3GPP TSG-RAN WG2 #121 R2-23xxxxx

Athens, Greece, 27th February – 3rd March 2023

**Source: NTT DOCOMO, INC.**

**Title: Summary of [Post121][045][MCE] UL TX Switching (Docomo)**

**Document for: Discussion and decision**

**Agenda Item: 8.21.2**

## Introduction

This document is to report on the following offline discussion:

* [Post121][045][MCE] UL TX Switching (Docomo)

 Scope: “left overs” from this meeting (e.g. FS discussion based on HW tdoc) incl discussion of additional late LS from R1 and R4 if any.

 Intended outcome: Report

 Deadline: Long

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## Discussions

## RAN2 leftovers

##  UE capability for Feature set combinations

**Background**

In RAN2#121, Huawei [1] proposed followings:

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| **Proposal 5: If RAN2 agree the 3/4 *FeatureSetUplink* are reported in one row for the 3/4 UL bands involved in Rel-18 UL Tx switching for a given BC, fallback and backward compatibility should be supported in the following way:*** **The UE needs to guarantee the *FeatureSetUplink*s reported for Rel-18 UL Tx switching are applicable to Rel-16/Rel-17 Tx switching if the Rel-16/Rel-17 switching period is reported for that band pair and the same switching option of the band pair is supported for Rel-16/Rel-17 switching.**
* **The UE needs to report FSC row for Rel-16/Rel-17 UL Tx switching explicitly if the Rel-16/Rel-17 switching period is reported for that band pair.**

**Proposal 6: In order to reduce signalling overhead, the *FeatureSets* reported for Rel-16/Rel-17 Tx switching between 2 bands can be combined to substitute the FSC row of 3/4 UL bands for Rel-18 UL Tx switching.**  |

For Proposal 5, Rapporteur understands that two bullets are ways to avoid cases like:

A legacy network supports up to Rel-17 features while a UE supports both of Rel-18 UL Tx switching and legacy Rel-16/17 UL Tx switching. The legacy network use feature sets on two bands from a feature set combination and starts Rel-16/17 UL Tx switching, while the reported FSC is not applicable for Rel-16/17 switching from UE perspective.

Note that it is under RAN4 discussion whether UEs supporting Rel-18 UL Tx switching always support Rel-16/17 UL Tx switching for the same BC as well. We do not discuss that point and focus on discussion in case of “if the UE supports both Rel-18 and Rel-16/17 UL Tx switching for the same band combination”.

Proposal 6 provides a potential technique to reuse Rel-16/17 FSCs to apply to Rel-18. P6 approach enables to reduce signallings of an FSC specific to a Rel-18 UL Tx switching BC.

As some companies pointed out in the last RAN2 meeting, if we agree on the “combine” of FSCs described in P6, it seems that UEs do not have to report Rel-18 specific FSC, thus we do not have to ensure the first bullet in P5.

First, considering above dependency between P5 and P6, Rapporteur would like to ask which approach for UEs to report an FSC applied to a BC for both Rel-18 and Rel-16/17 UL Tx switching is better for companies:

Approach 1: the 3/4 FeatureSetUplink are reported in one row in FSC for the 3/4 UL bands involved in Rel-18 UL Tx switching;

Approach 2: the FeatureSets reported for Rel-16/17 Tx switching between 2 bands can be combined to indicate UL capabilities on the 3/4 UL bands for Rel-18 UL Tx switching;

Second, if we go with Approach 1, Rapporteur would like to ask whether the first bullet in P5 should be ensured, i.e., the UE needs to guarantee the FeatureSetUplinks reported for Rel-18 UL Tx switching are applicable to Rel-16/Rel-17 Tx switching if the Rel-16/Rel-17 switching period is reported for that band pair and the same switching option of the band pair is supported for Rel-16/Rel-17 switching.

Third, if we go with Approach 1, Rapporteur would like to ask whether the second bullet in P5 should be ensured, i.e., the UE needs to report FSC row for Rel-16/Rel-17 UL Tx switching explicitly if the Rel-16/Rel-17 switching period is reported for that band pair.

