**3GPP TSG RAN WG1 #110bis-e R1-2210280**

**e-Meeting, October 10th – 19th, 2022**

**Agenda item:** 9.9.2

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

**Title:** Summary#1 of discussion on multi-carrier UL Tx switching scheme

**Document for:** Discussion and Decision

1. Introduction

This contribution summarizes the following email discussion in AI 9.9.2 regarding the multi-carrier UL Tx switching scheme.

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| [110bis-e-R18-MC\_Enh-02] Email discussion on multi-carrier UL TX switching scheme by October 19 – Hiroki (NTT DOCOMO)* Check points: October 14, October 19
 |

1. References

[1] RP-222251 Revised WID on Multi-carrier enhancements NTT DOCOMO, INC.

[2] R1-2208427 Discussion on multi-carrier UL Tx switching Huawei, HiSilicon

[3] R1-2208487 Discussion on Multi-carrier UL Tx switching scheme ZTE

[4] R1-2208565 Discussion on multi-carrier UL Tx switching scheme Spreadtrum Communications

[5] R1-2208659 Discussion on UL TX switching vivo

[6] R1-2208780 Discussion on UL Tx switching across up to 3 or 4 bands China Telecom

[7] R1-2208861 Discussion on multi-carrier UL Tx switching scheme OPPO

[8] R1-2208992 Discussion on multi-carrier UL Tx switching scheme CATT

[9] R1-2209068 Discussions on multi-carrier UL Tx switching scheme Intel Corporation

[10] R1-2209300 Discussion on multi-carrier UL Tx switching scheme xiaomi

[11] R1-2209353 Discussion on multi-carrier UL Tx switching scheme CMCC

[12] R1-2209455 Discussion on Multi-carrier UL Tx switching scheme LG Electronics

[13] R1-2209596 On multi-carrier UL Tx switching Apple

[14] R1-2209747 On multi-carrier UL Tx switching Samsung

[15] R1-2209772 On multi-carrier UL Tx switching scheme MediaTek Inc.

[16] R1-2209861 Multi-carrier UL Tx switching Ericsson

[17] R1-2209918 Discussion on Multi-carrier UL Tx switching scheme NTT DOCOMO, INC.

[18] R1-2210001 Discussion on Rel-18 UL Tx switching Qualcomm Incorporated

[19] R1-2210035 Discussion on multi-carrier UL Tx switching scheme Google Inc.

[20] R1-2210192 On Multi-Carrier UL Tx Switching Nokia, Nokia Shanghai Bell

1. Discussions on complexity reduction options for Rel-18 multi-carrier UL Tx switching

At the last RAN1 meeting, following working assumption was made, and companies are encouraged to investigate the complexity reduction options with striving for down-selection at this RAN1 meeting.

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| **Working Assumption*** If Rel-18 UL Tx switching is supported, following switching mechanism is considered as baseline for the Rel-18 UL Tx switching across 3 or 4 bands
	+ 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 dynamic grant and/or RRC configuration for UL transmission
* RAN1 will support one or more of following complexity reduction options, considering at least the potential additional preparation time, additional interruption time, and RF complexity for certain switching cases/patterns, if Rel-18 UL Tx switching is supported based on Alt.1, and companies are encouraged to investigate options with striving for down-selection at RAN1#110bis-e.
	+ Option 1: UE is allowed to support only some of concurrent UL cases (band pairs)
		- FFS: at least one band pair should be supported as in Rel-17
		- FFS: for both 3 and 4 bands cases or only for 4 bands case
		- FFS: potential capability/RRC signaling
	+ Option 2: UE is allowed to support 2 ports transmission only on some of bands out of configured bands for UL Tx switching
		- FFS: at least two bands should support up to 2 Tx as in Rel-17
		- FFS: for both 3 and 4 bands cases or only for 4 bands case
		- FFS: for both switched UL and dual UL cases or only for dual UL case
		- FFS: whether/how to reuse or extend existing capability/RRC signaling
	+ Option 3: UE is allowed with more preparation procedure time (or interruption time) only for some specific switching cases/patterns
		- FFS: specific switching cases/patterns where more preparation procedure time (or interruption time) is necessary, e.g., switching patterns not existed in Rel-17
		- FFS: how long preparation procedure time and/or interruption time is necessary, and whether RAN4 involvement is necessary
		- FFS: whether/how to report/indicate the specific switching cases/patterns and/or value(s) of preparation procedure time (or interruption time)
		- FFS: what is the definition of preparation procedure time or interruption time, including whether interruption happens during the preparation procedure time and whether it includes switching period
		- FFS: whether/how long minimum interval between two succeeding UL Tx switching is necessary
	+ Option 4: UE is allowed to support only some of band pairs for tx switching
		- FFS: at least one band pair should be supported as in Rel-17
		- FFS: for both 3 and 4 bands cases or only for 4 bands case
		- FFS: for switched UL and/or dual UL
		- FFS: potential capability/RRC signaling
	+ Other options are not precluded
 |

## 3.1 Option 1: UE is allowed to support only some of concurrent UL cases (band pairs)

In contributions in AI 9.9.2, following observations and proposals were made regarding complexity reduction option 1.

|  |  |
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| [2] | ***Observation 5:*** *Both* ***complexity reduction*** *Option 1 and Option 4 are dedicated only to UL-CA Option 2.****Observation 6:*** *For dynamic UL Tx switching among 3 or 4 bands,** *Option 1 can alleviate UE memory management for UL-CA Option2.*
* *Option 4 cannot solve the UE memory issue and is unreasonable because the size of UE memory is not related to the number of band pair.*
* *Option 2 has been supported by existing UE capability reporting.*
 |
| [3] | ***Observation 2****: For complexity reduction Option 4, UE can achieve the same reporting flexibility as complexity reduction Option 1 by indicating different band pairs for switchedUL and dualUL. Meanwhile, the switchedUL/dual UL indication remains as per BC (band combination) report.****Proposal******6****: If one of complexity reduction Option 1 and complexity reduction Option 4 is to be adopted, then Option 4 is supported.* |
| [4] | 1. ***RAN1 can support Option 1: UE is allowed to report the supportive only some of concurrent UL cases (band pairs) for both 3 and 4 bands.***
 |
| [5] | Observation 1: Option 1 and option 2 allow flexible UE implementation and reduce UE complexity.**Proposal 1: If Option 1 and option 2 are supported, they can be applied for TX switching with 3 bands and TX switching with 4 bands. Moreover, option 2 can be applied for both switched UL and dual UL cases.** |
| [6] | **Proposal 11: For Rel-18 UL Tx switching across up to 3 or 4 bands, to reduce UE complexity,*** **UE is allowed to support only some of concurrent UL cases on 2 (out of 3 or 4) bands.**
* **UE is allowed to support 2 ports transmission only on at least 1 band out of configured bands.**
* **UE is allowed with more preparation procedure time only for some specific switching cases/patterns.**
 |
| [7] | ***Proposal 1: Option 1 -4 are benefit for complexity reduction and can be considered to be specified.***  |
| [8] | **Proposal 1：UE is allowed to support only some of concurrent UL cases (band pairs)*** **For 3 bands operation, up to one band pair can be supported.**
* **For 4 bands operation, up to two band par(s) can be supported, and there is no intersection band between two band pairs(s)**

**Proposal 19: All UL Tx switching cases are supported in R18 specification, and gNB can configure sub-set of switching cases according to reported UE capability.** |
| [9] | **Proposal 4*** For Rel-18 multi-carrier Tx switching, at least Option 1 and Option 2 can be supported for complexity reduction.
	+ For Option 1, at least one band pairs need to support concurrent uplink transmission.
	+ For Option 2, at least two bands should support up to 2 Tx.
	+ UE capability is introduced UE to report concurrent uplink cases or 2 ports transmission on some of the bands that are supported for Tx switching
 |
| [11] | **Proposal 2. For Rel-18 UL Tx switching, concurrent transmission on any two bands among 3 or 4 bands can be supported based on UE CA capability reporting.** |
| [12] | **Proposal #1: Complexity reduction options for UL Tx switching across 3 or 4 bands can be supported as a UE capability.** **Proposal #2: Revise the WA as follows.*** **Remove Option 4**
* **Add the following Notes and remove FFSs which is related to the Note**
	+ **Note: Rel-18 UL Tx switching should cover all switching cases which are supported in Rel-17.**
	+ **Note: Above option(s) can be applied for both 3 and 4 bands cases, if supported.**

**Proposal #5: Discuss how to configure one of options between {‘switchedUL’, ‘dualUL’} when UL Tx switching is configured for a set of bands belonging to multiple different band combinations.** |
| [13] | ***Proposal 2: For supporting NR Rel-18 UL Tx switching across 3 or 4 bands, limiting/removing certain switching cases for certain bands/band combinations should be avoided:**** ***Option 1, 2 and 4 from the WA should be considered with lower priority***
 |
| [14] | **Proposal 2:** *Rel-18 UL Tx Switching for 3 or 4 bands supports UE complexity reduction Options 1, 2 and 4***Proposal 3:** *For Options 1, 2 and 4, at least one band pair should be supported as in Rel-17 and UE capability indication is provided separately for 3 and 4 bands cases* |
| [15] | 1. ***For UL Tx switching among 3/4 bands:***
* ***Support Option#1 and Option#2.***
* ***Do not support Option#4.***
* ***Consider Option#3 with the following modification: “UE is allowed with more preparation procedure time ~~(or interruption time) only~~ for ~~some specific~~ all switching cases/patterns”.***
 |
| [16] | 1. Dynamic UL TX switching across 3 or 4 bands for UL CA should include concurrent transmission on any two bands among 3 or 4 bands.
 |
| [17] | **Observation 1: The complexity reduction Option 1 is applicable to Inter-band UL CA dual UL scenario where a UE is capable of at least one band pair among 3 or 4 bands for concurrent UL transmission. For UL Tx switching with 3 or 4 bands, there would be some implementations where a Tx chain is applicable to only some of 3 or 4 bands but not all bands so that concurrent UL transmission for some band pair(s) cannot be performed.****Proposal 2: To ensure the clear performance gain of Rel-18 dual UL with complexity reduction Option 1 over Rel-17 dual UL or Rel-18 switched UL, it is preferable to consider complexity reduction Option 1 with some condition, e.g., for both 3 and 4 bands cases, at least two band pairs should be supported for the concurrent transmission if the UE indicates the support of dual UL.****Proposal 3: For complexity reduction Option 1, whether the number of supported switching cases is reduced or not should be discussed.****Proposal 8: At least following UE capability and RRC signaling should be considered for Rel-18 UL Tx switching across 3 or 4 bands with potential complexity reduction options.*** **UE capability regarding the supported option (switched UL and/or dual UL) for Rel-18 UL Tx switching across 3 or 4 bands**
	+ **Corresponding RRC signaling to configure either switched UL or dual UL**
		- **If the complexity reduction Option 1 is supported, UE may support concurrent transmission only on some of band pairs, and hence UE/gNB needs to report/configure specific band pairs where concurrent transmission is possible/expected. Existing parameter such as *up-linkTxSwitchingOption* in *CellGroupConfig* cannot be reused in such case and new parame-ter would be necessary.**
 |
| [19] | **Observation 1: Option 1 can be satisfied by introducing a new UL Tx switching band pair capability for 1T-1T case (e.g. *ULTxSwitchingBandPair*-r18 and *uplinkTxSwitching-OptionSupport-r18*).** **Proposal 1: UE should support Option 1, 2 and 3 by introducing new band pair UE capability for 1T-1T (e.g. *ULTxSwitchingBandPair*1T-1T-r18), 1T-2T (e.g. *ULTxSwitchingBandPair*1T-2T-r18), and 2T-2T (e.g. *ULTxSwitchingBandPair*2T-2T-r18) Tx states, each band pair parameter includes*** **a uplink Tx switching option indication (e.g. *uplinkTxSwitching-OptionSupport-r18*), and**
* **a Tx switching period (e.g. *uplinkTxSwitchingPeriod1T1T-r18*)**
 |
| [20] | **Proposal 3: Complexity reduction Option 1 is not supported:** * **A DualUL capable UE is required to be able to transmit simultaneously two 1-port transmissions on any band pair out of the band combination**
 |

