3GPP TSG-RAN WG2 Meeting #119 Electronic R2-22xxxxx

Online, 17th – 26th August, 2022

**Agenda item: 8.15**

**Source: NTT DOCOMO INC. (Moderator)**

**Title: [Draft] Summary of [AT119-e][026][NR18] UL Tx Switching (NTT Docomo)**

**Document for: Discussion and Decision**

# 1 Introduction

This document is to report on the following offline discussion:

* [AT119-e][026][NR18] UL Tx Switching (NTT Docomo)

Scope: This is an initial discussion. It may be difficult to make firm agreements, but it may be possible to converge on initial assumptions, possibilities on the table. Take into account [R2-2208327](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_119-e\Docs\R2-2208327.zip), [R2-2208324](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_119-e\Docs\R2-2208324.zip), [R2-2208107](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_119-e\Docs\R2-2208107.zip), [R2-2208481](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_119-e\Docs\R2-2208481.zip), Identify on a high level the main RAN2 impacts for the UL Tx switching schemes across up to 3 or 4 bands. Identify discussion points for future meetings, including UE capability and RRC configuration related signaling (Note: strive for RAN1/2 design agnostic with the number of bands, i.e., common design between 3 and 4 bands).

Intended outcome: Report

Deadline: Ready for online CB W2 Tuesday

# 2 Contact Points

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| Docomo (moderator) | Riki Okawa | riki.ookawa.rp@nttdocomo.com |
| Ericsson | Lian Araujo | lian.araujo@ericsson.com |
| Huawei, HiSilicon | Rui Wang | wangrui46@huawei.com |
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# 3 Discussion

RAN1 started discussion on Multi-carrier enhancements in May meeting, in advance of RAN2 and RAN4. RAN1 agreed to down-select a mechanism of UL Tx switching with more-than-two bands from following candidate alternatives in August meeting or maybe later.

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| ***Agreement***  *Companies are encouraged to investigate pros and cons of following possible mechanisms for dynamic Tx carrier switching across the configured bands, and RAN1 strives for the down-selection at RAN1#110*   * *Alt.1: Dynamic Tx carrier switching can be across all the supported switching cases by the UE and based on the UL scheduling, i.e., via UL grant and/or RRC configuration for UL transmission* * *Alt.2: NW indicates 2 bands out of the configured bands (3 or 4 bands) via DCI or MAC-CE, and dynamic Tx carrier switching between indicated bands is same as Rel-17* * *Alt.3: One anchor band is selected among configured bands (3 or 4 bands), and dynamic Tx carrier switching can be performed only from the anchor band to a non-anchor band and from a non-anchor band to the anchor band* * *Note: Other mechanisms are not precluded* |

In RAN2#119-e, three companies[1][2][4] submitted TDocs to provide their view on general issues, i.e. what we should discuss regardless which alternative is down-selected in RAN1, and potential issues which should be discussed after RAN1 down-selects a switching mechanism and RAN1/4 input LSes to RAN2.

## 3.1 General Issues

### 3.1.1 UE capabilities

**Report of supported bands**

ZTE[1] described the UE capabilities in Rel-16/17 UL Tx switching framework as Figure 1. For Rel-16 UL Tx switching (i.e. 1Tx-2Tx switching), a list of band combinations which support Rel-16 UL Tx switching is reported via *supportedBandCombinationList-UplinkTxSwitch-r16*. Furthermore, a list of supported band pairs within that band combination is reported via *supportedBandPairList-r16*. On the other hand, for Rel-17 UL Tx switching (i.e. 2Tx-2Tx switching), *supportedBandCombinationList-UplinkTxSwitch-r16* is reused to report a list of band combinations which support Rel-17 UL Tx switching.



