ disable/enable is configured in RRC signalling, the MBS DRX configuration for PTM leg only includes *drx-onDurationTimerPTM*, *drx-InactivityTimerPTM*, *drx-LongCycleStartOffsetPTM*, *drx-SlotOffsetPTM*. The multicast DRX operation in this case is similar as broadcast MBS.**
* **If DCI based HARQ disable/enable is configured in RRC signalling, the MBS DRX configuration for PTM leg includes *drx-HARQ-RTT-TimerDLPTM* and *drx-RetransmissionTimerDLPTM and also drx-onDurationTimerPTM*, *drx-InactivityTimerPTM*, *drx-LongCycleStartOffsetPTM*, *drx-SlotOffsetPTM*.**
* **When HARQ is disable in DCI, do not start the *drx-HARQ-RTT-TimerDLPTM* and *drx-RetransmissionTimerDLPTM* timer and stop the two timers if running.**

**Q17: Do companies agree the above proposal for NACK only based feedback?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | No | Even if HARQ feedback is disabled for a UE, gNB can retransmit the data for other UEs or perform blind retransmission. In this case, UE should be able to receive the retransmission. Especially, cell-edge or poor-coverage UEs without HARQ FB can be benefited. |
| Ericson | No | See earlier input |
| CATT | No | Same view as that for the HARQ ack/nack case. |
| Nokia | No | See previous questions. |
| Lenovo, Motorola Mobility | No |  |
| Qualcomm | Yes |  |
| LGE | No | Similar with Q15, the first bullet is unclear to me. I think that If RRC based HARQ disable/enable is configured in RRC signalling and HARQ is configured to be disabled, the MBS DRX configuration only includes drx-onDurationTimerPTM, drx-InactivityTimerPTM, drx-LongCycleStartOffsetPTM, drx-SlotOffsetPTM. |
| TD Tech, Chengdu TD Tech | No | Reason: There’s the case that the DCI format is used to diable/enaible the HARQ feedback for some UEs and the HARQ feedback is enabled by RRC signalling for some other UEs. |
| Fujitsu | Yes | See the previous answers. |
| MediaTek | No | Same as previous question |
| vivo | No |  |
| Xiaomi | No |  |
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### 2.3.6 CSI and SRS reporting due to MBS DRX

In MAC running CR for MBS, there is an editor note about CSI and SRS reporting due to MBS DRX.

Editor’s note: FFS to CSI and SRS reporting due to MBS DRX.

RAN2 once agreed that the MBS DRX will be independent from unicast DRX. It is not clear whether the MBS DRX will also impact the CSI and SRS reporting like below text.

|  |
| --- |
| 1> if *drx-onDurationTimer* associated with the current DRX cycle is not started as specified in this clause:  2> if the MAC entity would not be in Active Time considering grants/assignments/DRX Command MAC CE/Long DRX Command MAC CE received and Scheduling Request sent until 4 ms prior to symbol n when evaluating all DRX Active Time conditions as specified in this clause:  3> not transmit periodic SRS and semi-persistent SRS defined in TS 38.214 [7];  3> not report semi-persistent CSI configured on PUSCH;  3> if *ps-TransmitPeriodicL1-RSRP* is not configured with value *true*:  4> not report periodic CSI that is L1-RSRP on PUCCH.  3> if *ps-TransmitOtherPeriodicCSI* is not configured with value *true*:  4> not report periodic CSI that is not L1-RSRP on PUCCH.  1> else:  2> in current symbol n, if a DRX group would not be in Active Time considering grants/assignments scheduled on Serving Cell(s) in this DRX group and DRX Command MAC CE/Long DRX Command MAC CE received and Scheduling Request sent until 4 ms prior to symbol n when evaluating all DRX Active Time conditions as specified in this clause:  3> not transmit periodic SRS and semi-persistent SRS defined in TS 38.214 [7] in this DRX group;  3> not report CSI on PUCCH and semi-persistent CSI configured on PUSCH in this DRX group.  2> if CSI masking (*csi-Mask*) is setup by upper layers:  3> in current symbol n, if *drx-onDurationTimer* of a DRX group would not be running considering grants/assignments scheduled on Serving Cell(s) in this DRX group and DRX Command MAC CE/Long DRX Command MAC CE received until 4 ms prior to symbol n when evaluating all DRX Active Time conditions as specified in this clause; and  4> not report CSI on PUCCH in this DRX group.  NOTE 4: If a UE multiplexes a CSI configured on PUCCH with other overlapping UCI(s) according to the procedure specified in TS 38.213 [6] clause 9.2.5 and this CSI multiplexed with other UCI(s) would be reported on a PUCCH resource either outside DRX Active Time of the DRX group in which this PUCCH is configured or outside the on-duration period of the DRX group in which this PUCCH is configured if CSI masking is setup by upper layers, it is up to UE implementation whether to report this CSI multiplexed with other UCI(s). |