Based on above, the situation can be summarized as below.

|  |
| --- |
| * Support complexity reduction option 1 for dual UL [2], [4], [5], [6], [7], [8], [9], [11], [12], [14], [15], [17], [19]
	+ Regarding the restriction on number of band pairs to be supported for concurrent transmission:
		- No restriction for both 3 bands and 4 bands [4], [12]
		- At least one band pair for both 3 bands and 4 bands if dual UL support is reported [6], [7], [9], [14]
		- Up to one band pair for 3 bands and up to two band pairs for 4 bands [8]
		- At least two band pairs for both 3 bands and 4 bands if dual UL support is reported [17]
	+ UE capability to report the supported band pairs [4], [5], [6], [7], [9], [12], [14], [17], [19]
		- Just depend on UE CA capability and band type [11]
		- The supported band pairs for concurrent transmission require support of UL CA [5], [6]
	+ RRC signaling to indicate the possible band pairs [4], [12], [17]
	+ The switching case associated with not supported concurrent transmission band pair(s) is unnecessary [9]
		- gNB can configure subset of switching cases according to reported capability [8]
		- Whether such switching case is removed or not can be discussed [17]
* Between complexity reduction option 1 and 4, option 4 is preferred [3]
* Complexity reduction option 1 should be considered with lower priority [13]
* The design should not impose restriction on concurrent transmission, but the complexity can be addressed by capability [16]
* Dual UL capable UE is required to support concurrent transmission on any band pair [20]
 |

It seems that majority is ok to support the complexity reduction option 1 based on the UE capability. In addition, although [3] argued that Option 4 can achieve same flexibility and is more preferred, it is just details on UE capability reporting mechanism which should be discussed in RAN2. Therefore, the moderator would like to ask companies to provide feedback if any on the above summary and following potential FL proposal.

### **Proposed agreement 3.1**

* **If Rel-18 UL Tx switching for 3 or 4 bands with dual UL is supported, UE is allowed to support only some of band pairs for concurrent UL transmission based on UE capability**
	+ **The supported band pair for concurrent transmission requires the support of UL CA**
	+ **Details on the UE capability such as how to report the support of dual UL and the supported band pair(s) for concurrent UL transmission are further discussed [in RAN2]**
	+ **Details on the gNB configuration/indication such as how to indicate the band pair(s) UE should expect for concurrent UL transmission are further discussed [in RAN2]**
	+ **Note: UE is also allowed to support all band pairs for concurrent transmission, and the design of Rel-18 UL Tx switching for 3 or 4 bands with dual UL does not impose any restriction**

#### 1st round Feedback form for 3.1

|  |  |
| --- | --- |
| Company | Comment |
| MediaTek | Support |
| Qualcomm | We are ok with the FL proposal, but we slightly prefer to discuss & agree on the basic principle of UE capability in RAN1 based on whole agreements of complexity reduction methods.  |
| ZTE | As we commented in our contribution [3], the main difference between complexity reduction 1 vs 4 can be summarized as following.

|  |  |
| --- | --- |
| Complexity reduction Option1 | Report band combination: A+B+CReport supported band pairs and switched/dual UL: A+B (switched UL, dual UL), A+C (switched UL, dual UL), B+C (switched UL) |
| Complexity reduction Option4 | Report band combination: A+B+CSwitched/dual UL: Switched ULReport supported band pairs: A+B, A+C, B+CReport band combination: A+B+CSwitched/dual UL: Dual ULReport supported band pairs: A+B, A+C |

Complexity reduction option1 will introduce mixed switchedUL and dualUL, which is not supporeted via Rel-16/17. Do companies want to support the scenario where both switchedUL and dualUL are configured for the same band combination and network dynamically switches between switchedUL and dualUL? This will introduce additional RAN1 spec impacts and implementation complexity, e.g., how to indicate the dynamic switching between switchedUL and dualUL and how to determine the switching period for this case. It is not just UE capability reporting issue if such dynamic switching is supported. If the motivation is not to introduce dynamic switching between switchedUL and dualUL, it should be clarified in the proposal. Thus, we are not supportive for complexity reduction option1 which requires dynamic switching between switchedUL and dualUL from our understanding. Evaluation should be done for this mixed mode to justify introducing this new scenario. |

## 3.2 Option 2: UE is allowed to support 2 ports transmission only on some of bands out of configured bands for UL Tx switching

In contributions in AI 9.9.2, following observations and proposals were made regarding complexity reduction option 2.

|  |  |
| --- | --- |
| [2] | ***Observation 6:*** *For dynamic UL Tx switching among 3 or 4 bands,** *Option 1 can alleviate UE memory management for UL-CA Option2.*
* *Option 4 cannot solve the UE memory issue and is unreasonable because the size of UE memory is not related to the number of band pair.*
* *Option 2 has been supported by existing UE capability reporting.*

***Proposal 5:*** *Confirm the working assumption with following revision for UL-CA Option 1** *UE complexity Reduction Option 2 is supported by reusing the existing UE capability reporting mechanism for uplink MIMO, e.g., per feature set reporting granularity.*

***Proposal 6:*** *Confirm working assumption with following revision for UL-CA Option 2,** *UE complexity Reduction Option 2 is supported by reusing the existing UE capability reporting mechanism for uplink MIMO, e.g., per feature set reporting granularity.*
 |
| [3] | ***Proposal 5****: Regarding the complexity reduction for Rel-18 UL Tx switching, prioritize Option 2 (UE is allowed to support 2 ports transmission only on some of bands out of configured bands for UL Tx switching).** *At least two bands should support up to 2 Tx*
* *It is applied to both switched UL and dual UL.*
* *It is applied to both 3-band case and 4-band case.*
 |
| [4] | 1. ***RAN1 can support Option 2: UE is allowed to report the supportive only 2 ports transmission only on some of bands out of configured bands for both 3 and 4 bands.***
 |
| [5] | Observation 1: Option 1 and option 2 allow flexible UE implementation and reduce UE complexity.**Proposal 1: If Option 1 and option 2 are supported, they can be applied for TX switching with 3 bands and TX switching with 4 bands. Moreover, option 2 can be applied for both switched UL and dual UL cases.** |
| [6] | **Proposal 11: For Rel-18 UL Tx switching across up to 3 or 4 bands, to reduce UE complexity,*** **UE is allowed to support only some of concurrent UL cases on 2 (out of 3 or 4) bands.**
* **UE is allowed to support 2 ports transmission only on at least 1 band out of configured bands.**
* **UE is allowed with more preparation procedure time only for some specific switching cases/patterns.**
 |
| [7] | ***Proposal 1: Option 1 -4 are benefit for complexity reduction and can be considered to be specified.***  |
| [8] | **Proposal 2： From perspective of specification, UE is allowed to support 2 ports transmission all of bands out of configured 3/4 bands UL Tx switching.****Proposal 3： UE also can be allowed to support 2 ports transmission only on some of bands of configured 3/4 bands, and the limitations is based UE capability reported.** |
| [9] | **Proposal 4*** For Rel-18 multi-carrier Tx switching, at least Option 1 and Option 2 can be supported for complexity reduction.
	+ For Option 1, at least one band pairs need to support concurrent uplink transmission.
	+ For Option 2, at least two bands should support up to 2 Tx.
	+ UE capability is introduced UE to report concurrent uplink cases or 2 ports transmission on some of the bands that are supported for Tx switching
 |
| [11] | **Proposal 3. For Rel-18 UL Tx switching mechanism, 2 Tx transmission (0/1/2 ports) can be supported on any of 3 or 4 bands to provide scheduling flexibility and performance improvements.** |
| [12] | **Proposal #2: Revise the WA as follows.*** **Remove Option 4**
* **Add the following Notes and remove FFSs which is related to the Note**
	+ **Note: Rel-18 UL Tx switching should cover all switching cases which are supported in Rel-17.**
	+ **Note: Above option(s) can be applied for both 3 and 4 bands cases, if supported.**
 |
| [13] | ***Proposal 2: For supporting NR Rel-18 UL Tx switching across 3 or 4 bands, limiting/removing certain switching cases for certain bands/band combinations should be avoided:**** ***Option 1, 2 and 4 from the WA should be considered with lower priority***
 |
| [14] | **Observation 1:** *Full flexible port switching, e.g., any UE Tx chain can be mapped to any arbitrary band configurable for 3- or 4-bands UL Tx Switching is not a realistic assumption.***Observation 2:** *Support for full flexible 2p/1p/0p port switching in the NR band where UL MIMO is supported by the UE cannot be assumed.***Proposal 2:** *Rel-18 UL Tx Switching for 3 or 4 bands supports UE complexity reduction Options 1, 2 and 4***Proposal 3:** *For Options 1, 2 and 4, at least one band pair should be supported as in Rel-17 and UE capability indication is provided separately for 3 and 4 bands cases***Proposal 4:** *Options 2 and 4 are supported for both switched UL and dual UL cases* |
| [15] | 1. ***For UL Tx switching among 3/4 bands:***
* ***Support Option#1 and Option#2.***
* ***Do not support Option#4.***
* ***Consider Option#3 with the following modification: “UE is allowed with more preparation procedure time ~~(or interruption time) only~~ for ~~some specific~~ all switching cases/patterns”.***
 |
| [16] | 1. Dynamic UL TX switching across 3 or 4 bands should include 2 TX transmission (i.e. 0/1/2 ports transmission) on any of the 3 or 4 bands.
 |
| [17] | **Observation 2: The complexity reduction Option 2 is applicable to both switched UL and dual UL scenarios. For UL Tx switching with 3 or 4 bands, there would be some implementations where a Tx chain is applicable to only some of 3 or 4 bands but not all bands so that 2 ports transmission cannot be performed on some band(s) among 3 or 4 bands.****Proposal 4: To ensure the clear performance gain of Rel-18 UL Tx switching with complexity reduction Option 2 over Rel-17 UL Tx switching where 2 ports transmission is supported for 2 bands, it is preferable to consider complexity reduction Option 2 with some condition, e.g., at least 2 or 3 bands should support 2 ports UL transmission for Rel-18 UL Tx switching with 3 or 4 bands.****Proposal 8: At least following UE capability and RRC signaling should be considered for Rel-18 UL Tx switching across 3 or 4 bands with potential complexity reduction options.*** **UE capability regarding the supported band(s) for 2 ports transmission for Rel-18 UL Tx switching across 3 or 4 bands**
	+ **Corresponding RRC signaling to configure up to 2 ports transmission mode for a band**
		- **If the complexity reduction Option 2 is supported, UE may support up to 2 ports transmission only on some of bands, and hence UE/gNB needs to report/configure specific bands where up to 2 ports transmission is possible/expected. Existing parameters such as *uplinkTxSwitching-2T-Mode* in *CellGroupConfig* and *uplinkTxSwitchingCarrier* in *ServingCellConfig* may or may not be reused.**
 |
| [18] | **Proposal 3: For inter-band UL CA Option 1 and Option 2 without SUL for UL Tx switching among 3 or 4 bands, adopt following Options for complexity reduction with the highlighted revisions.*** **Identify an anchor band in the switching band combination among the bands.**
* **Direct switching is only between anchor band and non-anchor band.**
* **Indirect switch between non-anchor bands is allowed and revised Option 3 as below.**
	+ **Indirect switch means that the gap time is increased, which in principle allows going through a two-step RF state switch sequence {non-anchor  anchor  other non-anchor}, irrespective of whether transmission in anchor in the middle state is performed or not.**
	+ **Revised Option 3: UE is allowed with more ~~preparation procedure time (or~~ interruption time~~)~~ only for non-direct switching band pairs ~~some specific switching cases/patterns~~.**
		- **The non-direct switching band pairs could be reported as UE capability and/or configured by network.**
		- **The longer interruption time could use the sum of the two switches and no RAN4 work is expected.**
* **No restriction on the UEs choice of MIMO capability on any of the bands/CCs involved in the Rel-18 UL Tx switching band combination**
* **After one RF state switch, the next RF state switch must occur after 14 symbols or later.**
	+ **Which SCS assumed for symbol duration is TBD.**
 |
| [19] | **Observation 1: Option 2 can be satisfied by using Rel. 16, Rel. 17 band pair capability and with a new UL Tx switching band pair capability for 1T-1T case (e.g. *ULTxSwitchingBandPair*-r18 and *uplinkTxSwitching-OptionSupport-r18*).****Proposal 1: UE should support Option 1, 2 and 3 by introducing new band pair UE capability for 1T-1T (e.g. *ULTxSwitchingBandPair*1T-1T-r18), 1T-2T (e.g. *ULTxSwitchingBandPair*1T-2T-r18), and 2T-2T (e.g. *ULTxSwitchingBandPair*2T-2T-r18) Tx states, each band pair parameter includes*** **a uplink Tx switching option indication (e.g. *uplinkTxSwitching-OptionSupport-r18*), and**
* **a Tx switching period (e.g. *uplinkTxSwitchingPeriod1T1T-r18*)**
 |
| [20] | **Proposal 4: Complexity reduction Option 2 is supported:** * **Do not require the UE to support 2-port transmission in all the bands in a UL Tx Switching band combination**
 |

