**3GPP TSG-RAN WG2 Meeting #118electronic R2-220xxxx**

**Online, May 9th – May 20th, 2022**

**Agenda item: 6.1.3.2**

**Source: Xiaomi**

**Title: [AT118-e][032][MBS] PDCP (Xiaomi)**

**Document for:**  **Discussion**

# 1. Introduction

This paper is to trigger the following email discussion of MBS PDCP:

* [AT118-e][032][MBS] PDCP (Xiaomi)

Scope: Treat R2-2204626, R2-2204683, R2-2204906, R2-2205714, R2-2205630, R2-2205479, R2-2205155, R2-2205454, Collect one round of comments, pave the way for on-line agreement (identify agreeable points, discussion points),

Intended outcome: Report

Deadline: For online CB W1 Thursday

Deadline (for companies' feedback): Wednesday 2022-05-11 18:00 UTC

## 1.1 Contacts

Contact person for each participating company:

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# 2. Discussion

## 2.1 Negative HFN issue of multicast

The RAN2 agreements related to the PDCP variables are quoted as follows:

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| RAN2#116-e meeting agreements:   * for multicast MRB, the initial value of the SN part of RX\_NEXT is (x +1) modulo (2[*PDCP-SN-Size*]), where x is the SN of the first received PDCP Data PDU. * the initial value of RX\_DELIV is set to a value before RX\_NEXT, e.g. the initial value of the SN part of RX\_DELIV is (x – 0.5 × 2[*PDCP-SN-Size*–1]) modulo (2[*PDCP-SN-Size*]), where x is the SN of the first received PDCP Data PDU. * for multicast MRB, the initial value of the SN part of RX\_NEXT is (x +1) modulo (2[*PDCP-SN-Size*]), where x is the SN of the first received PDCP Data PDU. |
| RAN2#116bis-e meeting agreements:   * [027] HFN is needed for both multicast and broadcast. * [027] For multicast, the initial value of HFN is indicated by the gNB via RRC. * [027] For broadcast, the initial value of HFN is selected by the UE. * [027] If the initial value of HFN is indicated by the gNB, a reference SN corresponding to the initial value of HFN can be indicated to the UE. * [027] For both multicast and broadcast, the initial value of the SN part of RX\_DELIV is (x – 0.5 × 2[*PDCP-SN-Size*–1]) modulo (2[*PDCP-SN-Size*]), where x is the SN of the first received PDCP Data PDU. |
| RAN2#117-e meeting agreements:   * On HFN < 0, The current derivation formula of initial RX\_DELIV in 38.323 CR is kept. R2 assumes it is up to network implementation to ensure that HFN part of RX\_DELIV should be a positive value (TS impact if any is FFS, e.g. a NOTE in RRC or PDCP) |

According to the current PDCP specification, how to use the reference SN for setting the initial value of HFN is up to the UE implementation.

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| 36.323: 6.3.5 COUNT Length: 32 bits  The COUNT value is composed of a HFN and the PDCP SN. The size of the HFN part in bits is equal to 32 minus the length of the PDCP SN. For MRBs, HFN with a reference SN can be provided by upper layers. If provided, the initial value of HFN is set according to the HFN and the reference SN. Otherwise, the initial value of HFN is set by UE implementation.  NOTE: For MRBs, the provisioning of HFN from the upper layer may cause HFN desynchronization. It is up to UE implementation to prevent HFN desynchronization by using the reference PDCP SN associated to the HFN. |

As companies have different understandings on how to use the reference SN to set the initial value HFN according to [2]-[8], this leads to the different calculation results of the initial HFN when the SN of the first received PDCP Data PDU is smaller than 0.5 × 2[PDCP-SN-Size–1].