**Q18: Do companies agree that the similar text in above box should also be captured in MAC running CR for MBS DRX in section 5.7b?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | No | CSI reporting/SRS can follow unicast DRX. We do not think MBS DRX should additionally affect them.  [OPPO] If there is no unicat data transmission/reception. The CSI report will not be report due to the above text even if there is MBS tranmssion. The network will not receive the CSI-RS and can not do the right decision of the scheduling. |
| Ericsson | No | We do not see why the unicast mechanism is impacted and why not the same principles can be reused also for MBS |
| CATT | No | SRS/CSI reporting should not be considered in MBS DRX. |
| Nokia | No | Agree with Samsung and Ericsson. In case of doubt, could ask RAN1 to confirm. |
| Lenovo, Motorola Mobility | No |  |
| Qualcomm | No | CSI and SRS reporting should be allowed in case of MBS DRX active period , same as Unicast DRX. |
| LGE | No | CSI and SRS reporting is transmitted based on unicast DRX operation. We don’t see critical reason to consider multicast DRX operation for transmission of CSI and SRS reporting. |
| TD Tech, Chengdu TD Tech | No | Agree with Samsung. |
| Fujitsu | No | This can be discussed directly in RAN1. Then RAN2 can just wait. |
| MediaTek | No | Unicast CSI/SRS reporting principles can be reused |
| vivo | No | CSI reporting/SRS is used for legacy unicast transmission and we have already agreed that MBS DRX is independent of unicast DRX. In this sense, we don’t see the need to combine CSI reporting and SRS with MBS DRX. |
| Xiaomi | No |  |
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### 2.3.7 Active Time in MBS

In MAC running CR for MBS, there is an editor note about active time for MBS DRX.

Editor’s note: FFS other condition to define the Active Time.

For now, rapporteur cannot see other condition to define the active time for MBS DRX.

**Q19: Do companies agree to remove this editor note about active time for MBS DRX?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | Yes |  |
| Ericsson | Yes |  |
| CATT | Yes |  |
| Nokia | Probably | Can be done last once all open items are concluded. |
| Lenovo, Motorola Mobility | No | It can be revisted according to the concolusion of Q10 |
| Qualcomm | Yes |  |
| LGE | Yes |  |
| TD Tech, Chengdu TD Tech | Yes so far |  |
| Fujitsu | Yes | For now. |
| MediaTek | Yes |  |
| vivo | Yes |  |
| Xiaomi | Yes |  |
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## 2.4 Others

### 2.4.1 The necessary to specify to define subPDU discarding

In #67 email discussion on the MBS MAC running CR, some companies propose that UE should discard some subPDU and the subPDU is not for the UE based on following agreement made in RAN2#116.

* one-to-many mapping between G-RNTI and MBS sessions is supported and it is assumed that this does not introduce additional specification work.

So the following spec change is made:

|  |
| --- |
| 5.3.3 Disassembly and demultiplexing The MAC entity shall disassemble and demultiplex a MAC PDU as defined in clauses 6.1.2 and 6.1.5a.  When a MAC entity receives a MAC PDU scrambled by a G-RNTI containing one or more LCIDs corresponding to the MBS sessions that the UE is not interested in, the MAC entity shall:  1> discard the received subPDU. |

However, some companies think that smart network implementation would avoid the case where the UE receives a service that it is not interested in.

The following questions need RAN2 further to confirm.

Q1: Whether the above agreement is valid for both multicast and broadcast?

Q2: Network ensure that all MBS sessions associated one G-RNTI are interested by UE?

For Q1, it depends on Q2. Anyway, it is hard for network to ensure that all MBS sessions associated one G-RNTI are interested by all UEs in MBS broadcast. If the answer to Q2 is yes, then the above agreement is not valid for broadcast case and only one to one mapping is supported in broadcast MBS. If the answer to Q2 is no, the above agreement is also valid for broadcast MBS and RAN2 should confirm the above change is captured in MBS MAC running CR or not.

**Option 1:** Network ensure that all MBS sessions associated one G-RNTI are interested by UE for both multicat MBS and broadcast MBS. Only one to one mapping between G-RNTI and MBS sessions is supported for broadcast MBS.

**Option 2:** Network may not ensure that all MBS sessions associated one G-RNTI are interested by UE, the above spec change is captured in MBS MAC running CR.