Based on above, the situation can be summarized as below.

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| * Support complexity reduction option 2 for both switched UL and dual UL [2], [3], [4], [5], [6], [7], [8], [9], [11], [12], [14], [15], [17], [18], [19], [20]
	+ Regarding the restriction on number of bands to be supported for 2 ports transmission:
		- At least two bands for both 3 bands and 4 bands [3], [9]
		- At least one band for both 3 bands and 4 bands [6]
		- At least three bands for both 3 bands and 4 bands [11]
		- At least two bands for 3 bands and at least three bands for 4 bands [17]
		- Only for dual UL [9]
		- No restriction [12], [18]
	+ UE capability to report the supported bands [2], [4], [5], [6], [7], [8], [12], [14], [17], [18], [19]
		- Reuse existing capability reporting mechanism for UL MIMO e.g., per FS [2], [7], [20]
	+ RRC signaling to indicate up to 2 ports transmission mode for a band [17]
		- Existing parameters for Rel-16/17 UL Tx switching may or may not be reused [17]
* Complexity reduction option 2 should be considered with lower priority [13]
* The design should not impose restriction on 2 ports transmission, but the complexity can be addressed by capability [16]
 |

It seems that majority is ok to support the complexity reduction option 2 based on the UE capability. The moderator would like to ask companies to provide feedback if any on the above summary and following potential FL proposal.

### **Proposed agreement 3.2**

* **If Rel-18 UL Tx switching for 3 or 4 bands is supported, UE is allowed to support only some of band(s) for up to 2 ports UL transmission based on UE capability**
	+ **FFS on potential restriction**
		- **Alt.1: no restriction for both switched UL and dual UL and for both 3 bands and 4 bands**
		- **Alt.2: at least one band should support up to 2 ports UL transmission for both switched UL and dual UL and for both 3 bands and 4 bands**
		- **Alt.3: at least two bands should support up to 2 ports UL transmission for both switched UL and dual UL and for both 3 bands and 4 bands**
	+ **Details on the UE capability such as whether existing per-FS UL-MIMO capability can be reused or not are further discussed [in RAN2]**
	+ **Details on the gNB configuration/indication such as whether/how to indicate 2 ports UL transmission mode for a band/cell are further discussed [in RAN2]**
	+ **Note: UE is also allowed to support all bands for up to 2 ports UL transmission, and the design of Rel-18 UL Tx switching for 3 or 4 bands does not impose any restriction**

#### 1st round Feedback form for 3.2

|  |  |
| --- | --- |
| Company | Comment |
| MediaTek | Support |
| Qualcomm | We support Alt. 1 as this is inline with current MIMO layer which is already a UE capability.To correctly includes this, we propose revision of major bullet to include Alt. 1.* **If Rel-18 UL Tx switching for 3 or 4 bands is supported, UE is allowed to support only some or none of band(s) for up to 2 ports UL transmission based on UE capability**
 |
| ZTE | We are open to consider this proposal for complexity reduction. Regarding the three alternatives above, our first preference is Alt.3 as we commented in last meeting since Rel-17 already supported 2-ports on 2 bands. |

## 3.3 Option 3: UE is allowed with more preparation procedure time (or interruption time) only for some specific switching cases/patterns

In contributions in AI 9.9.2, following observations and proposals were made regarding complexity reduction option 3.

|  |  |
| --- | --- |
| [2] | ***Observation 4:*** *From UE memory perspective, each unit of memory serves each band, instead of band pair or switching path.****Observation 7:*** *The same mechanism of memory sharing is applicable to both UL-CA Option 1 and 2. But with the same limited UE memory size, there is more scheduling restriction to minimize transmission interruption for UL-CA Option 2 than UL-CA Option 1 simply because more UE memory are occupied at one time for UL-CA Option 2 than UL-CA Option 1.****Observation 8:*** *Memory sharing is useful but not essential for UL-CA Option 1.****Observation 9:*** *Since UL-CA Option 1 is an operation subset of UL-CA Option 2, the mechanisms of memory sharing can be also applicable to UL-CA Option 1 if memory sharing are introduced for UL-CA Option 2.****Proposal 6:*** *Confirm working assumption with following revision for UL-CA Option 2,** *UE complexity Reduction Option 2 is supported by reusing the existing UE capability reporting mechanism for uplink MIMO, e.g., per feature set reporting granularity.*
* *UE complexity Reduction Option 3 with additional preparation time is supported and only required if either of the following switching condition meets*
	+ *Switching condition 1: the number of bands within a band set that contains all transmitted bands involved in both determinations of the triggered UL Tx switching and its preceding UL Tx switching is more than X*
	+ *Switching condition 2: the number of bands within a band set that contains all transmitted bands involved in determination of the triggered UL Tx switching is more than X for UL-CA Option 2*
	+ *The additional preparation time can be reported by UE*
	+ *Minimum interval between the triggered UL Tx switching and its preceding UL Tx switching is Y(us)*
	+ *The reduction Option 3 should be common solution and also applicable to UL-CA Option 1*
	+ *FFS: the value of X and Y*
 |
| [3] | ***Proposal 7****: Study potential performance impact if more preparation procedure time or more interruption time is introduced. If it is introduced, UE supports per BC report on whether/how much more preparation procedure time or more interruption time is needed.* |
| [4] | 1. ***RAN1 can support Option 3: UE is allowed with more preparation procedure time for some specific switching cases for both 3 and 4 bands.***
2. ***Switching cases that require more preparation procedure time can include more than 2 bands involved in one switching.***
 |
| [5] | Proposal 3: It is suggested to make more clarification on option 3, including which switching cases to apply a longer preparation time and how to indicate the longer preparation time. |
| [6] | **Proposal 11: For Rel-18 UL Tx switching across up to 3 or 4 bands, to reduce UE complexity,*** **UE is allowed to support only some of concurrent UL cases on 2 (out of 3 or 4) bands.**
* **UE is allowed to support 2 ports transmission only on at least 1 band out of configured bands.**
* **UE is allowed with more preparation procedure time only for some specific switching cases/patterns.**
 |
| [7] | ***Proposal 1: Option 1 -4 are benefit for complexity reduction and can be considered to be specified.***  |
| [8] | **Proposal 4：For the UE that can pre-stored two bands RF parameter configuration, the following cases that more preparation procedure time are necessary*** **Case 1: one new band is involved on the next transmission state, and the new band is not any band included in current UL TX switching band pair.**
* **Case 2: two new bands are involved on the next transmission state, and the two new bands are all not same as bands in current UL TX switching band pair.**

**Proposal 5：For the UE that can pre-stored three bands RF parameter configuration, the following case that more preparation procedure time is necessary*** **Case 3: one new band is involved on the next transmission state, the new band is not any of current UL TX switching band pair whose RF parameter are stored in firs two memory units or not the band whose RF parameter is stored in the third memory unit.**

**Proposal 6: when the special switching is occurring, which band(s) RF parameter will be replaced by new band transmission shall be specified.****Proposal 7：The duration of more preparation procedure time can be a reference slot, and the reference slot can be same as SCS of configured for the band transmission. And it may not be RAN4 issue****Proposal 8：The earliest timing of more preparation procedure for loading new band parameter can be as following*** **On the start of first symbol of uplink transmission whose band parameter will be replaced by new band transmission.**