**Understanding 1 (causes negative HFN): When receving the first PDCP data PDU, the UE processes the procedure of section 5.2.2.1 before initializing the RX\_DELIV as specified in section 7.1.**

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| **Specificaiton procedure** | **Initial value of HFN** |
| 5.2.2.1 Actions when a PDCP Data PDU is received from lower layers At reception of a PDCP Data PDU from lower layers, the receiving PDCP entity shall determine the COUNT value of the received PDCP Data PDU, i.e. RCVD\_COUNT, as follows:  - if RCVD\_SN < SN(RX\_DELIV) – Window\_Size:  - RCVD\_HFN = HFN(RX\_DELIV) + 1.  - else if RCVD\_SN >= SN(RX\_DELIV) + Window\_Size:  - RCVD\_HFN = HFN(RX\_DELIV) – 1.  - else:  - RCVD\_HFN = HFN(RX\_DELIV);  - RCVD\_COUNT = [RCVD\_HFN, RCVD\_SN]. | - if SN(RX\_DELIV) < SN\_ref – Window\_Size:  - HFN(RX\_DELIV) = HFN\_initial + 1.  - else if SN(RX\_DELIV) >= SN\_ref + Window\_Size:  - HFN(RX\_DELIV) = HFN\_initial – 1.  - else:  - HFN(RX\_DELIV) = HFN\_initial;  The UE sets RCVD\_HFN based on the indicated HFN and then derive HFN(RX\_DELIV) from RCVD\_HFN [6].  This determination leads to negative HFN values if HFN\_initial=0 and SN\_ref < 0.5 × 2[*PDCP-SN-Size*–1]. |

**Understanding 2 (No negative HFN, but may cause HFN desync): The UE firstly sets the initial value of RX\_DELIV according to section 7.1. Then the UE processes the procedure of section 5.2.2.1.**

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| **Specification procedure** | **Initial value of HFN** |
| Step 1:  7.1 State variables  b) RX\_DELIV  This state variable indicates the COUNT value of the first PDCP SDU not delivered to the upper layers, but still waited for. The initial value is 0, except for sidelink broadcast and groupcast, for SRBs configured with state variables continuation, and for MRBs. For NR sidelink communication for broadcast and groupcast or sidelink SRB4 for broadcast and groupcast based sidelink discovery, the initial value of the SN part of RX\_DELIV is (x – 0.5 × 2[*sl-PDCP-SN-Size*–1]) modulo (2[*sl-PDCP-SN-Size*]), where x is the SN of the first received PDCP Data PDU. For MRBs, the initial value of the SN part of RX\_DELIV is set to (x – 0.5 × 2[*PDCP-SN-Size*–1]) modulo (2[*PDCP-SN-Size*]), where x is the SN of the first received PDCP Data PDU. For target SRB configured with state variables continuation, the initial value is the value stored in PDCP entity for the corresponding source SRB. For source SRB configured with state variables continuation, the initial value is the value stored in PDCP entity for the corresponding target SRB. 6.3.5 COUNT Length: 32 bits  The COUNT value is composed of a HFN and the PDCP SN. The size of the HFN part in bits is equal to 32 minus the length of the PDCP SN. For MRBs, HFN with a reference SN can be provided by upper layers. If provided, the initial value of HFN is set according to the HFN and the reference SN. Otherwise, the initial value of HFN is set by UE implementation.  Step 2: 5.2.2.1 Actions when a PDCP Data PDU is received from lower layers At reception of a PDCP Data PDU from lower layers, the receiving PDCP entity shall determine the COUNT value of the received PDCP Data PDU, i.e. RCVD\_COUNT, as follows:  - if RCVD\_SN < SN(RX\_DELIV) – Window\_Size:  - RCVD\_HFN = HFN(RX\_DELIV) + 1.  - else if RCVD\_SN >= SN(RX\_DELIV) + Window\_Size:  - RCVD\_HFN = HFN(RX\_DELIV) – 1.  - else:  - RCVD\_HFN = HFN(RX\_DELIV);  - RCVD\_COUNT = [RCVD\_HFN, RCVD\_SN]. | According to the calculation provided in [8], there is no negative HFN issue.  Example:  Step 1: RRC provides the following configuration for multicast MRB.   |  | | --- | | pdcp-SN-SizeDL: 12 bits (i.e. 212 = 4096, 2(12-1) = 2048)  multicastHFN-AndRefSN: HFN = 0; SN = 10 |   Step 2: The UE receives the first PDCP Data PDU (i.e. x), with PDCP SN = 10.  Step 3: The UE initializes the variables for the receiving PDCP entity as follows:  The initial value of HFN is set to 0.  The initial value of the SN part of RX\_NEXT is calculated as follows:  (x +1) modulo (2[*PDCP-SN-Size*]) = (10 + 1) modulo (4096) = 11  RX\_NEXT = [0, 11]  The initial value of the SN part of RX\_DELIV is calculated as follows:  (x – 0.5 × 2[*PDCP-SN-Size*–1]) modulo (2[*PDCP-SN-Size*]) = (10 – 0.5 × 2[*12*–1]) modulo (2[*12*]) = (-1014) modulo 4096 = (-1014) – (-1)\*4096 = 3082  RX\_DELIV[HFN\_initial, SN\_initial] = [0, 3082] |