**Questions**

**Question 1: Regarding FS reporting for a BC supporting both of Rel-18 UL Tx switching and Rel-16/17 UL Tx switching, which approach do you prefer?**

**Approach 1: the 3/4 FeatureSetUplink are reported in one row in FSC for the 3/4 UL bands involved in Rel-18 UL Tx switching;**

**Approach 2: the FeatureSets reported for Rel-16/17 Tx switching between 2 bands can be combined to indicate UL capabilities on the 3/4 UL bands for Rel-18 UL Tx switching;**

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| Company |  Preference  | Comments |
| OPPO | 1 | Approach-1 seems straightforward, since the point of Tx switching is to allow simul-configuration while avoid simul-scheduling beyond UE capability. And the source of the simul-configuration is the simul-report of 3/4 bands in a same FSC row.  |
| Ericsson | Approach 1 | We think approach 2 is not in line with the current design of UE capabilities. We do not think we should have an entirely different logic on every UE capability aspect just for the sake of UL Tx switching, we should strive to minimize changes as usual. Also the benefits do not seem to justify the complexity. We are saving just one row of feature sets – we already designed featureSetIDs so that there is reuse of features within the UE, thus a single row of featuresetIDs should not be costly in terms of signaling overhead. |
| Huawei, HiSilicon | Approach 2 | First, we think approach 2 is in line with the current UE cap reporting design. Because although in Rel-18 3/4 UL bands are configured at same time, the concurrent transmission/UL scheduling are performed in the scope of a band pair, and each Tx is switched within one band pair. So basically, the Rel-18 switching is composed of a sequence of legacy 1Tx-2Tx/2Tx-2Tx switching, that is why reusing Rel-16/17 UE capability is feasible. Then for clarification, approach 1 will have more than one Rel-18 rows in FSC. For instance, if band pair A+B can support 1Tx-2Tx switching, 2Tx-1Tx switching, as well as 2Tx-2Tx switching, it will report 2 Rel-16 rows and 1 Rel-17 row, i.e. 3 separate rows in Rel-16/17. If this band pair also support Rel-18 switching together with band pair B+C/A+C, then 3 rows need to be reported for Rel-18. And if band pair B+C/A+C also support more than one switching modes, the number of rows will increase exponentially in FSC. A B C DRel-16 row1 1T 2TRel-16 row2 2T 1TRel-16 row3 2T 1TRel-16 row4 1T 2TRel-16 row5 2T 1T Rel-17 row6 2T 2TRel-17 row7 2T 2TIf approach 1 is selected:Rel-18 row8 1T 2T 1T 0TRel-18 row9 2T 1T 2T 0TRel-18 row10 1T 2T 2T 1TRel-18 row11 2T 1T 2T 1TRel-18 row12 2T 2T 2T 1TIf approach 2 is selected, a set of row combination can be reported, i.e.:RowComb1=row1+row3, RowComb2=row2+row4, RowComb3=row1+row7+row5, RowComb4=row2+row4+row5, RowComb5=row2+row2+row5The asn.1 could be straightforward as below:supportedFSC-RowComblist-r18  SEQUENCE (SIZE (1..maxULTxSwitchingFSC-RowComb)) OF FSC-RowCombFSC-RowComb::= SEQUENCE (SIZE (1..maxULTxSwitchingBandPairs)) OF FSC-RowFSC-Row ::= INTEGER(1..maxFeatureSetsPerBand)But the most significant benefit of approach 2 is that it can indicate the maximum UE capability on each band more precisely than approach 1. For instance, the bandwidth of band A is wider than band C, then due to the limitation of baseband capability, the supported bandwidth of band B has to be different when working on band pair A+B from when working on band pair B+C. Approach 1 (i.e. the UE can only report one row for Rel-18 switching on BC A+B+C) cannot reflect the different bandwidth, while approach 2 can (i.e. different bandwidth is reported in different rows). Therefore using approach 2, network can configure multiple BWPs on band B, so that the most appropriate BWP can be used when UL Tx switched on different band pair, to achieve better performance.[ZTE] Just to clarify the above example, for supported bandwidth, it will impact the RRC configuration of UE CBW, so the network cannot change UE’s bandwidth via BWP switching, isn’t it? |
| vivo | Approach 1 | 1. According to our RAN1 colleague, RAN4 did not conclude that support of Rel-18 UL tx switching necessarily requires the support of Rel-16/17 UL tx switching. Some of the UEs are restricted by their capability.2. It is complex for UE to support approach 2. The capability for different releases should be separately reported. |
| ZTE | Approach 1 | Approach 1 looks straightforward. For Approach 2, it seems to have the following restrictions/problems:1. For a given band pair, the UE is unable to report different capability values for the band pair with Rel-16/17 UL Tx switching and the band pair with Rel-18 UL Tx switching.
2. The network is unclear which feature set rows can be combined together, we think we cannot assume that all the combinations are naturally supported by the UE for Rel-18 UL Tx switching.
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| CATT | Approach 1 | Approach 1 is straightforward to us. In addition, since the supported band pairs for Rel-18 can be more than that for Rel-16/17, the feature set row combination of Rel-16/17 may not be able to cover all the switching band-pairs for Rel-18. |
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**Question 2: If Approach 1 is preferred, do you agree The UE needs to guarantee the FeatureSetUplinks reported for Rel-18 UL Tx switching are applicable to Rel-16/Rel-17 Tx switching if the Rel-16/Rel-17 switching period is reported for that band pair and the same switching option of the band pair is supported for Rel-16/Rel-17 switching?**