**Proposal 9：It does not include interruption happens during the preparation procedure time. And it should not include switching period.****Proposal 10：The report/indicate the specific switching cases/patterns is necessary, and UE capability reported is based on number of band RF parameter configuration can be pre-loaded, the range of number is {2,3,4}.****Proposal 11：Minimum interval between two succeeding special UL Tx switching can be duration of prepare time. And the special UL Tx switching case refers to the cases that need preparation procedure time.** |
| [9] | For Option 3, the main motivation is to allow more preparation time for a UE with shared memory across different bands. In this case, memory flushing and reloading is needed in case of Tx switching. Note that this option may need input from RAN4 on the exact preparation time for Tx switching, which highly depends on specific UE implementation. Further, this additional preparation time may impose certain restriction on the gNB scheduling for dynamic Tx switching across 3 or 4 bands, and also degrade the system performance.  |
| [10] | ***Observation 4:*** ***UL Tx switching across more than two bands may increase UE memory.******Proposal 3: UE is allowed with more preparation procedure time for UL Tx switching across more than 2 bands once band pair is changed.******Proposal 4: The preparation procedure time needs to be defined independently.******Proposal 5: UE doesn’t expect any uplink transmission during preparation procedure time caused by band information updating.******Proposal 6: The preparation procedure time needs to be reported to the gNB.******Observation 5: The values of the preparation procedure time needs insights from RAN4.*** |
| [11] | From our perspective, Option 3 was proposed to address UE complexity issue related to UE memory sharing and hardware resources. The specific switching cases/patterns that require more preparation procedure time needs to be identified firstly, which also need RAN4 involvement to determine whether extra preparation time is needed for these specific switching cases, and whether different value can be reported for the band pair with the specific switching cases/patterns also need to be discussed.  |
| [12] | **Proposal #3: Additional preparation time (as a UE capability) can be supported only for the switching cases newly introduced in Rel-18.****Proposal #4: The minimum interval between two succeeding Tx switching should be defined separately depending on the number of bands involved with the Tx switching.**  |
| [13] | ***Proposal 1: For supporting NR Rel-18 UL Tx switching across 3 or 4 bands, the baseline assumption is that UE is not mandated/required to have increased memory requirements compared to Rel-16/17 switching across 2 bands**** ***Memory sharing is assumed for 3 or 4 bands (2 memory units shared across 3 or 4 bands)***

***Proposal 3: For supporting NR Rel-18 UL Tx switching across 3 or 4 bands, support additional preparation/processing time reporting by UE for the cases where at least one of the two memory units is actively used for a band for UL transmission in the preceding state and the same memory unit needs to be reallocated to a different band for UL transmission in the succeeding state:**** ***Case 1: Switching from State 1: 1Tx (band A) – 1Tx (band B) to State 2: 1Tx (band C) – 1Tx (band D)***
* ***Case 2: Switching from State 1: 1Tx (band A) – 1Tx (band B) to State 2: 2Tx (band C or band D)***
* ***Case 3: Switching from State 1: 2Tx (band C or band D) to State 2: 1Tx (band A) – 1Tx (band B)***

***Proposal 4: For supporting NR Rel-18 UL Tx switching across 3 or 4 bands, RAN1 should consider further restriction in terms of minimum duration between two consecutive switching instances**** ***FFS whether such minimum duration is applied only to new switching cases in Rel-18***
 |
| [14] | **Proposal 5:** *For Option 3, RAN4 to discuss and decide the need and applicability for increased interruption and preparation procedure time for some specific switching cases/patterns* |
| [15] | 1. ***For UL Tx switching among 3/4 bands:***
* ***Support Option#1 and Option#2.***
* ***Do not support Option#4.***
* ***Consider Option#3 with the following modification: “UE is allowed with more preparation procedure time ~~(or interruption time) only~~ for ~~some specific~~ all switching cases/patterns”.***
 |
| [16] | ***Observation 3 To support Alt 1 while addressing the claimed UE complexity, the notion of anchor band to switch a TX chain to/from, can be reflected properly in the procedure such that the relaxed UE complexity does not result in scheduling complexity.******Proposal 5 Apply the following procedures for dynamic UL Tx switching across 3 or 4 bands:******• Indicate N band(s) among 3 or 4 bands are configured as anchor band(s).*** ***• N = 1 for dynamic UL TX switching across 3 bands******• N = 2 for dynamic UL TX switching across 4 bands (FFS N=1)******• For an indicated UL transmission, if after the preceding UL transmission, the UE is under operation state that is different from the ending state, and if none of the bands in the ending and operation states are an anchor band, the UE expects that the indicated UL transmission to occur after at least a gap of duration X after the end of the proceeding transmission.*** ***• Note: Operation state refers to the state of Tx chains on two bands before an indicated UL transmission******• Note: Ending state refers to the state of Tx chains on two bands after transmission of an indicated UL transmission******• FSS on X (e.g. slot duration corresponding to the band w largest SCS)*** |
| [17] | **Observation 3: The complexity reduction Option 3 is applicable to both switched UL and dual UL scenarios. For UL Tx switching with 3 or 4 bands, there would be some implementations where UE memory flushing and loading are necessary for the specific switching patterns such as followings.*** **Switching from a case where Tx chains are on two bands (e.g., band A and B) to another case where Tx chains are on different band from the two bands (e.g., band C) assuming the memory size of 2**
* **Switching from a case where Tx chains are on one band (e.g., band A) to another case where Tx chains are on different bands from the band (e.g., band B and C) assuming the memory size of 2**
* **Switching from a case where Tx chains are on two bands (e.g., band A and B) to another case where Tx chains are on two different bands from the two bands (e.g., band C and D) assuming the memory size of 2 or 3**

**Observation 4: The additional preparation procedure time is different from the switching period. During the procedure for the memory flushing for band A and loading for band B, UL transmission on the band A and/or B would not be possible, while if another unit of the memory has band C information and no flushing/loading is performed in the unit, UL transmission on the band C would be possible even during the memory flushing/loading at another unit.****Proposal 6: The complexity reduction Option 3 should be considered as possible optional restriction based on UE capability.*** **Reporting the UE memory size is required, while reporting/indicating specific switching patterns where the additional preparation procedure time is required would not be necessary.**

**Proposal 8: At least following UE capability and RRC signaling should be considered for Rel-18 UL Tx switching across 3 or 4 bands with potential complexity reduction options.*** **UE capability regarding the supported memory size for Rel-18 UL Tx switching across 3 or 4 bands**
	+ **There is no such capability for Rel-16/17 UL Tx switching, and hence new capability signaling is necessary if the complexity reduction Option 3 is supported.**
	+ **Corresponding RRC signaling would not be necessary since UE and gNB can have common understanding regarding when the additional preparation procedure time is necessary for the UE based on the memory size reported by the UE.**
 |
| [18] | **Proposal 3: For inter-band UL CA Option 1 and Option 2 without SUL for UL Tx switching among 3 or 4 bands, adopt following Options for complexity reduction with the highlighted revisions.*** **Identify an anchor band in the switching band combination among the bands.**
* **Direct switching is only between anchor band and non-anchor band.**
* **Indirect switch between non-anchor bands is allowed and revised Option 3 as below.**
	+ **Indirect switch means that the gap time is increased, which in principle allows going through a two-step RF state switch sequence {non-anchor  anchor  other non-anchor}, irrespective of whether transmission in anchor in the middle state is performed or not.**
	+ **Revised Option 3: UE is allowed with more ~~preparation procedure time (or~~ interruption time~~)~~ only for non-direct switching band pairs ~~some specific switching cases/patterns~~.**
		- **The non-direct switching band pairs could be reported as UE capability and/or configured by network.**
		- **The longer interruption time could use the sum of the two switches and no RAN4 work is expected.**
* **No restriction on the UEs choice of MIMO capability on any of the bands/CCs involved in the Rel-18 UL Tx switching band combination**
* **After one RF state switch, the next RF state switch must occur after 14 symbols or later.**
	+ **Which SCS assumed for symbol duration is TBD.**
 |
| [19] | **Observation 2: Option 3 can be satisfied by using Rel. 16, Rel. 17 band pair switching period indication and with a new UL Tx switching band pair switching period indication for 1T-1T case (e.g. *uplinkTxSwitchingPeriod1T1T-r18*).****Proposal 1: UE should support Option 1, 2 and 3 by introducing new band pair UE capability for 1T-1T (e.g. *ULTxSwitchingBandPair*1T-1T-r18), 1T-2T (e.g. *ULTxSwitchingBandPair*1T-2T-r18), and 2T-2T (e.g. *ULTxSwitchingBandPair*2T-2T-r18) Tx states, each band pair parameter includes*** **a uplink Tx switching option indication (e.g. *uplinkTxSwitching-OptionSupport-r18*), and**
* **a Tx switching period (e.g. *uplinkTxSwitchingPeriod1T1T-r18*)**
 |

Based on above, the situation can be summarized as below.

|  |
| --- |
| * Support complexity reduction option 3 [2], [4], [6], [7], [8], [10], [12], [13], [15], [16], [17], [18], [19]
	+ Switched UL and/or Dual UL
		- Only for Dual UL [2]
		- For both Switched UL and Dual UL [2], [17]
	+ Definition of additional preparation procedure time or interruption time
		- Additional preparation procedure time is required when memory is flushing and reloading [2], [3], [4], [6], [8], [10], [13], [17]
		- UL transmission on a band for which the memory is flushing and reloading cannot be performed [2], [6], [10], [13], [17]
		- UL transmission on a band for which the memory is flushing and reloading is possible and memory flushing/reloading can start after the start of the UL transmission [8]
		- The value of additional preparation time or interruption time should be discussed in RAN4 [5], [9], [10], [11]
			* How long additional preparation time is required can be discussed in RAN1 [8], [12], [18]
		- Additional preparation time can be within a reference slot (minimum interval between two UL Tx switchings) and does not include interruption and switching period [8]
		- Additional preparation time is required when switching between non-anchor bands is performed and it is minimum gap from the end of the preceding transmission to succeeding transmission [16]
		- Longer interruption time which is sum of two switching periods for indirect switching [18]
		- Longer interruption time based on per band pair switching period [19]
	+ Specific switching cases/patterns
		- When the number of bands involved for a switching exceeds the memory size [2], [8], [17]
		- When the memory of a band combination including 3 or 4 bands is larger than a bandwidth threshold [3]
		- When more than 2 bands are involved for a switching [4], [10], [12], [13]
		- All switching cases/patterns [15]
		- When none of the bands involved in the switching is an anchor band [16], [18]
	+ UE capability
		- Reporting the memory size [2], [8], [17]
		- Reporting whether/how long the additional preparation time is needed [2], [3], [4], [6], [7], [10], [12], [13]
		- Reporting the cases requiring the additional preparation time [5], [7]
		- Reporting per band pair switching period [19]
	+ Anchor band(s)
		- One anchor band is indicated among 3 bands configured for UL Tx switching, and two anchor bands are indicated among 4 bands configured for UL Tx switching [16]
		- One anchor band is identified among 3 or 4 bands configured for UL Tx switching [18]
* Study potential performance impact due to additional preparation procedure time or interruption time [3], [9]
* Further clarification is necessary [5], [11]
* RAN4 should discuss and decide the need and applicability for additional preparation procedure time or interruption time [14]
* Memory sharing across bands is possible and necessary in some cases [2], [6]
* Memory is related to supported bandwidth of each band [3]
* Memory is necessary for each switching band pair and cannot be shared by different band pairs [18]
 |

It seems that majority is ok to support the complexity reduction option 3 in principle, but there are some different understandings on the implication of the complexity reduction option 3. In addition, companies may have different implementations in mind regarding the memory used for UL Tx switching. Therefore, the moderator would like to ask companies to provide feedback if any on the above summary and following discussion points to reach some common understandings.