**Figure 1. Signalling structure of R16 and R17 UL Tx switching (Quoted from [1])**

ZTE[1] proposes to extend reuse of *supportedBandCombinationList-UplinkTxSwitch-r16* to Rel-18 framework:

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| ***Open issue on band combination:***  *Question 1-1: For a given BC, whether a UE supports Rel-18 UL Tx switching shall also support Rel-16 and Rel-17 UL Tx switching?*  Question 1-1 relates to the band combination reporting structure, e.g. whether the same BC list can be reused for Rel-18 UL Tx switching? In our understanding, when a UE supports switching across 3 or 4 bands, the UE must firstly support switching across 2 bands, so for a BC which the UE indicates the support of Rel-18 UL Tx switching, the UE shall be able to support Rel-16 UL Tx switching for at least two band pairs of the BC.  Based on the current specification, for a given BC, the Rel-16 UL Tx switching capability IE is mandatory present, thus there is no problem to reuse the band combination structure for Rel-18 capability reporting.  **Proposal 1 Reuse the same band combination list (i.e. *BandCombinationList-UplinkTxSwitch-r16*) for Rel-18 UL Tx switching capability reporting.u** |

Huawei[4] also proposes that Rel-16/17 BC list framework should be reused:

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| In Rel-16/Rel-17, RAN2 has specified signaling for 1Tx-2Tx/2Tx-2Tx switching. In particular, a UL Tx specific band combination list has been introduced to report UE capability used in UL Tx switching operation. As a design principle, the existing RAN2 signaling for UL Tx switching should be reused as much as possible in order to save signaling overhead.  **Proposal 1: The Rel-16/17 UL Tx switching BC list and signalling framework should be reused for Rel-18 UL Tx switching enhancements.** |

**Question 1: Do you agree that we can reuse Rel-16/17 UL Tx switching band combination list (i.e. *BandCombinationList-UplinkTxSwitch-r16*) for Rel-18 UL Tx switching capability reporting?**

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| Company | Yes or No | Comments |
| Ericsson | Yes | Since we already have this BC list for UL Tx switching, it should be reused as much as possible. |
| Huawei, HiSilicon | Yes |  |
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### 3.1.2 RRC configuration

**Indication of band combination**

Huawei[4] provides the existing design of RRC configuration in Rel-16/17 framework, and shares their view on how to indicate band combination to be used for Rel-18 UL Tx switching:

It can follow the legacy, i.e. three or four uplink bands used for switching are configured by *UplinkConfig*.

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| The existing design in Rel-16/Rel-17 is summarized as below:   * Two uplinks (one uplink on one band, the other uplink on the other band) or three uplinks (one uplink on one band, the other two uplinks as contiguous CA on the other band) are configured by *UplinkConfig*. * For each *UplinkConfig*, the *uplinkTxSwitching* is setup:   + In case two uplinks configured, one uplink is indicated as switching period location. One uplink is indicated as carrier1 and the other is carrier2.   + In case three uplinks can be configured to the UE, the two uplinks for contiguous UL CA should have the same configuration in terms of period location and carrier role. * In *CellGroupConfig*,   + The present of *uplinkTxSwitching-2T-Mode* indicates the 2Tx-2Tx switching is configured. If absent, the UE should interpret the 1Tx-2Tx switching is configured based on the present of Rel-16 *uplinkTxSwitching* in *UplinkConfig*.   + *uplinkTxSwitchingOption* indicates option1/option2 for 1Tx-2Tx/2Tx-2Tx switching for CA case;   + *uplinkTxSwitchingPowerBoosting* indicates if power boosting is allowed for 1Tx-2Tx switching in CA case;   + *uplinkTxSwitching-DualUL-TxState* indicates the Tx location as descripted in TS 38.214 for 2Tx-2Tx switching in CA case option2. * The UL MIMO is configured in legacy way, and the UE shall follow L1 scheduling and determine if the UL Tx switching needs to be performed according to section 6.1.6 in TS 38.214. During UL Tx switching, the switching period will be applied to the uplink configured as switching period location.   From the RAN1 discussion in May meeting, we understand in general the dynamic switching is still triggered by L1 scheduling as same as what we have in Rel-16/Rel-17. Whether there is further enhancement/restriction on the dynamic switching mechanism is FFS. Then from RAN2 point of view, the main task is to configure uplinks on 3 bands/4 bands with UL MIMO as shown in Figure 2, and provides corresponding UL Tx switching configurations. For the first part, the existing signaling included in *UplinkConfig* seems to be sufficient, i.e. 3 uplinks/4 uplinks configured by *UplinkConfig*. For the second part, in Rel-16/Rel-17 one band is configured as period location as only two UL bands are involved, while in Rel-18 the signaling extension is required to provide information about when Tx is switched between two uplinks which one would be the switching period location when multiple band pairs exist.  ...  **Observation 3: It is straightforward that the uplinks on 3 bands/4 bands for Rel-18 UL Tx switching are configured as in legacy way, i.e. by *UplinkConfig*.**  **Observation 4: Assuming UL Tx switching may involve multiple band pairs in Rel-18, RAN2 signaling extension is required to configure period location for each band pair, which is also pending to RAN1 discussion.** |