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| Company |  Yes or No  | Comments |
| OPPO | Yes |  |
| Ericsson | Yes | Assuming the UE reported support also for Rel-16 and Rel-17 switchiong options for that band combination. |
| Huawei, HiSilicon | Yes |  |
| vivo | Yes |  |
| ZTE | Yes |  |
| CATT | Yes |  |
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**Question 3: If Approach 1 is preferred, do you agree the UE needs to report FSC row for Rel-16/Rel-17 UL Tx switching explicitly if the Rel-16/Rel-17 switching period is reported for that band pair?**

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| Company |  Yes or No  | Comments |
| OPPO | No | That seems break the fallback spirit in UE capability reporting. |
| Ericsson | No | If Question 2 is agreed, there is no need to report a row only for Rel-16/17 switching.  |
| Huawei, HiSilicon | Yes | This is to ensure that Rel-16/17 network have per-FS Rel-16/17 UE capability. Unlike NR CA for which 32 CCs are supported from the first release, when UL Tx switching was introduced in Rel-16, the objective/scope is clearly limited to two bands, which is also captured in specifications. So it is not the same case of NR CA fallback capability. And it is risky to assume Rel-16/17 network can predict there will be more than 2 UL bands reported, and it needs to be able to comprehend UE capability reporting for a BC including more than 2 UL bands, and derive the UE capability for a band pair. So we think it would be safer if UE reports Rel-16/17 rows in FSC to avoid potential inter-operability issue with Rel-16/17 network.Please also note that even if assuming legacy network can derive legacy UL Tx switching capability from the Rel-18 row, the UE may still want to report Rel-16/17 rows indicating bigger UE cap, just like for NR CA, the UE reports a lot of “different fallback capability”. |
| vivo | No | According to Q2, it should not be required to do so. |
| ZTE | Yes with comment | In our understanding, with approach 1, the logics are:1. For feature sets row reported for Rel-18 UL Tx switching, the components are also applicable for Rel-16/17 UL Tx switching (fallback rule);
2. The UE **may** report separate feature sets row for Rel-16/17 UL Tx switching, if the UE supports different (or higher) capability values compared with the values signalled for Rel-18 UL Tx switching.
 |
| CATT | Yes | On our perspective, Rel-16/Rel-17 UL Tx Switching capabilities should anyway be reported separately for:1. The supported band pairs for Rel-16/Rel-17 may be different with those for Rel-18, thus it’s not feasible to derive all the Rel-16/Rel-17 capabilities directly from the Rel-18 UL Tx Switching capability.
2. The network may not be able to decode Rel-18 capability IEs that it would not obtain Rel-16/17 capabilities if only Rel-18 feature sets for UL Tx Switching are reported.
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##  RRC configuration of *uplinkTxSwitching-DualUL-TxState-r17*

**Background**

RAN2 has made following agreement in RAN2#121.

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| * For RRC configuration to clarify ambiguous Tx state, RAN2 should introduce an RRC configuration that associates a band to another band which the unused Tx chain is switched to when the switch is from concurrent transmission on two bands to 1 Tx transmission on another band.
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Related to above agreement, yellow part of following proposal by Huawei [1] was discussed but not concluded.