### **Proposed discussion 3.3**

* **Companies are encouraged to provide views on following points**
	+ **Q1: Regarding the memory unit**
		- **Option 1: memory unit is related to number of bands**
		- **Option 2: memory unit is related to bandwidth of each band**
		- **Option 3: memory unit is related to number of band pairs**
	+ **Q2: Regarding the memory sharing and definition of additional preparation time or interruption time**
		- **Option 1: memory sharing is possible, and additional preparation time is a time required for memory flushing and reloading where UL transmission cannot be performed on a band for which the memory is flushing and reloading**
		- **Option 2: memory sharing is not possible, and additional interruption time is a time required for indirect switching such as a sum of two switching periods**
	+ **Q3: Regarding the memory size**
		- **Option 1: memory size is UE capability**
		- **Option 2: only same memory size as in Rel-17 is assumed**
	+ **Q4: Regarding the value of additional preparation time or interruption time**
		- **Option 1: it should be discussed in RAN1**
		- **Option 2: it should be discussed in RAN4**
	+ **Q5: Regarding the specific switching case/pattern where the additional preparation time or interruption time is necessary**
		- **Option 1: only when the number of bands involved for a switching exceeds the memory size**
		- **Option 2: when bandwidth of 3 or 4 bands exceeds a certain threshold based on the memory size**
		- **Option 3: only when none of the bands involved in the switching is an anchor band**
		- **Option 4: all switching cases/patterns**

#### 1st round Feedback form for 3.3

|  |  |
| --- | --- |
| Company | Comment |
| MediaTek | Based on RAN4 input, R4-2214464, “*For UL switching period with Tx switching across 3 or 4 bands, RAN4 agreed to reuse the same set of values as in Rel-16/17, i.e., {35 us, 140 us, 210 us} for UL CA and SUL*.”, we don’t see a need for new switching period from RF perspective.However, if there are some UEs require more PUSCH preparation time due to having more configured carriers, then this should be applicable to all the switching cases within the 3 or 4 bands.Regarding the “meomory sharing”, it is not clear to us at what level this sharing is done, is it for “RF configurations”? or is it for “L1/RRC configurations”? Anyway, we don’t think RAN1 should discuss such detailed UE implementations. All what RAN1 need to discuss if there is a need to introduce new UE capability for extra PUSCH preparation time or not. |
| Qualcomm  | Please find our response to the questions.Q1: There are two types of memory used for UL transmission, which includes the memory storage of UL data and the RF memory for switching accessed by RF components for Tx switching. To optimize the fast switching the UE needs larger memory to store the RF configurations, status and some data before and after switching. The first memory storage is for each band but the memory for RF is needed for each switching band pair. Our most concerned memory is the 2nd - memory for RF which is per band pair.Q2: The answer is Option 2 as the memory for RF could not be shared and thus additional interruption time is needed for indirect switching between band pairs.Q3: Considering Rel-18 requires switching among 3 or 4 bands, the memory would be likely larger than Rel-17. However, as it could not be shared UE may not need to directly report its memory as a UE capability. Q4: For indirect switch, the switching period could use sum of two switches as starting point. Q5: we prefer Option 3. |
| ZTE | First of all, the memeory sharing is highly dependent on the implementation, we don’t think it helps to discuss memory sharing in RAN1. In addition, the previous RAN1 simulation results are based on the legacy switching period, if requires additional processing delay or interruption time is required, more simulation is needed to justify the potential gain for this case.Below, we share our views in terms of the above questions raised by FL.Q1: Our understanding is Option2. A band with 10MHz bandwith clearly requires less memory compared with a band with 100MHz.Q2: We don’t think memory sharing is possible for both switchedUL and dualUL cases. Since Tx switching is done dynamically, frequent memory sharing operation e.g. flushing is needed to catch up with Tx switching, which is not realistic in most of the cases. Q3/Q4: We don’t think RAN1 can determine how to report UE memory size, which highly depends on UE implementation and has never been specified in NR.Q5: We are negative on memory sharing and it is impossible define specific switching case/pattern for memory sharing.  |

## 3.4 Option 4: UE is allowed to support only some of band pairs for tx switching

In contributions in AI 9.9.2, following observations and proposals were made regarding complexity reduction option 4.

|  |  |
| --- | --- |
| [2] | ***Observation 5:*** *Both* ***complexity reduction*** *Option 1 and Option 4 are dedicated only to UL-CA Option 2.****Observation 6:*** *For dynamic UL Tx switching among 3 or 4 bands,** *Option 1 can alleviate UE memory management for UL-CA Option2.*
* *Option 4 cannot solve the UE memory issue and is unreasonable because the size of UE memory is not related to the number of band pair.*
* *Option 2 has been supported by existing UE capability reporting.*
 |
| [3] | ***Observation 2****: For complexity reduction Option 4, UE can achieve the same reporting flexibility as complexity reduction Option 1 by indicating different band pairs for switchedUL and dualUL. Meanwhile, the switchedUL/dual UL indication remains as per BC (band combination) report.****Proposal******6****: If one of complexity reduction Option 1 and complexity reduction Option 4 is to be adopted, then Option 4 is supported.* |
| [5] | Proposal 2: If UE capability is reported per band pair, Option 4 can be considered.  |
| [6] | This option limits the flexibility for one Tx switching procedure and would result in more switching times with possible longer total switching period. For example, Tx switching is performed across 3 bands and Tx switching is not supported between the second band and the third band. When the current state of Tx chains is 2Tx on the second band, and the third band is the best band for next UL transmission, the Tx should switch to the first band firstly and then switch from the first band to the third band. The switching period takes the two switching times into account which may be longer than directly switching from the second to the third band. |
| [7] | ***Proposal 1: Option 1 -4 are benefit for complexity reduction and can be considered to be specified.***  |
| [9] | For Option 4, it is not clear the benefit of only supporting some of band pairs for Tx switching for complexity reduction. This can be realized by appropriate configuration for Tx switching across 3 or 4 bands.  |
| [10] | ***Proposal 1: There should be no restrictions on the band pairs for Rel-18 UL Tx switching.*** |
| [11] | Considering whether to support only some of band pairs for UL Tx switching, our understanding is that this may have great impact on network scheduling flexibility, which is contrary to the motivation of flexible spectrum utilization. Besides, the principle of selecting the band pairs that support UL Tx switching need to be clarified, otherwise, different UE can support different band pairs, which may result in the increasing network implementation complexity.  |
| [12] | * Regarding Option 4, we have the similar view on the first three FFSs. However, we believe that Rel-17 UL Tx switching should be prerequisite for Rel-18 UL Tx switching. According to Option 4, UE may restrict supporting UL Tx switching for some of band pairs, though such restriction is not supported even in Rel-17. If this is correct understanding, we don’t see the motivation of introducing such restrictions as in Option 4 (so, it can be removed).
 |
| [13] | ***Proposal 2: For supporting NR Rel-18 UL Tx switching across 3 or 4 bands, limiting/removing certain switching cases for certain bands/band combinations should be avoided:**** ***Option 1, 2 and 4 from the WA should be considered with lower priority***
 |
| [14] | **Proposal 2:** *Rel-18 UL Tx Switching for 3 or 4 bands supports UE complexity reduction Options 1, 2 and 4***Proposal 3:** *For Options 1, 2 and 4, at least one band pair should be supported as in Rel-17 and UE capability indication is provided separately for 3 and 4 bands cases***Proposal 4:** *Options 2 and 4 are supported for both switched UL and dual UL cases* |
| [15] | 1. ***Option#4 doesn’t offer UE complexity reduction, and it will require two switching gaps in some scenarios, which degrades the UL performance.***
2. ***For UL Tx switching among 3/4 bands:***
* ***Support Option#1 and Option#2.***
* ***Do not support Option#4.***
* ***Consider Option#3 with the following modification: “UE is allowed with more preparation procedure time ~~(or interruption time) only~~ for ~~some specific~~ all switching cases/patterns”.***
 |
| [17] | **Observation 5: The complexity reduction Option 4 is equivalent to Alt.3 scheme which was dropped by the working assumption. Since this option allows UE to not support some switching patterns, this complexity reduction option does not follow the fundamental principle of the Alt.1 and working assumption that the dynamic Tx carrier switching can be across all the supported switching cases by the UE and based on the UL scheduling, i.e., via dynamic grant and/or RRC configuration for UL transmission.****Proposal 7: The complexity reduction Option 4 should not be further discussed.** |
| [19] | As for Option 4, it not clear to us. In one example, it may mean that a UE can report a number of band pairs in a band combination, which is larger than the UE can support. Then the UE should indicate a number of supported band pairs to the base station, where the base station can configure band pairs to the UE accordingly. If it is the case, it can be an optional feature on top of Option 1, 2 and 3. However, in our opinion, adopting Option 1, 2, and 3 directly is clear to us. **Observation 3: Option 4 can be an optional feature on top of Options 1, 2, and 3.**  |
| [20] | **Proposal 6: Complexity reduction Option 4 is not supported:** * **All transitions from one valid band/port combination transmission to another valid band/port combination transmission of the indicated band combination should be supported by the UE**
 |

Based on above, the situation can be summarized as below.

|  |
| --- |
| * Support complexity reduction option 4 for both switched UL and dual UL [3], [7], [14]
	+ For both switched UL and dual UL [14]
	+ UE capability to report the supported band pairs [3], [14]
	+ Option 4 can achieve same reporting flexibility as Option 1 [3]
* Depends on whether U capability is reported per band pair or per band combination containing 3 or 4 bands [5]
* Complexity reduction option 4 should be considered with lower priority [13]
* Do not support complexity reduction option 4 [2], [6], [9], [10], [11], [12], [15], [17], [19], [20]
	+ This option means indirect switching with doubled switching periods [6], [15]
 |

It is observed that companies have different understanding or unclear understanding on option 4. Some companies consider this option as similar to option 1, while some other companies consider this option as similar to Alt.3 (anchor band based switching mechanism). However, such considerations can be covered by the discussion on option 1 and option 3. Therefore, the moderator would like to ask companies to provide feedback if any on the above summary and following potential FL proposal.