**Q20: Which option do companies agree?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Option 2 | It is simple and no restriction to network. |
| Samsung | Option 1 | UE can be configured with multiple G-RNTIs. Thus, NW can avoid the multiplxing of interested service and non-interested service. Also, UE does not need to decode data in which UE is not interested. This unnecessary decoding just increase UE’s power consumption and processing. |
| Ericsson | Option 2 | A reasonable NW and MBS Session and RB configuration would not lead to any big issues in most cases. In any case, the specification allows for UEs to discard unknown or errorneus payload |
| CATT | Option 1,but | Option 1 is preferred, but even Network may not ensure that all MBS sessions associated one G-RNTI are interested by UE, the UE can discard the MAC subPDUs that the UE is not interested in per the existing mechanism,no additional spec change is needed. |
|  |  |  |
| Nokia | Option 2 |  |
| Lenovo, Motorola Mobility | Option 1 | Network ensure that all MBS sessions associated one G-RNTI are interested by UE.  We believe RAN2 assumed there is no impact on UE when RAN2 made the agreement. |
| Qualcomm | Option 2 | Same view as Ericsson and OPPO. |
| LGE | Option 2 | Option 1 will reduce the chances of one-to-many mapping very much. Since a multicast group membership chage will requires remapping, reconfiguration signalling are expected to be frequent.  To take benefits (e.g. flexible configuration option) by one-to-many mapping, option 2 is necessary.  Regarding specification change, there is a text for handling subPDU whose LCID is not configured in clause 5.13 in MAC. Therefore, we think the following change in clause 5.13 in MAC can be discussed.  When a MAC entity receives a MAC PDU for the MAC entity's C-RNTI or CS-RNTI, or by the configured downlink assignment, or G-RNTI, containing an LCID or eLCID value which is not configured, the MAC entity shall at least:  1> discard the received subPDU. |
| TD Tech, Chengdu TD Tech | Option 2 |  |
| Fujitsu | Option 2 | It is the sensible network implementation. |
| MediaTek | Option 2 | Network may not ensure that all MBS sessions associated one G-RNTI are interested by UE, otherwise UE is very likely to monitor multiple G-RNTIs/G-CS-RNTIs simultaneously when UE is interested in multiple MBS sessions. Supporting multiple G-RNTIs/G-CS-RNTIs simultaneously will put a big burden to UE and need the support of UE capability.  Also, option2 has less restriction to network. |
| vivo | Option 1 | Smart NW implementation can avoid UE receiving packets that it is not interested in. |
| Xiaomi | Option 2 |  |
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### 2.4.2 Impact on BWP switching inactivity timer due to multicast and broadcast reception

According to RAN1 agreements in RAN1#107, the multicast MBS reception will impact BWP switching inactivity timer, but the broadcast MBS reception will not. RAN2 should confirm it.

|  |
| --- |
| **Agreement**  For multicast, if a UE is configured with a CFR in the active DL BWP, for timer-based active DL BWP switching to a default BWP, option 1 is supported.   * Option 1: UE also starts or restarts BWP-InactivityTimer when it successfully decodes a GC-PDCCH addressed to group-common RNTI (e.g., G-RNTI or G-CS-RNTI) for multicast on/for the active BWP or when a MAC PDU for is received in a configured downlink assignment for multicast.   + UE does not start or restart BWP-InactivityTimer when it successfully decodes a GC-PDCCH addressed to group-common RNTI (e.g., G-RNTI or G-CS-RNTI) for broadcast. |

**Q21: Do companies confirm the multicast MBS reception will impact BWP switching inactivity timer, but the broadcast MBS reception will not, and capture it in MAC running CR?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | Yes |  |
| Ericsson | Yes, comment | It is unclear what is to be captured in the specification in the above. Suggest this to be part of the running CR discussion. |
| CATT | Yes |  |
| Nokia | Yes |  |
| Lenovo, Motorola Mobility | Yes |  |
| Qualcomm | Yes |  |
| LGE | Yes |  |
| TD Tech, Chengdu TD Tech | Yes |  |
| Fujitsu | None | This discussion can be up to RAN1 discussion. |
| MediaTek | Yes |  |
| vivo | Yes | We can now follow the RAN1 agreement. |
| Xiaomi | Yes |  |
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Furthermore, if the UE is receiving broadcast reception and the default BWP is not initial BWP, whether the UE should active initial BWP instead of default BWP for broadcast BWP reception, when the BWP inactivity timer expiry.

**Option 1**: If the UE is receiving the broadcast MBS when enter RRC\_CONNECTED state, the network will not configure the default BWP not contain the initial BWP.

**Option 2**: If the UE is receiving the broadcast MBS in RRC\_CONNECTED state, UE should active initial BWP instead of default BWP when BWP-InactivityTimer expiries.