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| **Proposal 9: For Rel-18 UL Tx switching among 3/4 bands, existing signalling *uplinkTxSwitching-DualUL-TxState-r17* is reused to indicate the state of Tx chains for *dualUL* mode. A new per-band RRC configuration is introduced to configure associated band for each band, which indicates on which band one Tx is assumed when the other Tx chain is to be switched to a band, if *oneT* is configured in *uplinkTxSwitching-DualUL-TxState-r17*.** |

**Questions**

**Question 4: Do you agree to reuse *uplinkTxSwitching-DualUL-TxState-r17* to indicate the state of Tx chains for dualUL mode?**

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| Company |  Yes or No  | Comments |
| Docomo | Yes | RAN1 made following agreements in RAN1#111.

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| Agreement:Following working assumption is confirmed with updates.Working Assumption~~At least~~ for dual UL, reuse existing RRC parameter {oneT, twoT} via uplinkTxSwitching-DualUL-TxState to solve the issue on ambiguous switching state at least for following cases* Case#1 of the issue: two Tx chains are currently associated with band A, and next transmission is 1 port transmission on band B, but there are multiple possible switching cases where 1P on band B is supported
	+ if twoT is indicated, both of two Tx chains are switched to band B
	+ if oneT is indicated, one Tx chain is switched to band B while another Tx chain remains on band A
* Case#2 of the issue: two Tx chains are currently associated with band A and B, and next transmission is 1 port transmission on band C, but there are multiple possible switching cases where 1P on band C is supported
	+ if twoT is indicated, both of two Tx chains are switched to band C
	+ if oneT is indicated, one Tx chain is switched to band C while how to determine the associated band for another Tx chain is ~~FFS~~
		- ~~Alt.1:~~ based on ~~gNB’s configuration/indication e.g.,~~ new RRC parameter
		- ~~Alt.2: based on predefined rule~~
		- ~~Other alternative is not precluded~~
* ~~FFS for other potential cases~~
 |

As highlighted as blue, RAN2 is required to reuse *uplinkTxSwitching-DualUL-TxState*. In our understanding, when only one Tx chain is expected to be transmitting, the UE and the gNB identify the other Tx chain’s state by following parameters:* *uplinkTxSwitching-DualUL-TxState* (per cell group): configures whether the other Tx chain should be associated with the same band as transmitting band (twoT), or not (oneT).
* *associatedBand* (per band, new parameter agreed in RAN2#121): configures the associated band to which the other Tx chain switches when “oneT” is configured to the cell group and the switching pattern is like A+B => C (i.e., the Tx chains are associated with two different bands before switching and these bands are different from the target band).
 |
| OPPO | See comment | If the suggested way-out in Q6 is adopted, OK, otherwise, we need to further analyse.  |
| Ericsson | Yes | Agree with rapporteur. |
| Huawei, HiSilicon | Yes | Agree with rapporteur. It is RAN1’s agreement to reuse existing uplinkTxSwitching-DualUL-TxState. There might be ambiguity when a band involved in dualUL and switchedUL at the same time, but it can be addressed via some clarification as discussed in Q5/6, thus we think RAN2 can follow this RAN1 agreement. |
| vivo | Yes | Agree with rapporteur. |
| ZTE | Yes | Agree with rapporteur. |
| CATT | Yes | Agree with rapporteur. |
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##  RRC configuration of Tx states (chicken-and-egg issue)

**Background**

In RAN2#121, OPPO [2] proposed to solve a chicken-and-egg issue on the RRC configuration of associated Tx chain as following:

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| …So obviously per-BC configuration is clear, i.e., all bands in the CG share the same configuration. But it loses some flexibility, i.e., network has to ensure dualUL, if configured, applies to all configured bands. For the proposal of adding per-band/cell-pair configuration on top of the per-BC configuration, it is contradictory since* On the one hand, UE has to rely on option configuration to know whether to check Tx-State configuration, and further to know the state of the other Tx;
* On the other hand, only after knowing the state of the other Tx, UE can based on the corresponding per-band/cell-pair option configuration to know whether to check Tx-state configuration.