### **Proposed conclusion 3.4**

* **Complexity reduction option 4 is not supported**

#### 1st round Feedback form for 3.4

|  |  |
| --- | --- |
| Company | Comment |
| MediaTek | Support |
| ZTE | Let’s further clarify complexity reduction Option4. The main difference between complexity reduction option1 vs option4 can be summarized in the following table.

|  |  |
| --- | --- |
| Complexity reduction Option1 | Report band combination: A+B+CReport supported band pairs and switched/dual UL: A+B (switched UL, dual UL), A+C (switched UL, dual UL), B+C (switched UL) |
| Complexity reduction Option4 | Report band combination: A+B+CSwitched/dual UL: Switched ULReport supported band pairs: A+B, A+C, B+CReport band combination: A+B+CSwitched/dual UL: Dual ULReport supported band pairs: A+B, A+C |

Note that, complexity reduction Option 4 can already be supported by current report information ‘*supportedBandPairListNR*’ within ‘*BandCombination-UplinkTxSwitch*’ in Rel-16/17 since UE can already indicate the supported band pairs since Rel-16. We don’t understand why something without any additional cost is not supported. If such kind of complexity reduction is needed, it is straightforward to support Option4 with the exisiting capability report. Otherwise, it is acceptable to us that neither of Option1 and Option4 is supported.  |
|  |  |

## 3.5 Other complexity reduction options

In contributions in AI 9.9.2, following observations and proposals were made regarding other complexity reduction options.

|  |  |
| --- | --- |
| [8] | **Proposal 21: The UE is not expected to perform more than one uplink switching in a reference slot, where the SCS of the reference slot for 3/4 bands is determined by the minimum SCS of the reference slot in Rel-16/Rel-17 for combinations of any two bands among 3 or 4 bands.** * **Case 1: if the UE is configured with 3 bands for UL Tx switching, and the SCS of the carrier n is the SCS of reference slot for 3 bands shall be as below:**

***µUL* =** * **Case 2: If the UE is configured with 3 bands for UL Tx switching, and the SCS of the carrier n is , the reference slot shall be as below:**

***µUL* =**  |
| [12] | **Proposal #4: The minimum interval between two succeeding Tx switching should be defined separately depending on the number of bands involved with the Tx switching.**  |
| [13] | ***Proposal 4: For supporting NR Rel-18 UL Tx switching across 3 or 4 bands, RAN1 should consider further restriction in terms of minimum duration between two consecutive switching instances**** ***FFS whether such minimum duration is applied only to new switching cases in Rel-18***
 |
| [18] | * **After one RF state switch, the next RF state switch must occur after 14 symbols or later.**
	+ **Which SCS assumed for symbol duration is TBD.**
 |

Based on above, the situation can be summarized as below.

|  |
| --- |
| * No more than one uplink Tx switching in a certain time duration [8], [12], [13], [18]
	+ Within a reference slot where SCS is determined by minimum SCS of the reference slot in Rel-16/Rel-17 for combinations of any two bands among 3 or 4 bands [8]
	+ Within 14 symbols where SCS is TBD [18]
	+ the minimum interval between two succeeding Tx switching can be defined per specific switching case [12]
 |

Several companies proposed to define the minimum separation time between two UL Tx switchings. Although it seems some company considers it is similar to complexity reduction option 3, probably it can be separate discussion. The moderator would like to ask companies to provide feedback if any on the above summary and following potential FL proposal.

### **Proposed agreement 3.5**

* **Define the minimum separation time between two UL Tx switchings for Rel-18 UL Tx switching schemes across up to 3 or 4 bands**
	+ **FFS on the minimum separation time**
		- **Alt.1: 14 symbols based on a SCS (FFS on SCS)**
		- **Alt.2: no more than one uplink Tx switching within a reference slot based on a SCS (FFS on SCS)**

#### 1st round Feedback form for 3.5

|  |  |
| --- | --- |
| Company | Comment |
| MediaTek | We don’t support such restriction. |
| Qualcomm | We support FL proposal. |
| ZTE | We understand the intention of this proposal. However, we think this proposal should be deprioritized until we have concensus on the previous complexity reduction options first and then come back to this proposal later on. |

## 3.6 Other general aspects related to the working assumption

In contributions in AI 9.9.2, following observations and proposals were made regarding other general aspects related to the working assumption.

|  |  |
| --- | --- |
| [2] | ***Proposal 5:*** *Confirm the working assumption with following revision for UL-CA Option 1** *UE complexity Reduction Option 2 is supported by reusing the existing UE capability reporting mechanism for uplink MIMO, e.g., per feature set reporting granularity.*

***Proposal 6:*** *Confirm working assumption with following revision for UL-CA Option 2,** *UE complexity Reduction Option 2 is supported by reusing the existing UE capability reporting mechanism for uplink MIMO, e.g., per feature set reporting granularity.*
* *UE complexity Reduction Option 3 with additional preparation time is supported and only required if either of the following switching condition meets*
	+ *Switching condition 1: the number of bands within a band set that contains all transmitted bands involved in both determinations of the triggered UL Tx switching and its preceding UL Tx switching is more than X*
	+ *Switching condition 2: the number of bands within a band set that contains all transmitted bands involved in determination of the triggered UL Tx switching is more than X for UL-CA Option 2*
	+ *The additional preparation time can be reported by UE*
	+ *Minimum interval between the triggered UL Tx switching and its preceding UL Tx switching is Y(us)*
	+ *The reduction Option 3 should be common solution and also applicable to UL-CA Option 1*
	+ *FFS: the value of X and Y*
 |
| [4] | 1. ***Confirm the following part in the working assumption.***

***If Rel-18 UL Tx switching is supported, following switching mechanism is considered as baseline for the Rel-18 UL Tx switching across 3 or 4 bands**** + ***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 dynamic grant and/or RRC configuration for UL transmission***
 |
| [12] | **Proposal #1: Complexity reduction options for UL Tx switching across 3 or 4 bands can be supported as a UE capability.** |
| [14] | **Proposal 1:** *Confirm the RAN1#110 WA that Rel-18 UL Tx switching supports Alt.1: dynamic Tx carrier switching across all the supported switching cases by the UE and based on UL scheduling, i.e., via UL grant and/or RRC configuration for UL transmission* |
| [16] | 1. Design principle for extension of dynamic UL Tx switching to three or four bands, should ensure additional performance enhancements as compared to legacy procedures without introducing scheduling complexity or discarding UE complexity.

Observation 1 UL Tx switching across 3 or 4 bands design based on Alt 2 and Alt 3 results in scheduling dependency and error propagation. Any design based on Alt 2 and Alt 3 makes the promised benefits and usefulness of dynamic UL Tx switching across more than 2 bands questionable.Observation 2 If UL Tx switching across 3 or 4 bands is supported, only operation based on Alt1 that properly addresses UE complexity is meaningful. 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 (i.e. Alt 1).
 |
| [17] | **Proposal 1: Any complexity reduction option to be supported on top of Alt.1 scheme should be basically optional and should still be able to provide clear performance gain over Rel-17 UL Tx switching scheme.** |
| [20] | **Proposal 1: Confirm the 1st part of the RAN1#110 working assumption as below****Working Assumption*** If Rel-18 UL Tx switching is supported, following switching mechanism is considered as baseline for the Rel-18 UL Tx switching across 3 or 4 bands
	+ 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 dynamic grant and/or RRC configuration for UL transmission

**Proposal 2: The UE complexity reduction solutions adopted should not increase the network implementation complexity** |

Based on above, the situation can be summarized as below.

|  |
| --- |
| * Confirm working assumption for Alt.1 [2], [4], [14], [16], [20]
* Complexity reduction options are supported as optional capability [12], [17]
* Rel-18 UL Tx switching with complexity reduction options should ensure the performance enhancement from Rel-16/17 UL Tx switching [16], [17]
* Rel-18 UL Tx switching with complexity reduction options should not increase the network implementation complexity [20]
 |

There is no contribution proposing to revert the working assumption and the proposals in previous sub sections for complexity reduction options are discussed with positive manner. Hence, some companies proposed that it should be fine to confirm the working assumption. Other general proposals for the working assumption seem to be already considered in proposals in previous sub sections. Therefore, the moderator would like to ask companies to provide feedback if any on the above summary and the following potential FL proposal.

### **Proposed agreement 3.6**

* **Confirm the following working assumption made at the RAN1#110 meeting.**

**Working Assumption**

* If Rel-18 UL Tx switching is supported, following switching mechanism is considered as baseline for the Rel-18 UL Tx switching across 3 or 4 bands
	+ 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 dynamic grant and/or RRC configuration for UL transmission

#### 1st round Feedback form for 3.6

|  |  |
| --- | --- |
| Company | Comment |
| MediaTek | Support |
| Qualcomm | As far as complexity issue could be solved, we are ok to support this WA.  |
| ZTE | We are ok to confirm this working assumption. However, we would like to emphasize that the switching period is reported per band pair as agreed by RAN4. Without clear rule or indication of the band pair or the corresponding switching period, Alt.1 may not work. |

1. Discussions on the detailed mechanisms for Rel-18 multi-carrier UL Tx switching

## 4.1 Issue on ambiguous switching state

In contributions in AI 9.9.2, following observations and proposals were made regarding the issue on ambiguous switching state.

|  |  |
| --- | --- |
| [2] | ***Observation 3:*** *For UL-CA Option 2, the following specification impacts need to be considered,** *Tx state ambiguity after Tx switching*
* *Switching ambiguity issue*
* *4 new switching instances, i.e. current UL transmission band(s) and the preceding band(s) involve 3 or 4 bands, should be specified*
* *Supporting only some concurrent UL transmission cases by UE reporting.*
* *Switching location configuration issue for 4 new switching instances*
* *Switching period issue for 4 new switching instances*
 |
| [3] | ***Proposal 10****: The legacy RRC configuration* {*oneT*, *twoT*} *via uplinkTxSwitching-DualUL-TxState is reused to address the ambiguity issue.** *If the band pair is indicated after the Tx switching,*
	+ *oneT indicates 1Tx is assumed on each band of the indicated band pair;*
	+ *twoT indicates 2Tx is assumed on the carrier with UL scheduling.*
* *If the band pair is not indicated after the Tx switching,*
	+ *oneT indicates 1Tx is assumed on the band with UL scheduling and the band with a lowest/highest carrier frequency among the bands other than the band with UL scheduling;*
	+ *twoT indicates 2Tx is assumed on the carrier with UL scheduling.*