#### Question 1: Which of the followings should be the understanding for the PDCP procedure of the multicast MRB?

* Understanding 1 (causes negative HFN): When receving the first PDCP data PDU, the UE processes the procedure of section 5.2.2.1 before initializing the RX\_DELIV as specified in section 7.1.
* Understanding 2 (No negative HFN, but may cause HFN desync): The UE firstly sets the initial value of RX\_DELIV according to section 7.1. Then the UE processes the procedure of section 5.2.2.1.

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| **Company** | **Answer (**Understanding 1 or  Understanding 2**)** | **Comments** |
| Xiaomi | Understanding 2 | We think that it should be natural to firstly initialize all state variables before processing the received PDCP data PDUs, as this is also the legacy PDCP behaviour in which the PDCP entity initializes all its variables at the PDCP establishment.  Whether some clarification is needed in PDCP can be discussed later. |
| MediaTek | Understanding 2  With comment | The UE should firstly sets the initial value of RX\_DELIV according to the first received PDU, then processes the procedure of section 5.2.2.1 when a PDCP PDU (actually not the very first PDU) is received.  However, we see problems in the example which UE set RX\_NEXT = [0, 11] and RX\_DELIV = RX\_DELIV[HFN\_initial, SN\_initial] = [0, 3082] after receiving the multicastHFN-AndRefSN: HFN = 0; SN = 10and the PDCP PDU with SN = 10.  The reason is that the COUNT of RX\_DELIV should be always smaller than RX\_NEXT to keep a proper reordering window and the PDCP reordering function working. In that case the RX\_NEXT = [0, 11] while RX\_DELIV should be [-1,3082]. And this will lead to negative HFN to RX\_DELIV.  Therefore we suggest to set RX\_DELIV to RRC indication multicastHFN-AndRefSN instead of setting a fixed initial value to RX\_DELIV to avoid this happen, since this indication will be delivered to UE anyway. |
| CATT | Understanding 2 | We agree with Xiaomi. Furthermore, RCVD\_HFN is calculated by the receiving PDCP entity which has been specified in TS 38.323 which is copied below.  - RCVD\_HFN: the HFN of the received PDCP Data PDU, calculated by the receiving PDCP entity; |
| LG | Understanding 2 | The UE should initialize all the state variables first, and then process the received PDU. This is logical order. |
| Samsung | None | We see none of Understanding is correct.  Understanding 1 is not correct. There’s a restriction of RX\_DELIV >=0.  Understanding 2 is not correct. The specification does not allow RX\_DELIV > RX\_NEXT as Mediatek mentioned. Understanding 2 means that UE can select RX\_DELIV greater than RX\_NEXT or less than RX\_NEXT. This means that there is no rule to select RX\_DELIV.  For instance,  pdcp-SN-SizeDL: 12 bits (i.e. 212 = 4096, 2(12-1) = 2048)  multicastHFN-AndRefSN: HFN = 1; SN = 10  - Implementation 1. RX\_DELIV=[0, 3082], RX\_NEXT=[1, 11] -> UE start the reordering timer.  - Implementation 2. RX\_DELIV=[1, 3082],, RX\_NEXT=[1, 11] -> UE does not start the reordering timer.  NW does not expect the UE behaviour at all. The UE behaviour should be specified.Implementation 2 is align with Understanding 2. But implementation 2 does not start the reordering timer. What we agreed for initial variable setup will be useless.  Since none of the understandings above is not correct, UE has not idea on the initial variable setup. Thus we think it should be clarified. |
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#### Question 2: If Understanding 1 is selected, which of the following options is preferred to resolve the negative HFN issue for multicast MRB?