**Question 2: Do you agree that uplink bands for Rel-18 UL Tx switching are configured as in legacy way, i.e. by *UplinkConfig*?**

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| Company | Yes or No | Comments |
| Ericsson | Yes |  |
| Huawei, HiSilicon | Yes |  |
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## 3.2 Potential Issues

### 3.2.1 UE capabilities

**Switching periods**

ZTE[1] raises an open issue on switching option. In Rel-16/17 framework, switching periods are reported per band pair via *ULTxSwitchingBandPair-r16*. In Rel-18, it is unclear which way to go:

1) Switching period is reported per band combination (3 or 4 bands). All the switching patterns across within the band combination takes the same length of switching period.

2) Switching period is reported per band pair. As for one band, both “switch from” period and “switch to” period should be configured.

Anyway, this issue may be affected by the result of RAN1 down-selection. RAN2 may not tave to even implement a new capability to report switching periods for Rel-18 framework, especially when Alt.2 is selected. Thus this may be a potential issue to be discussed after RAN1 input.

**Question 3: Do you agree that RAN2 should discuss after RAN1 input whether the switching period is configured per band pair or per band combination?**

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| Company | Yes or No | Comments |
| Ericsson | Yes |  |
| Huawei, HiSilicon | Yes with comments | We understand the question is for UE capability reporting.  The switching period in Rel-16/17 is a UE requirement defined by RAN4, therefore whether in Rel-18 it is the same as in Rel-16/Rel-17 needs to be confirmed by RAN4 first. |
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**Switching options**

ZTE[1] raises an open issue on UE capability to report switching options:

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| ***Open issues on switching option (i.e. CA option 1/2):***  *Question 2-1: Whether Rel-18 UL Tx switching option (e.g. CA option 1/2) is per-BC or per-band pair signaled?*  *Question 2-2: For a given BC, or a given band pair, whether the switching option can be different for Rel-18 and Rel-16/17 UL Tx switching?*  For Question 2-1, the existing switching option is per-BC reported, if we reuse this mechanism for Rel-18 UL Tx switching, it means for the selected 3 or 4 bands, no matter which 2 bands are “activated” for UL transmission, the switching option should be the same. If companies think this is too restricted, then finer granularity (e.g. per-band pair) should be considered.  For Question 2-2, currently, whether to define separate switching option capabilities for Rel-16 and Rel-17 UL Tx switching is still under discussion. Technically, it is reasonable to define separate capabilities to allow UE flexibility. For Rel-18 UL Tx switching, no matter the switching option is defined as per-BC or per-band pair level, if different values can be reported for Rel-18 and Rel-16/17 UL Tx switching, then separate capability fields are needed.  However, for both Question 2-1 and Question 2-2, RAN2 needs more inputs from RAN1 before making a decision.  **Observation 1 It is unclear how switching option capability should be signaled (e.g. per-BC level or per-band pair level, same or different values for R16/R17/R18 cases), input from RAN1 is needed.** |

In Rel-16/17, the switching option (switchedUL, dualUL, or both) is reported via *BandCombination-UplinkTxSwitch-r16*, i.e., the option is configured per band combination. This issue provides a way forward to relax the restriction.