So there is a chicken-and-egg issue, and thus not a feasible solution. 1. For RRC configuration on option and Tx state, adopt per-BC configuration. If per-cell-pair configuration is used, R2 clarifies how to make use of it together with the ‘associated-band’ configuration agreed by R1.
 |

Now we have concluded to introduce both “per-cell-pair” configuration (of switching options) and “associated-band configuration agreed by R1” as follows [3], thus we could have to clarify how the UE should behave in above situation.

Rapporteur tries to elaborate this issue based on our understanding. RAN1 made following agreements in RAN1#111:

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| Agreement:Following working assumption is confirmed with updates.Working Assumption~~At least~~ for dual UL, reuse existing RRC parameter {oneT, twoT} via uplinkTxSwitching-DualUL-TxState to solve the issue on ambiguous switching state at least for following cases* Case#1 of the issue: two Tx chains are currently associated with band A, and next transmission is 1 port transmission on band B, but there are multiple possible switching cases where 1P on band B is supported
	+ if twoT is indicated, both of two Tx chains are switched to band B
	+ if oneT is indicated, one Tx chain is switched to band B while another Tx chain remains on band A
* Case#2 of the issue: two Tx chains are currently associated with band A and B, and next transmission is 1 port transmission on band C, but there are multiple possible switching cases where 1P on band C is supported
	+ if twoT is indicated, both of two Tx chains are switched to band C
	+ if oneT is indicated, one Tx chain is switched to band C while how to determine the associated band for another Tx chain is ~~FFS~~
		- ~~Alt.1:~~ based on ~~gNB’s configuration/indication e.g.,~~ new RRC parameter
		- ~~Alt.2: based on predefined rule~~
		- ~~Other alternative is not precluded~~

~~FFS for other potential cases~~ |

What we would like to emphasize is, “for dualUL”, highlighted as blue. Simply thinking, this condition means to exclude the use of *uplinkTxSwitching-DualUL-TxState* when the switching option is configured as switchedUL.

By the way, we have agreed to configure switching options per band pair. Now given a UE is switching across bands A, B, and C, like A+B=>C where the switching option is configured as “A+C: switchedUL” and “B+C: dualUL”.



**Figure X. The UE knows the switching option when the Tx chain is fixed.**

As Figure X shows, the UE knows which switching option is configured only after the state of Tx chains is fixed. As said above, it depends on the option whether *uplinkTxSwitching-DualUL-TxState* can be read. However, the UE cannot identify the Tx state unless it reads *uplinkTxSwitching-DualUL-TxState* (and the associated band). This is something like a deadlock.

First, rapporteur would like to ask if we need some clarification for this issue.

If some clarification is needed, one simple way is that the UE reads *uplinkTxSwitching-DualUL-TxState* (and the associated band) regardless of the switching option. Rapporteur would like to ask whether this solution is ok for companies, or other solutions can be considered. If we go with this interpretation, an LS to inform RAN1 of our understanding may be needed.

**Questions**

**Question 5: Do you agree that it is unclear which band the UE should switch to when the UE is scheduled to one-band one-Tx chain transmission while the switching options for band pairs including the band are different?**

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| Company |  Yes or No  | Comments |
| OPPO | See comment | If we follow the legacy way: i.e., firstly check the option configuration and then check Tx-state if the option configuration =dualUL, then the problem exists.  |
| Ericsson |  | Similar view as OPPO |
| Huawei, HiSilicon |  | The question seems to be which option (i.e. switchedUL or dualUL) is followed when the to-be-scheduled band is involved in one switchedUL band pair and one dualUL at the same time. |
| vivo |  | Agree with OPPO |
| ZTE | No | We have different views on the problem that we are discussing. The confusion appears because the RAN1 agreement starts with “dual UL”. But based on the discussion with our RAN1, we think this “dualUL” does not mean the switching option of “target” band pair. The intention is to say the network needs to ensure the UE supports dual UL for “scheduled band” and “associated band”. From UE perspective, based on the scheduling, the UE knows whether 1T(1 port) or 2T(2 ports) is switched to band C. If only 1Tx is switched to band C and uplinkTxSwitching-DualUL-TxState is set to 1T, then the UE can switch another Tx chain to the associated band.  |
| CATT | Yes | As legacy approach, if the switching option is not dualUL, UE will consider the Tx state is 2T. But, if the switching options for (A,C) or (B,C) are different, i.e., one of them is configured as switchedUL, both 1T and 2T are possible. However, it’s not clear whether UE should check *uplinkTxSwitching-DualUL-TxState* or not, hence it’s not clear the the Tx state will be 1T or 2T in that case. |
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**Question 6: Do you agree to allow UEs to follow *uplinkTxSwitching-DualUL-TxState* (and the associated band) regardless of the switching option?**