***Proposal 11****: Introduce band pair indication for Alt.1.* |
| [4] | 1. ***RRC parameter can be used for resolving the ambiguous states.***
 |
| [5] | Observation 2: For approach 1 and approach 2, ambiguity issue remains, a RRC indication is needed to resolve the ambiguity.Observation 3: For approach 3 and approach 4, there is no ambiguity issue because 1-port transmission only maps to one Tx chain state. However, unnecessary interruption and more frequent Tx switching may be required. Observation 4: For approach 4, switchedUL is only applied for the Tx chain state with 2 Tx in the same band.Proposal 8: Either approach 2 or approach 4 can be considered to handle the ambiguity issue.**Approach 2**: For <1T+1T> in each Tx chain combination, the port-mapping combination is one of <0P+1P> and <1P+0P> for option1 to mitigate the ambiguity issue.**Approach 4**: For <0T+2T> in each Tx chain combination, the corresponding port-mapping combination are <0P+1P> and <0P+2P>. The <1T+1T> in each Tx chain combination is only applied to option 2, with the corresponding port-mapping combination <1P+1P> |
| [6] | **Proposal 8: Reuse the Rel-17 RRC configuration principle to address the issue that the state of Tx chains after Tx switching may not be unique.** |
| [8] | **Proposal 20: For ambiguity switching cases issue, RRC parameter (e.g. uplinkTxSwitching-DualUL-TxState) can be re-used.*** **If the parameter is configured as twoT, no further indication is needed.**
* **If the parameter is configured as oneT, gNB shall give further indication, detail is FFS.**
 |
| [9] | **Proposal 3*** RRC configuration as defined in Rel-17 can be extended to resolve the issues that state of Tx chains after Tx switching is not unique for Rel-18 Tx switching across 3 or 4 bands.
 |
| [10] | ***Observation 1: There may be ambiguity on determining the Tx chain state between two adjacent uplink transmissions in some cases, i.e. band pairs contains the same band on which single port transmission is allowed.******Observation 2: UE is aware of its operation state and whether switching period is needed or not before a pending uplink transmission.******Observation 3: Limited combinations of UL transmission will not only limit the flexibility of base station scheduling, but also introduce additional delay.******Proposal 2: Ambiguity on switching period can be resolved by implementation.*** |
| [12] | **Proposal #7: Reuse *uplinkTxSwitching-DualUL-TxState* to handle the ambiguous cases in Rel-18 UL Tx switching. In addition, a new RRC parameter or a pre-defined rule can be considered to determine one state of Tx chain when the states of Tx chains after Tx switching is not unique even configured with *uplinkTxSwitching-DualUL-TxState*.**  |
| [14] | **Proposal 6:** *For Rel-18 UL Tx Switching with 3 or 4 bands, when more than one resulting state of Tx chain configuration is possible for the UE during UL Tx switching, the UE assumes the state resulting in the smallest number of Tx switches* |
| [16] | **Proposal 6 To support dynamic UL Tx switching across 3 or 4 bands, resolve any ambiguity in TX chains state transition via RRC configurations (similar to Rel-17).** |
| [17] | **Proposal 8: At least following UE capability and RRC signaling should be considered for Rel-18 UL Tx switching across 3 or 4 bands with potential complexity reduction options.*** **RRC signaling to solve ambiguous state issue in Rel-18 UL Tx switching across 3 or 4 bands**
	+ **Since the existing parameter *uplinkTxSwitching-DualUL-TxState* in *CellGroupConfig* has only {oneT, twoT} as candidate values, extension of this parameter or new parameter would be necessary for ambiguous state issue in Rel-18 UL Tx switching across 3 or 4 bands where the number of possible switching cases in ambiguous state issue is more than 2.**
 |
| [19] | **Proposal 2: When UE is to switch to a Tx operation state that is not unique, the UE configures the non-scheduled Tx according to a RRC configuration, where the configuration can indicate a single carrier to all antenna port assignments (e.g. 1P-0P-0P, 0P-1P-0P, and 0P-0P-1P) that cause non-unique cases or indicate one carrier to each of the antenna port assignments (e.g. 1P-0P-0P, 0P-1P-0P, and 0P-0P-1P) that cause non-unique cases.** |

Based on above, the situation can be summarized as below.

|  |
| --- |
| * Reuse existing RRC parameter {oneT, twoT} via uplinkTxSwitching-DualUL-TxState [3], [4], [6], [8], [9], [12], [16], [17], [19]
	+ If twoT is indicated, 2T are on the transmitting band
	+ If oneT is indicated, 1T is on the transmitting band and
		- Remaining 1T is on the band based on gNB indication/configuration [3], [8], [12], [17], [19]
		- Remaining 1T is on the lowest or highest carrier frequency among bands (i.e., based on a predefined rule) [3]
		- Remaining 1T is on the band which can minimize the number of Tx chains to be switched (i.e., based on a predefined rule) [12], [14]
			* [moderator] but this rule alone is not sufficient e.g., in case that current state is 1T+1T on band A+B and next transmission is 1 port on band C, switching either A or B to C results the same number of switched Tx chains, as many contributions explained
	+ Introduce new RRC parameter as extension of uplinkTxSwitching-DualUL-TxState [4], [9], [17], [19]
* Limit the possible port mapping patterns [5]
	+ For each 1T+1T case, only either one of 1P+0P or 0P+1P is allowed [5]
	+ For each 1T+1T case, only 1P+1P is allowed (i.e., in dual UL)
* Can be solved by implementation [10]
* The ambiguous switching state issue is only in Dual UL [2], [6], [8], [9]
	+ For switched UL, only Tx chain states with 2T are assumed (i.e., states with 1T+1T are not assumed so that there is no ambiguous state issue)
* The ambiguous switching state issue can also be in Switched UL [3], [5], [14]
	+ E.g., if some of the bands support up to 2 ports while other bands support up to 1 port, Tx chain states with 1T+1T on some bands may be supported so that there may be ambiguous state issue
 |

The majority proposes to solve the ambiguous switching state issue based on RRC configuration similar to Rel-17. In addition, multiple companies pointed that existing parameter ({oneT, twoT} in uplinkTxSwitching-DualUL-TxState) may not be sufficient for Rel-18 with 3 or 4 bands and some new parameter or predefined rule especially for the case of oneT would be necessary. By the way, many companies have assumed that this issue exists only in dual UL since only 2T switching cases are assumed for switched UL by those companies, while several companies considered that 1T+1T switching case(s) would exist for switched UL. Such points can be discussed in section 4.3.

The moderator would like to ask companies to provide feedback if any on the above summary and following potential FL proposal.

### **Proposed agreement 4.1**

* **Reuse existing RRC parameter {oneT, twoT} via uplinkTxSwitching-DualUL-TxState to solve the issue on ambiguous switching state**
	+ **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**
			* **Alt.2: based on predefined rule**

#### 1st round Feedback form for 4.1

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | We support the principle to use RRC to solve this ambiguity issue.However, this might rely on the output of complexity reduction discussion and would be better to be discussed with progress of complexity reduction methods. |
| ZTE | Another ambiguity issue for switchedUL also needs to be discussed. We mark it as Case#3.* + **Case#3 of the issue for switchedUL: two Tx chains are currently associated with band A, and next transmission is 1 port transmission on band B and the 3rd transmission is 1 port transmission on band C, but there are multiple possible switching cases where 1P on band B is supported**
		- **both of two Tx chains are switched to band B**
		- **one Tx chain is switched to band B while another Tx chain remains on band A**
		- **one Tx chain is switched to band B while another Tx chain is switched to band C**

Another issue needs to be discussed for switchedUL is, if band B only supports 1-port transmission but not 2-port transmission, is it possible to switched both of the two Tx chains to band B? |
|  |  |

## 4.2 Issue on ambiguous switching period location and/or duration

In contributions in AI 9.9.2, following observations and proposals were made regarding the issue on ambiguous switching period location and/or duration.

|  |  |
| --- | --- |
| [2] | ***Observation 3:*** *For UL-CA Option 2, the following specification impacts need to be considered,** *Tx state ambiguity after Tx switching*
* *Switching ambiguity issue*
* *4 new switching instances, i.e. current UL transmission band(s) and the preceding band(s) involve 3 or 4 bands, should be specified*
* *Supporting only some concurrent UL transmission cases by UE reporting.*
* *Switching location configuration issue for 4 new switching instances*
* *Switching period issue for 4 new switching instances*
 |
| [3] | ***Proposal 2****: RAN1 discusses how to determine the switching gap for each of the following switching cases considering different switching periods may be reported for different band pairs.****Proposal 3****: In order to derive the switching gap (Tgap) for different switching cases, consider the following method.** *The band before Tx switching and the band after Tx switching for each Tx is considered as a band pair.*
	+ *If UE is able to switch the 1st Tx and 2nd Tx independently, Tgap = max { Tswitch\_period\_1, Tswitch\_period\_2}*
	+ *If UE is not able switch the 1st Tx and 2nd Tx independently, Tgap = Tswitch\_period\_1 + Tswitch\_period\_2*
* *Tswitch\_period\_1 and Tswitch\_period\_2 are the switching period for band pair for the 1st Tx and 2nd Tx, respectively.*

***Observation 1****: Network is not able to figure out the exact switching opt the UE adopted. Without this information, network has to assume the maximum switching period for all the potential opts, which will negate the potential gain of per-band-pair reported switching period.** *Different UEs may apply different Tx switching options for different band pairs. For example, for the same Tx switching from Band A + Band B to Band C (1-port transmission), UE1 may implement it as switching the Tx on Band A to Band C, while UE2 may implement it as switching Tx on Band B to Band C.*

***Proposal 4****: For Rel-18 UL Tx switching, network indicates the band pair for UE in order to enjoy the gain of per-band-pair reported switching period.* |
| [6] | **Proposal 4: For inter-band UL CA Option 1, if Tx switching across 3 or 4 bands is configured, the switching period for a switching procedure depends on the actually involved band pair.****Proposal 9: For inter-band UL CA Option 2, if Tx switching across 3 or 4 bands is configured, the maximum length switching period is applied for a switching procedure, among the switching periods corresponding to all the possible band pairs as the previous and next bands of the switched Tx.** |
| [12] | **Proposal #6: The location of switching period for Rel-18 UL Tx switching can be pre-defined as the switch-from band or switch-to band.**  |
| [15] | 1. ***For UL Tx switching among 3/4 bands, the required switching period is reported separately from R16/R17 switching period.***
* ***Reuse the existing set for switching periods {35 us, 140 us, 210 us}.***
* ***The switching period is reported per band pair.***
* ***For each band pair, the switching period can be reported separately for 1Tx-2Tx and 2Tx-2Tx switching.***
* ***For each band pair, the switching period can be reported separately for “2 bands” and “3/4 bands” switching.***
* ***The supported Tx switching option (switchedUL or dualUL) is reported per band pair.***
 |
| [18] | **Proposal 8: On which band taking the switching period, leverage current RRC configuration structure and select one among** **the two alternatives below.*** **Alt. 1: Configure the anchor band as the band to take the switching period.**
* **Alt. 2: For direct switching between anchor and non-anchor bands, configure the non-anchor band as the band to take the switching period. For indirect switching between non-anchor bands, indicate the switch-from or switch-to to take the switching period.**
 |
| [19] | **Proposal 3: The switching period location is indicated to the cell group with one of the following options*** **Option-1: The configuration indicates the switching period location by using a time slot in either the current or scheduled carriers/bands.**
* **Option-2: The configuration indicates the switching period location per band pair, if the UE determines a switching period of a 1st Tx in the current cell and another switching period of a 2nd Tx in the scheduled cell, the UE use the earliest time slot (i.e. current cell) to conduct the Tx switching.**
 |