It should be noted that this issue is also affected by RAN1 down-selection. RAN2 may be able to reuse existing capabilities for Rel-18 framework, especially when Alt.2 is selected. Thus this may be a potential issue to be discussed after RAN1 input.

**Question 4: Do you agree that RAN2 should discuss after RAN1 input whether the switching option (i.e. switchedUL or dualUL) is configured per band pair or per band combination?**

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| Company | Yes or No | Comments |
| Ericsson |  | Ok to wait |
| Huawei, HiSilicon | See comments | We agree that the switching option should be discussed and decided by RAN1/4, RAN2 work is to implement their agreements in RAN2 specifications. |
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### 3.2.2 RRC configuration

**Switching period and DL interruption**

Huawei[4] provides existing design of RRC configuration in Rel-16/17 and raised an issue that switching period location cannot be configured if we simply reuse existing *UplinkConfig*, because it cannot appropriately locate the period in all the band pairs within more than two bands:

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| The existing design in Rel-16/Rel-17 is summarized as below:   * Two uplinks (one uplink on one band, the other uplink on the other band) or three uplinks (one uplink on one band, the other two uplinks as contiguous CA on the other band) are configured by *UplinkConfig*. * For each *UplinkConfig*, the *uplinkTxSwitching* is setup:   + In case two uplinks configured, one uplink is indicated as switching period location. One uplink is indicated as carrier1 and the other is carrier2.   + In case three uplinks can be configured to the UE, the two uplinks for contiguous UL CA should have the same configuration in terms of period location and carrier role. * In *CellGroupConfig*,   + The present of *uplinkTxSwitching-2T-Mode* indicates the 2Tx-2Tx switching is configured. If absent, the UE should interpret the 1Tx-2Tx switching is configured based on the present of Rel-16 *uplinkTxSwitching* in *UplinkConfig*.   + *uplinkTxSwitchingOption* indicates option1/option2 for 1Tx-2Tx/2Tx-2Tx switching for CA case;   + *uplinkTxSwitchingPowerBoosting* indicates if power boosting is allowed for 1Tx-2Tx switching in CA case;   + *uplinkTxSwitching-DualUL-TxState* indicates the Tx location as descripted in TS 38.214 for 2Tx-2Tx switching in CA case option2. * The UL MIMO is configured in legacy way, and the UE shall follow L1 scheduling and determine if the UL Tx switching needs to be performed according to section 6.1.6 in TS 38.214. During UL Tx switching, the switching period will be applied to the uplink configured as switching period location.   From the RAN1 discussion in May meeting, we understand in general the dynamic switching is still triggered by L1 scheduling as same as what we have in Rel-16/Rel-17. Whether there is further enhancement/restriction on the dynamic switching mechanism is FFS. Then from RAN2 point of view, the main task is to configure uplinks on 3 bands/4 bands with UL MIMO as shown in Figure 2, and provides corresponding UL Tx switching configurations. For the first part, the existing signaling included in *UplinkConfig* seems to be sufficient, i.e. 3 uplinks/4 uplinks configured by *UplinkConfig*. For the second part, in Rel-16/Rel-17 one band is configured as period location as only two UL bands are involved, while in Rel-18 the signaling extension is required to provide information about when Tx is switched between two uplinks which one would be the switching period location when multiple band pairs exist.  ...  **Observation 3: It is straightforward that the uplinks on 3 bands/4 bands for Rel-18 UL Tx switching are configured as in legacy way, i.e. by *UplinkConfig*.**  **Observation 4: Assuming UL Tx switching may involve multiple band pairs in Rel-18, RAN2 signaling extension is required to configure period location for each band pair, which is also pending to RAN1 discussion.** |

Anyway, this issue can be affected by the result of RAN1 down-selection. Thus this may be a potential issue to be discussed after RAN1 input.