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| Company |  Yes or No  | Comments |
| OPPO | Yes | This way-out is OK for us.  |
| Ericsson | Yes | We are fine with this option.  |
| Huawei, HiSilicon | Yes | This means dualUL is followed when the to-be-scheduled band is involved in one switchedUL band pair and one dualUL at the same time. It makes sense considering dualUL may achieve better performance than switchedUL. |
| vivo | Yes |  |
| ZTE | Yes with comment | As we commented in Q5, we agree that the UE can check uplinkTxSwitching-DualUL-TxState without checking the target switching option. But the network needs to ensure the configurations are compatible, for example:* + - 1. The network ensures the UE supports dualUL for a band and its associated band;
			2. associatedBand is configured only if at least one band pair is configured with dualUL and uplinkTxSwitching-DualUL-TxState is set to 1T;
			3. If only “switchedUL” is configured, uplinkTxSwitching-DualUL-TxState IE will not be configured, the UE always switches its 2Tx simultaneously;
 |
| CATT | No | We echo with ZTE’s comments. But we don’t agree there is no restriction on UE checking *uplinkTxSwitching-DualUL-TxState.* UE should only need to check *uplinkTxSwitching-DualUL-TxState and associatedBand* when there is at least one band pair is configured with dualUL. When both the associated band pairs are configured as swithedUL, 1Tx state is not possible and UE will assume the Tx state as 2Tx. |
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## RAN1 agreements

## RRC configuration of switching period location

**Background**

RAN1 has made following agreements in the latest meeting [4]:

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| **Agreement**Alt.5: gNB configures priorities to each carrier/band.* The gNB configures priority for each band. The UE determines the switching period location on either switching-from band(s) or switching-to band(s) that is involved in the UL Tx switching and is not with the highest priority band.
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This agreement is to “protect” high-priority bands out of suffering from Tx interruption due to switching period. The gNB configures priority for each band for use of Rel-18 UL Tx switching. Then the gNB and the UE interprets each switching period is located to switch-from or switched-to bands, avoiding the highest priority band among the bands involved in the switch.

In rapporteur’s understanding, all RAN2 should do is to implement an RRC configuration of the priority of bands. In concrete, it seems to be enough to introduce a list of bands in *CellGroupConfig*, in which the priority is configured by the order.

**Questions**

**Question 7: Do you agree to introduce a list of bands in *CellGroupConfig*, in which the priority is configured by the order?**

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| Company |  Yes or No  | Comments |
| OPPO | Yes |  |
| Ericsson | Yes, but | We assume it would be optional to configure this field. The NW would not be required to configure this as long as it schedules the UE respecting the switching period. |
| Huawei, HiSilicon | Yes | Similar view as Ericsson, RAN1 clarified for Rel-16/17 switching, the switching period location is to be used only when scheduling gap cannot cover the switching period. Thus whether to provide this configuration seems to be up to network implementation?  |
| vivo | Yes | Agree with above opinions that this is an optional field. |
| ZTE | Yes | Same view as Ericsson, the field can be optional.  |
| CATT | Yes | Agree with above comments. |
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## RAN4 agreements

##  UE capability for UL Tx while switching

**Background**

RAN4 has sent an LS [5] to RAN2 including following description:

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| **Issue 3: Impact from switching of one Tx chain on the other Tx chain****Scenario of one band with the number of Tx chain unchanged due to switching**When one of the two Tx chains is triggered to switch from one band (named “band A”) to another band (name “band B”), the other Tx chain is maintained on a different band (named “band C” or “band D” in the case of 4-band) and the number of Tx chain on band C or band D is unchanged due to the switching, RAN4 agreed the granularity of the optional UE capability to allow UL transmission on the band with the number of Tx chain unchanged during UL switching as follows: * Per band (only for the band(s) in the band combination but not included in the pair of bands before and after switching) for each pair of bands before and after switching in each band combination.