* Option 1 [3]: Up to the gNB implementation to ensure that HFN part of RX\_DELIV should be a positive value.
* Option 2 [6]: The UE should set the RX\_DELIV to 0 when the calculated RX\_DELIV < 0
* Option 3 [3]: The value of HFN for RX\_DELIV is temporarily allowed to be negative (-1). (This will not lead to negative value to the COUNT of receiving PDCP PDU).
* Option 4: Up to the UE implementation to ensure that HFN part of RX\_DELIV should be a positive value.

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| **Company** | **Answer**  **(**Option 1 or 2 or 3**)** | **Comments** |
| Xiaomi | Option 1 |  |
| MediaTek | None | It is argued that Op1 may not work as it is not gNB’s decision to set the HFN.  Op2,Op4 will lead to HFN desync between NW and UE.  Op3 can work, but we think it is not the best option.  Please see the further comment on Q1 and Q3. |
| LG | None | We think Understanding 1 is not correct. |
| Samsung | Option 1 |  |
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#### Question 3: If Understanding 2 is selected, which of the following options is preferred to resolove the HFN desync issue for multicast MRB?

* Option 1 [8]: Up to the gNB implementation.
* Option 2 [7]: Initial RX\_DELIV is configured by RRC: SN(RX\_DELIV) = SN\_ref and HFN(RX\_DELIV) = HFN\_initial where HFN\_initial and SN\_ref are provided by RRC for multicast.
* Option 3 [2]: The initial value of the SN part of RX\_DELIV is set to the SN of the first received PDCP Data PDU.
* Option 4 [2]: RX\_DELIV = MAX (0, COUNT(x) - 0.5 × 2[*PDCP-SN-Size*–1]), where x is the SN of the first received PDCP Data PDU.
* Option 5: Others

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| **Company** | **Answer**  **(**Option 1 or 2 or 3 or 4 or 5**)** | **Comments** |
| Xiaomi | Option 1 or Option 2 | We slightly prefer gNB implementation, as there are lots of ways for the gNB to avoid the HFN desync issue. For example, when the gNB configures the HFN via *multicastHFN-AndRefSN*, the configured HFN can be (the HFN of the transmitting PDCP entity - 1). The drawback is that “HFN=0” is wasted. However one value of HFN seems not a big issue.  Furthemore, eventhough the HFN is not synchronized betweent the UE and the gNB in some implementation still willing to use “HFN=0”, as the gNB knows the HFN value at the UE according to the initial HFN and the reference SN provided to the UE, the gNB by implementation can avoid the HFN wrap around at the UE. When the PDCP status report is reported to the gNB, the gNB is able to know that the HFN reported by the UE is (the HFN of the transmitting PDCP entity + 1). There is also no issue for the HFN desync once the HFH value at the UE is known by the gNB.  If network vendors have strong concerns on the complexity of the gNB implementation, we can also accept Option 2. |
| MediaTek | Option 2 | The same problem may happen to option1 that it may not be gNB’s decision to set the HFN.  We think option2 is more simple and concise. Now that RRC will indicate initial HFN and SN, we should specify how does UE use this indication rather than left it to UE implementation (also to avoid unnecessary HFN desync or HFN negative issues) |
| CATT | Option 2, 3 or 4 | Regarding option 1, as indicated by Xiaomi, “HFN= 0” is wasted in option 1. For MBS which is different from uncast, the gNB allocates the COUNT (HFN together with SN) based on the QFI SN per flow. If HFN= 0 is wasted, there may be gap between PDUs.  Regarding option 2, we think by proper network configuration, the issue can be solved. For example, when the SN falls between [0, 0.5 × 2[*PDCP-SN-Size*–1] ], the network can set the initial value SN to be max {0.5 × 2[*PDCP-SN-Size*–1], x}. But there is spec impact, i.e. RX\_DELIV is set as (x – 0.5 × 2[*PDCP-SN-Size*–1]) modulo (2[*PDCP-SN-Size*]), where x is the SN configured by RRC.  Regarding option 3 and 4, the RX\_DELIV is set as the same as COUNT of received packet when SN (RX\_DELIV) is smaller than 0.5 × 2[*PDCP-SN-Size*–1]. Then, the reception procedure is similar as that for unicast. The desync issue will not happen. |
| LG | Option 1 or Option 2 | We think Option 1 is enough, but if there is still concern, Option 2 is the cleanest way to solve the issue. |
| Samsung | Option 2 | Initial RX\_DELIV is a clean approach without problem. |
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## 2.2 Others

