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

## Contact Points

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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. |
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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. |
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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.  |
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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.
 |

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).
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| OPPO | See comment | If the suggested way-out in Q6 is adopted, OK, otherwise, we need to further analyse.  |
| Ericsson | 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 |
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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.  |
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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.
 |

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. |
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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. |
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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.
 |

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).
 |

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 |  |
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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. |
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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.