**In addition, RAN4 would like to ask RAN1 one question:** From RAN1 perspective, is it possible that the two Tx chains are switched concurrently between two different band pairs and with overlapping switching period? Two examples are given below:* Example #1: In the case of 3-band Tx switching, the switching is performed from 1T+1T on band A and B to 2T on band C.
* Example #2: In the case of 4-band Tx switching, the switching is performed from 1T+1T on band A and B to 1T+1T on band C and D.
 |

As highlighted in yellow, RAN4 has made an agreement on the granularity of the UE capability to allow UL transmission on the band whose number of Tx chain is unchanged through the switch. One simple way is to introduce a per-band-pair report of bands that can be transmitted while the other Tx chain is switching across that band pair. Following figure is an example where Band C is included in the new field for the band pair A and B, to report it can be transmitted without interruption while the other Tx chain is switching across Band A and B.



**Figure X. (Example) Band C can be transmitted without interruption while the other Tx chain is switching across Band A and B.**

**Questions**

**Question 8: Do you agree to introduce a per-band-pair report of bands that can be transmitted while the other Tx chain is switching across that band pair?**

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| Company |  Yes or No  | Comments |
| OPPO | Yes |  |
| Ericsson | Yes | We understand that absence of this field would mean that there is interruption in all bands during the switching. |
| Huawei, HiSilicon | Yes | Same view as Ericsson, this capability is optional, and the absence means all bands have interruption. |
| vivo | Yes |  |
| ZTE | Yes | This solution looks simple to us. Agree with Ericsson that the capability is optional.  |
| CATT | Yes | Agree with above comments. |
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##  UE capability for length of switching period

**Background**

RAN4 has sent an LS [5] to RAN2 including following description:

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| **Issue 1: Exact value of Tx switching period for each band pair**RAN4 discussed the exact value of Tx switching period for each band pair in the band combination, and has agreed that:* For Rel-18 UE, for a band pair within a band combination supporting Tx switching among 3/4 bands, the switching period reported by UE for Rel-18 3/4-band Tx switching can be the same or different from the switching period for Rel-16/17 2-band switching operations.
	+ Note 1: the set of candidate values is still the same, i.e., {35 us, 140 us, 210 us}, according to the agreement in RAN4 #104e.
	+ Note 2: here the band pair is a pair of bands within which there is a switching with a switching period.
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As highlighted in yellow, RAN4 agreed that a separate Rel-18 value of a length of the switching period can be reported. Rapporteur understands RAN2 should introduce a new field for per-band-pair report of a separate length of switching period for Rel-18, i.e., by the similar way to when *uplinkTxSwitchingPeriod2T2T-r17* was introduced in Rel-17.

In addition, there is one point we should clarify: does RAN2 introduce separate UE capabilities of length of switching periods for “1Tx-2Tx” switching and “2Tx-2Tx” switching, or that of one (unified) switching period? In legacy, the lengths of switching periods for Rel-16 switching and Rel-17 switching are reported separately.

ULTxSwitchingBandPair-r16 ::= SEQUENCE {

 bandIndexUL1-r16 INTEGER(1..maxSimultaneousBands),

 bandIndexUL2-r16 INTEGER(1..maxSimultaneousBands),

 uplinkTxSwitchingPeriod-r16 ENUMERATED {n35us, n140us, n210us},

 uplinkTxSwitching-DL-Interruption-r16 BIT STRING (SIZE(1..maxSimultaneousBands)) OPTIONAL

}

ULTxSwitchingBandPair-v1700 ::= SEQUENCE {

 uplinkTxSwitchingPeriod2T2T-r17 ENUMERATED {n35us, n140us, n210us} OPTIONAL

}

Now in Rel-18, the UE can report that only some bands support 2-layer MIMO UL according to following RAN2 agreement. This means that both 1Tx-2Tx switching and 2Tx-2Tx switching are possible in Rel-18 framework.

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| * For UE capability of 2-port UL transmission, RAN2 reuse the per-FS UL-MIMO UE capability (no spec change).
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Furthermore, RAN4 [5] informed us of their discussion on switching period applied for 1Tx-1Tx switching. It says that *the same length of switching period for 1Tx-1Tx switching and 1Tx-2Tx switching*, which implies there should be switching periods for “1Tx-2Tx switching” and “2Tx-2Tx switching”.