[4] states that companies did not have a common understanding that RX\_DELIV <= RX\_NEXT should be guaranteed for initial variable. The issue is if RX\_DELIV > RX\_NEXT can be selected by the UE. For instance, for 12-bit SN and initial value of RX\_NEXT = 4098 (HFN = 1, SN=2), the initial RX\_DELIV may be either 4098-1-1024=3073 (HFN = 0) or 7169 (HFN = 1). If RX\_DELIV = 7169, there will not be reordering at all.

#### Question 4: Do you agree that RX\_DELIV <= RX\_NEXT should be guaranteed for initial variable selection?

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| **Company** | **Answer**  **(**Yes or No**)** | **Comments** |
| Xiaomi | No  or left to gNB implementation. | Eventhough RX\_DELIV > RX\_NEXT happens at the initial variable selection, after receiving the first PDCP data PDU, the UE will have RX\_DELIV <= RX\_NEXT.  If most companies think this requirement is needed, we think that this can be a recommended requirement for the gNB implementation. |
| MediaTek | Yes | The PDCP reordering range start from RX\_DELIV and end with RX\_NEXT. We think RX\_DELIV <= RX\_NEXT should be guaranteed.  The point is that some options above do not violate this limitation and can still work well, so there may be no further requirement needed. |
| CATT | No | If the desync issue has been solved in Question 3, we think the issue for Q4 will not happen. |
| LG | No |  |
| Samsung | Yes | If RX\_DELIV <=RX\_NEXT is not guaranteed, there are at least two different UE implementation. In the example,  - Implementation 1. RX\_DELIV=3173, RX\_NEXT=4098 -> UE start the reordering timer.  - Implementation 2. RX\_DELIV=7169, RX\_NEXT=4098 -> UE does not start the reordering timer.  NW does not expect the UE behaviour at all. The UE behaviour should be specified.  Traditionally, unicast operation guarantees RX\_DELIV <=RX\_NEXT. Thus, there’s no reason to keep the same rule.  Anyway, Q4 depends on the outcoume of Q3. If initial RX\_DELIV is agreed, restriction RX\_DELIV > RX\_NEXT is not necessary, since UE will have a single behaviour.. |
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It seems that 38.331 still uses “pdcp-SN-SizeDL” for MRB. [4] proposes to change “*PDCP-SN-Size*” to “*PDCP-SN-SizeDL*”.

#### Question 5: Do you agree that PDCP-SN-Size is updated to PDCP-SN-SizeDL?

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| **Company** | **Answer**  **(**Yes or No**)** | **Comments** |
| Xiaomi | Yes | This is to align with the RRC specification. |
| MediaTek | Yes |  |
| CATT | Yes |  |
| LG | Yes |  |
| Samsung | Yes |  |
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[5] states that due to the situation that gNB allocates the COUNT value based on the QFI SN (which is provided by the MB-UPF) per flow rather than gNB itself, how to prevent the PDCP COUNT wrap-around needs to be further discussed.