**Question 5: Do you agree that RAN2 should discuss after RAN1 input how RRC configures a period location for each band pair within three or four bands?**

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| Company | Yes or No | Comments |
| Ericsson |  | OK to wait |
| Huawei, HiSilicon | See comments | We do agree that which band(s) to apply the switching period depends on RAN1/4 discussion, and it could be via RRC configuration (like in Rel-16/17), or specified directly in RAN1/4 spec. If it is the latter case, there is no RAN2 involvement. Therefore, we understand here is “RAN2 may need to discuss ...”. |
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**Tx state**

Docomo[2] raises a potential issue on the state of Tx chains. In short, the existing configuration of Tx state, *uplinkTxSwitching-DualUL-TxState*, does not have enough granularity to distinguish configured Tx state if candidate bands are more than two, because it has only two value (oneT and twoT):

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| ...  This field, *uplinkTxSwitching-DualUL-TxState-r17*, is configured as either *oneT* or *twoT*. Our understanding is, if configured as *oneT*, “*1Tx is assumed to be supported on the carriers on each band*”, in other words, the “free” Tx chain is switched to (or remaining) the other band than that the “busy” Tx chain is using to transmit, as shown in Figure 3 (b). On the other hand, if configured as *twoT*, “*2Tx is assumed to be supported on that carrier*”, in other words, the “free” Tx chain is switched to (or remaining) the same band as that the “busy” Tx chain is using to transmit, as shown in Figure 3 (c).  ...  However, in the Rel-18 framework, the number of candidate bands which the “free” Tx chain switches to (or remains) is supposed to be three or four, so existing field, *uplinkTxSwitching-DualUL-TxState-r17*, does not seem to have the enough granularity to distinguish possible Tx states, which may result in a mismatch on which band to be set between the UE and the network.  ...  We would like to note that this issue is not the case if Alt.2 is down-selected as a switching mechanism in RAN1, because switching mechanism itself in Alt.2 can be assumed to be the same as Rel-16/17 where a Tx chain switches across only two bands.  **Observation 6. If Alt.1 or Alt.3 is selected in RAN1 for Rel-18 mechanism, the existing RRC configuration does not seem to have the enough granularity to configure a state of Tx chains when the state after the UL Tx switching is not unique.**  **Proposal 6. After RAN1 down-selects a switching mechanism, RAN2 discuss how to configure a state of Tx chains after the UL Tx switching is not unique in Rel-18 framework.** |

Huawei[4] shares their view on this issue that some extension is needed and it can be configured per switching band pair.

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| Assuming both of option1 and option2 to be supported in Rel-18, the existing *uplinkTxSwitchingOption* can be reused to indicate which option is configured by network for UL Tx switching as in the way of Rel-16/Rel-17.  When 2Tx-2Tx switching are being configured in Rel-18 for option2, the *uplinkTxSwitching-DualUL-TxState* may be still needed to address the ambiguity of Tx location. So similarly like switching period location, the Tx state can be configured per switching band pair.  **Observation 5: In Rel-18, the configuration of switching option can reuse the existing *uplinkTxSwitchingOption*.**  **Observation 6: When 2Tx-2Tx switching is configured for option 2, assuming the Tx state of oneT and twoT are configured by RRC, RAN2 signaling extension is needed to configure *uplinkTxSwitching-DualUL-TxState* for each switching band pair, which is also pending to RAN1 discussion.** |

This issue can be affected by the result of RAN1 down-selection. Thus this may be a potential issue to be discussed after RAN1 input.

**Question 6: Do you agree that RAN2 should discuss after RAN1 input how to configure a state of Tx chains after the UL Tx switching is not unique in Rel-18 framework?**

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| Company | Yes or No | Comments |
| Ericsson | Yes |  |
| Huawei, HiSilicon | See comments | The Tx state configuration is an option2 specific issue, whether there is still the issue in Rel-18 should be discussed in RAN1. If RAN1 concludes to introduce a RRC configuration, then RAN2 can just implement the signalling correspondingly. |
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### 3.2.3 Other Issues

Companies raise more other potential issues, which depend on future requests from RAN1 or RAN4.