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| **Issue 2: 1Tx-1Tx switching case**In RAN4 #106, RAN4 discussed the scenario of 1Tx-1Tx switching, i.e., the UL carriers in both bands before and after switching are capable of one transmit antenna connector, and agreed to apply the same length of switching period for 1Tx-1Tx switching and 1Tx-2Tx switching. |

**Questions**

**Question 9: Do you agree to introduce (a) new per-band-pair UE capability(ies) to report a length of a switching period for Rel-18?**

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| Company |  Yes or No  | Comments |
| OPPO | Yes |  |
| Ericsson | Yes |  |
| Huawei, HiSilicon | Yes |  |
| vivo | Yes |  |
| ZTE | Yes |  |
| CATT | Yes |  |
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**Question 10: Which matches to your understanding better?**

**Alt.1: RAN2 introduce one per-band-pair UE capability to report a length of a switching period.**

**Alt.2: RAN2 introduce two per-band-pair UE capabilities, a length of a switching period for 1Tx-2Tx switching (like Rel-16) and that for 2Tx-2Tx switching (like Rel-17).**

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| Company |  Preference  | Comments |
| OPPO | Alt1 | After check with our R4 colleague, the reply on issue-2 did not mean to have separate reporting.  |
| Ericsson | Alt1 | We think Alt1 is sufficient. Even if the values between 1Tx-2Tx and 2Tx-2Tx would be slightly different, with a single field the UE could anyway report the higher applicable value. |
| Huawei, HiSilicon | Alt2 | According to the following RAN4 agreement in R4-2214464, both of 1Tx-2Tx switching and 2Tx-2Tx switching can be supported for a Rel-18 band pair, and switching period can be same or different. Then only alt.2 is feasible to report different values for 1Tx-2Tx switching and 2Tx-2Tx switching. And only alt.2 is feasible to cover 1Tx-1Tx case which means there should be a value for 1Tx-2Tx/1Tx-1Tx switching.* For each band pair, the switching period can be the same or different for 1Tx-2Tx switching and 2Tx-2Tx switching based on UE reporting, which is similar as in Rel-17.
	+ Note: For UE reporting different periods for 1Tx-2Tx switching and 2Tx-2Tx switching for a band pair, similar to Rel-17, it is RAN4 understanding that the 2Tx-2Tx switching period is applied when 2Tx-2Tx switching mode is configured.
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| vivo | Alt1 | If the periods of 1T2T and 2T2T are the same, then only one period to be reported is needed; otherwise, UE and gNB follows the period of 2T2T even if they are different.As a result, reporting only one period is enough. |
| ZTE | Alt 1, or up to RAN4 | We tend to agree with Ericsson that the UE can report a single value to cover both 1Tx-2Tx and 2Tx-2Tx.If we go for Alt2, then we also need to indicate 1Tx-2Tx and 2Tx-2Tx in RRC configuration, to inform the UE which switching period will be applied, if the UE supports both. This is more complex. But we are wondering whether this should be determined by RAN4? |
| CATT | Alt.2 with optimization | As it has been agreed by RAN1 that the value for 1Tx-2Tx switching and 2Tx-2Tx switching periods can be different, we don’t think it’s good for UE to report only one single value even if the bigger one among them is reported.Considering the big possibility that the value for 1Tx-2Tx and 2Tx-2Tx periods is the same, an optimization for signalling reduction on Alt.2 can be that the value for 2Tx-2Tx period is only reported when it is different to the value for 1Tx-2Tx period. |
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## Summary and proposal

TBD

## References

[1] R2-2301180, “RAN2 signalling design for Rel-18 UL Tx switching enhancements,” Huawei, HiSilicon, RAN2#121.

[2] R2-2300139, “Discussion on R18 UL Tx switching,” OPPO, RAN2#121.

[3] “Chair Notes,” RAN2 Chairman (MediaTek), RAN2#121.

[4] “Summary#3 of discussion on multi-carrier UL Tx switching scheme,” Moderator (NTT DOCOMO, INC.), RAN1”112.

[5] R4-2303507, “LS on Rel-18 Multi-carrier enhancement for NR,” RAN4#106.