**Q22: Which option do companies agree?**

|  |  |  |
| --- | --- | --- |
| Company | Option 1/2? | Comments |
| OPPO | Option 1 | Option 1 is simple and is up to network. |
| Samsung | none | We think broadcast can be a best-effort manner. It’s up to NW whether to guarantee the ongoing broadcast reception. What is only needed is MII reporting UE’s interested/ongoing broadcast service to the gNB. |
| Ericsson |  | Agree with Samsung. The options are also unclear in what is assumed in reception of BC in connected and what can be simultaneous etc |
| CATT | Option 1 |  |
| Nokia | Option 1 | But how does network know that UE is receiving broadcast MBS i.e. as part of other email discussion on MII (028) it seems clear that one needs to indicate MBS broadcast reception early to allow option 1 implemention by network |
| Lenovo, Motorola Mobility |  | Network implementation? |
| Qualcomm |  | Agree with Samsung and it is upto NW implementation. |
| LGE | Option 1 |  |
| TD Tech, Chengdu TD Tech | Option 1 |  |
| Fujitsu | Option 1 | BWP operation can be up to NW implementation. |
| MediaTek | Option 1 | It is up to NW implementation |
| vivo | Option 1 | It is up to NW implementation and we think option 1 can be considered as baseline. |
| Xiaomi | Option 1 | It is up to NW implementation |
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### 2.4.3 MBS support in MR-DC

In RAN2#111 meeting, RAN2 left a TBD for NR-DC and NE-DC to support MBS in MCG side.

* Focus initially on NR SA, TBD to what extent other scenarios NR DC, NE DC can be supported.

In rapporteur’s understanding, there is no spec impact to support multicast MBS in MCG side in NE-DC and NR-DC scenarios.

**Q23: Do companies agree that MBS can be supported in MCG side in NE-DC and NR-DC scenarios, i.e., MN terminated MCG bearer kind of MRB?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | No strong view |  |
| Ericsson |  | Think this needs a bit more discussion. What does “MBS” mean here w.r.t “sub” functionality in Multicast and BC. |
| CATT | Yes |  |
| Nokia | Yes, but | We should also limit implementation and testing efforts, could be deferred to Rel-18. Not urgent. |
| Lenovo, Motorola Mobility | Yes |  |
| Qualcomm | Yes | In R17, we should restrict MBS to MN only. |
| LGE | Yes |  |
| TD Tech, Chengdu TD Tech | Yes but no strong tendency |  |
| Fujitsu | Yes | It has not been really discussed in RAN2.  In R17, we should restrict MBS to MN only. |
| MediaTek |  | We prefer to postpone the implementation for MBS in MR-DC to R18 |
| vivo | Yes |  |
| Xiaomi | Yes |  |
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### 2.4.4 LCID for broadcast MRB

In RAN2#115 meeting, RAN2 achieve the following agreements for LCID for MRB.

* Single bearer ID is used for each Multicast RB.
* Multicast PTP and Unicast DTCH/DRB share common LCID space.
* Broadcast PTM/MTCH uses reserved LCID(s), which is different than Unicast DTCH/DRB LCID space.
* Broadcast MCCH uses reserved LCID .

During Email discussion of MAC running CR, one new table of LCID is defined for broadcast MRB.

Table 6.2.1-1c Values of LCID for NR broadcast MBS on DL-SCH

|  |  |
| --- | --- |
| Codepoint/Index | LCID values |
| 0 | MCCH |
| 1–32 | Identity of the logical channel for PTM MTCH via broadcast |
| 33–63 | Reserved |

Editor’s note: FFS new table for broadcast MBS and the maximal value.

Some companies think the new table should be defined for broadcast MRB based on following reasons:

* The MRBs for broadcast is multiple and multiple LCID will be used.
* The reserved LCID is limited, it is from 35 to 46.

However, some companies think the reserved LCID for DRB, i.e. in table “Table 6.2.1-1”, should be used for broadcast.

Consider the extension in the future, it is better to use new table as MAC running CR captured for MCCH, MTCH of broadcast.

**Q24: Do companies agree to remobe the editor notes for LCID in broadcast?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No? | Comments |
| OPPO | Yes |  |
| Samsung | No strong view |  |
| Ericsson | Yes | Seems ok, no strong view |
| CATT | Yes |  |
| Nokia | - | No strong view |
| Lenovo, Motorola Mobility | Yes |  |
| Qualcomm | Yes |  |
| LGE | Yes |  |
| TD Tech, Chengdu TD Tech | Yes |  |
| Fujitsu | Yes | Can accept the new table. |
| MediaTek | Yes |  |
| vivo | Yes |  |
| Xiaomi | Yes |  |
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# Conclusions

Based on the discussion above, we propose:

# Reference