- New value of switching period ([4], Observation 2)

- New UE capability in place of *ULTxSwitchingBandPair-r16* ([2], Proposal 2)

- New UE capability of switching configuration ([2], Proposal 4)

- New UE capability of band pairs that cannot transmit simultaneously ([2], Observation 5)

- New UE capability of band pairs that cannot be switched across by a Tx chain ([2], Observation 5)

- New UE capability about continuous UL transmission while switching ([2], Observation 5)

**Question 7: Please leave comment if you have concern on any potential issues above, or want to point out new open issues. (No agreements are intended. Hope useful for future discussion.)**

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## 3.3 Target scenario

**Maximum number of bands for Rel-18 switching**

RAN1/2/4 have not yet decided whether Rel-18 UL Tx switching supports up four bands or limit to three bands.

Huawei[4] provides their analysis of construction of UE capability and RRC configuration in their TDoc, and then proposes to agree that there is no issue foreseen that we suffer from only when four bands are supported.

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| Based on above analyze, we understand from RAN2 point of view, there is no issue to support up to 4 bands, as the UE capability reporting for Rel-18 switching period/DL interruption is likely to reuse/mimic the existing signaling framework, which can be common for 3 bands and 4 bands.  **Proposal 2: From RAN2 perspective, there is no issue foreseen for supporting UE capability reporting regardless whether there are 3 bands or 4 bands.** |

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| As explained above, the above extension could be made based on the current framework, and has common impacts for 3 bands and 4 bands.  **Proposal 3: From RAN2 perspective, there is no issue foreseen for reusing R16/R17 RRC configuration framework regardless whether there are 3 bands or 4 bands.** |

**Question 8: Do you agree that from RAN2 perspective, there is no issue foreseen for supporting UE capability reporting regardless whether there are 3 bands or 4 bands?**

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| Company | Yes or No | Comments |
| Ericsson | No | We don’t think we can assume that if we also agree to wait for further RAN1 input on many aspects. The statement is based on the assumption that the existing framework is likely to be reused, but it seems safer to simply wait for RAN1 input. We understand with or without this statement, the RAN2 work will not be affected for now. |
| Huawei, HiSilicon | Yes | The potential RAN2 impact pending to RAN1/4 discussion seems not relevant to the exact band number. |
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**Question 9: Do you agree that from RAN2 perspective, there is no issue foreseen for reusing R16/R17 RRC configuration framework regardless whether there are 3 bands or 4 bands?**

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| Company | Yes or No | Comments |
| Ericsson |  | See comment on Q8 |
| Huawei, HiSilicon | Yes | The potential RAN2 impact pending to RAN1/4 discussion seems not relevant to the exact band number. |
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# 4 Summary of Discussion

# 5 Conclusion

# References

[1] [R2-2208107](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_119-e\Docs\R2-2208107.zip) Consideration on Rel-18 UL Tx switching capability ZTE Corporation, Sanechips discussion Rel-18 NR\_MC\_enh-Core

[2] [R2-2208324](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_119-e\Docs\R2-2208324.zip) Potential issues on UL Tx switching schemes across up to 3 or 4 bands NTT DOCOMO INC. discussion Rel-18

[3] [R2-2208327](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_119-e\Docs\R2-2208327.zip) Work plan for Multi-carrier enhancements NTT DOCOMO INC. Work Plan Rel-18

[4] [R2-2208481](file:///C:\Users\mtk65284\Documents\3GPP\tsg_ran\WG2_RL2\TSGR2_119-e\Docs\R2-2208481.zip) RAN2 impact to support Rel-18 UL Tx switching enhancements Huawei, HiSilicon discussion Rel-18 NR\_MC\_enh-Core