According to the discussion in the RAN2#117-e meeting, RAN2 made the following agreement:

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| * P8. For Bcast, It’s fully up to UE implementation to prevent COUNT wrap-around. |

According to the current PDCP specification as quoted below, a NOTE is used to prevent the PDCP wrap around for both broadcast, multicast and unicast.

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| 6.3.5 COUNT Length: 32 bits  The COUNT value is composed of a HFN and the PDCP SN. The size of the HFN part in bits is equal to 32 minus the length of the PDCP SN. For MRBs, HFN with a reference SN can be provided by upper layers. If provided, the initial value of HFN is set according to the HFN and the reference SN. Otherwise, the initial value of HFN is set by UE implementation.  NOTE: For MRBs, the provisioning of HFN from the upper layer may cause HFN desynchronization. It is up to UE implementation to prevent HFN desynchronization by using the reference PDCP SN associated to the HFN.    Figure 6.3.5-1: Format of COUNT  NOTE: COUNT does not wrap around. |

#### Question 6: Which of the following options do you prefer for the prevention of the PDCP COUNT wrap-around of multicast MRB?

* Option 1: Up to the gNB implementation as captured in the current PDCP specification (i.e. no more specification change)
* Option 2 [5]: Add a note in 38.300: Since PDCP does not allow COUNT to wrap-around, it is up to the network to prevent it from happening (e.g., based on its observation on DL MBS QFI Sequence Number, gNB might initiate a release and add of the corresponding multicast radio bearer or a full configuration to the associated UEs).
* Option 3 [5]: Drop the support of HFN allocation by network, i.e., network entities and UEs maintain HFN separately.

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| **Company** | **Answer**  **(**Option 1 or 2 or 3**)** | **Comments** |
| Xiaomi | Option 1 or 2 | We think that the current NOTE in the PDCP specification is sufficient to cover all cases. And it is quite obvious that the node which sets the (initial) HFN should be responsible to avoid the COUNT wrap-around.  We are also ok to add some clarifications in 38.300, if network vendors consider that some guidance for the network implementation is useful. |
| MediaTek | Option 1 | We do not see any enhancement needed at UE side. |
| CATT | Option 4 | We understand wrap around case should be considered,but for option 2,there are 2 issues to clarify:  a. How to guarantee all packets are delivered towrad the UE when releasing the old leg or old MRB? Clarification is necessary.  b. Such "network implementation" will impact the interface between the gNB-CU-CP (which generates the RRC message) and the gNB-CU-UP (which hosts the PDCP entity). So collaboration with RAN3 is needed |
| LG | Option 1 | Current NOTE is enough. |
| Samsung | Option 1 | NW shall release the ongoing MRB and add a new MRB. It’s the same as unicast. |
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# 3. Conclusion

TBD

# 4. Reference

1. R2-2204626 R17 MBS UP remaining issues Qualcomm India Pvt Ltd discussion Rel-17 NR\_MBS-Core
2. R2-2204683 Consideration on PDCP Remaining Issues of MBS CATT discussion Rel-17 38.323 NR\_MBS-Core
3. R2-2204906 Discussion on HFN negative value for multicast MediaTek inc. discussion Rel-17 NR\_MBS-Core
4. R2-2205714 Correction of PDCP for MBS Samsung discussion Rel-17 NR\_MBS-Core
5. R2-2205630 Remaining issues in PDCP layer for NR MBS ZTE, Sanechips discussion Rel-17 NR\_MBS-Core
6. R2-2205479 Further discussion on how to prevent negative HFN Huawei, HiSilicon discussion Rel-17 NR\_MBS-Core
7. R2-2205155 Setting of RX\_DELIV for MBS Nokia, Nokia Shanghai Bell discussion Rel-17 NR\_MBS-Core
8. R2-2205454 Discussion on the HFN issue for multicast Xiaomi Communications discussion Rel-17 NR\_MBS-Core