Based on above, the situation can be summarized as below.

|  |
| --- |
| * There is ambiguity issue on switching period location with current RRC parameter [2], [12], [18], [19]
	+ Switching period location can be determined based on predefined rule such as switch-from or switch-to [12]
	+ Switching period location can be determined based on anchor band [18]
	+ Switching period location can be determined based on the indication of switching period location per band pair [19]
	+ Switching period location can be determined based on the indication of switching period location {switch-from, switch-to} [18], [19]
* There is ambiguity issue on switching period when either one of two Tx chains is required to switch [3], [6]
	+ Network indicates the band pair [3]
	+ Maximum switching period among possible switching periods is assumed [3], [6]
* Switching period per band pair is separately reported for 2 bands and 3/4 bands [15]
 |

Multiple companies pointed that there is ambiguity issue on switching period location with current RRC parameter, and hence a certain solution would be necessary. Regarding the potential ambiguity on which switching period needs to be assumed, the issue would be the same as ambiguity issue on switching state discussed in section 4.1 and hence the solution for determining the switching state can address the switching period as well. But only when four bands are involved for a switching (switching from 1T+1T on band A+B to 1T+1T on band C+D), there would be ambiguity on switching period such as whether switching is from A to C and from B to D or from A to D and from B to C assuming different switching periods for different band pairs. The moderator would like to ask companies to provide feedback if any on the above summary and following potential FL proposals.

### **Proposed agreement 4.2.1**

* **Down-select one of following alternatives for the ambiguity issue on switching period location**
	+ **Alt.1: Switching period location can be determined based on predefined rule such as switch-from or switch-to**
	+ **Alt.2: Switching period location can be determined based on anchor band**
	+ **Alt.3: Switching period location can be determined based on the indication of switching period location per band pair**
	+ **Alt.4: Switching period location can be determined based on the indication of switching period location {switch-from, switch-to}**

#### 1st round Feedback form for 4.2.1

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | We prefer Alt. 2. |
| ZTE | We are ok to further discuss these alternatives. But we think one alternative is missing in the above proposal.* + Alt.5: Switching period location can be determined based on RRC configuration, e.g., uplinkTxSwitchingPeriodLocation.

We think this issue is also related to the determination of the UL Tx switching gap. Take the following figure as an example, if different switching period locations are configured for Band pair A + C and band pair B+C, then the switching gap may be the sum of {switching period for Band pair A + C} and {switching period for band pair B+C}. However, if the same switching location is configured for Band pair A + C and band pair B+C, then the switching gap may be the maximum number of {switching period for Band pair A + C} and {switching period for band pair B+C} |
|  |  |

### **Proposed agreement 4.2.2**

* **Switching period is reported per band pair separately for 2 bands and 3/4 bands**
* **For the case where four bands are involved for a switching, down-select one of following alternatives for how to determine the switching period**
	+ **Alt.1: Switching period is determined based on the predefined rule e.g., minimum or maximum among possible switching periods**
	+ **Alt.2: Switching period is determined based on gNB indication or configuration**

#### 1st round Feedback form for 4.2.2

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | We support UE reports the switching periods as a UE capability for all the switching cases.  |
| ZTE | The first bullet can be left to RAN2/RAN4 discussion. Actually it is now under discussion in RAN4 according to the following info from RAN4 LS.* *For the same band pair, RAN4 has not concluded on whether the same or a different value can be reported for the specific band pair supporting Tx switching across 3 or 4 bands in Rel-18 compared to Tx switching across 2 bands specified in Rel-16/17.*

Regarding the second bullet, the determination of switching period is not just related to the case when 4 bands are involved for a switching, it is also related to the case when 2 or 3 bands are involved for a switching. * For 3 band case: if UE is currently in Band A (1Tx) + Band B (1Tx) and then UE needs to switch to Band C for 2-port transmission, multiple switching periods are involved due to 1Tx from Band A is switched to Band C and the other 1Tx from Band B is switched to Band C.
* For 3 band case: if UE is currently in Band A (1Tx) + Band B (1Tx) and then UE needs to switch to Band C for 1-port transmission, different switching period may be needed if 1Tx from Band A is switched or 1Tx from Band B is switched to Band C.
* For 2 band case: if UE is currently in Band A (2Tx) and then UE needs to switch to Band C for 1-port transmission, different switching period may be needed if 1Tx or 2Tx are switched from Band A to Band C.

Overall, we think all these cases should be considred together and we are open to alternatives for how to determine the switching period.  |
|  |  |

## 4.3 detailed switching cases and mechanisms for Switched UL and for Dual UL

In contributions in AI 9.9.2, following observations and proposals were made regarding detailed switching cases and mechanisms for Switched UL.

|  |  |
| --- | --- |
| [2] | ***Proposal 1:*** *Reuse the R17 triggering mechanism of UL Tx switching specified in S6.1.6.2 of TS 38.214 for UL-CA Option 1 for dynamic UL Tx switching across 3 or 4 bands.* |
| [3] | ***Proposal 8****: Adopt the following two tables for Rel-18 UL Tx switching as baseline.*

|  |  |  |
| --- | --- | --- |
|  | Number of Tx Chains(Band A + Band B + Band C) | Number of antenna ports for UL transmissionBand A(Carrier 1)+Band B(Carrier 2)+Band C(Carrier 3) |
| Case 1-1 | 1T+1T+0T | 1P+0P+0P, 1P+1P+0P, 0P+1P+0P |
| Case 1-2 | 0T+1T+1T | 0P+1P+0P, 0P+1P+1P, 0P+0P+1P |
| Case 1-3 | 1T+0T+1T | 1P+0P+0P, 1P+0P+1P, 0P+0P+1P |
| Case 2-1 | 2T+0T+0T | 2P+0P+0P, 1P+0P+0P |
| Case 2-2 | 0T+2T+0T | 0P+2P+0P, 0P+1P+0P |
| Case 2-3 | 0T+0T+2T | 0P+0P+2P, 0P+0P+1P |

|  |  |  |
| --- | --- | --- |
|  | Number of Tx Chains(Band A + Band B + Band C+Band D) | Number of antenna ports for UL transmissionBand A(Carrier 1)+Band B(Carrier 2)+Band C(Carrier 3) +Band D (Carrier 4) |
| Case 1-1 | 1T+1T+0T+0T | 1P+0P+0P+0P, 1P+1P+0P+0P, 0P+1P+0P+0P |
| Case 1-2 | 0T+1T+1T+0T | 0P+1P+0P+0P, 0P+1P+1P+0P, 0P+0P+1P+0P |
| Case 1-3 | 0T+0T+1T+1T | 0P+0P+1P+0P, 0P+0P+1P+1P, 0P+0P+0P+1P |
| Case 1-4 | 1T+0T+0T+1T | 1P+0P+0P+0P, 1P+0P+0P+1P, 0P+0P+0P+1P |
| Case 1-5 | 1T+0T+1T+0T | 1P+0P+0P+0P, 1P+0P+1P+0P, 0P+0P+1P+0P |
| Case 1-6 | 0T+1T+0T+1T | 0P+1P+0P+0P, 0P+1P+0P+1P, 0P+0P+0P+1P |
| Case 2-1 | 2T+0T+0T+0T | 2P+0P+0P+0P, 1P+0P+0P+0P |
| Case 2-2 | 0T+2T+0T+0T | 0P+2P+0P+0P, 0P+1P+0P+0P |
| Case 2-3 | 0T+0T+2T+0T | 0P+0P+2P+0P, 0P+0P+1P+0P |
| Case 2-4 | 0T+0T+0T+2T | 0P+0P+0P+2P, 0P+0P+0P+1P |

***Proposal 9****: At least introduce the following new switching cases for Rel-18 UL Tx switching.** *1-port transmission on carrier/band A + 1-port transmission on carrier/band B <-> 1-port transmission on carrier/band C*
* *1-port transmission on carrier/band A + 1-port transmission on carrier/band B <-> 2-port transmission on carrier/band C*
* *1-port transmission on carrier/band A + 1-port transmission on carrier/band B <-> 1-port transmission on carrier/band A or B + 1-port transmission on carrier/band C*
* *1-port transmission on carrier/band A + 1-port transmission on carrier/band B <-> 1-port transmission on carrier/band C + 1-port transmission on carrier/band D*
 |
| [5] | **Proposal 4: The Tx switching between different cases for 3 or 4 bands can at least include these scenarios that are almost identical to the Tx switching cases between 2 bands specified in Rel-16/Rel-17.*** **Scenario 1: Switching between the case of 1 Tx on band A and 1 Tx on band B, and the case of 0 Tx on band A and 2 Tx on band B, while 0Tx on band C (and band D if configured).**
* **Scenario 2: Switching between the case of 0 Tx on band A and 2 Tx on band B, and the case of 2 Tx on band A and 0 Tx on band B, while 0Tx on band C (and band D if configured).**
* **Scenario 3: Switching among the case of 1 Tx on band A and 1 Tx on band B, the case of 0 Tx on band A and 2 Tx on band B, and the case of 2 Tx on band A and 0 Tx on band B, while 0Tx on band C (and band D if configured).**

Proposal 5: The following Tx switching between different cases for 3 or 4 bands can be supported in Rel-18:* **Scenario 4: Switching between the case of 1 Tx on band A and 1 Tx on band B, and the case of 0 Tx on band A/B and 2 Tx on band C, (while 0Tx on band D if configured).**
* **Scenario 5: Switching between the case of 1 Tx on band A and 1 Tx on band B, and the case of 1 Tx on band A and 1 Tx on band C, (while 0Tx on band D if configured).**

Proposal 6: The following Tx switching between different cases for 4 bands can be supported in Rel-18:* **Scenario 6: Switching between the case of 1 Tx on band A and 1 Tx on band B, and the case of 1 Tx on band C and 1 Tx on band D.**
 |
| [6] | **Proposal 1: For Rel-18 UL Tx switching across 3 bands each supporting maximum 2Tx chain, the mapping between Tx chains and UL transmission antenna ports for inter-band UL CA Option 1 with and without SUL band is defined as follows.**

|  |  |  |
| --- | --- | --- |
|  | Number of **Tx chains** for Band A+ Number of **Tx chains** for Band B+ Number of **Tx chains** for Band C | Number of **antenna ports** for UL transmission in Band A+ Number of **antenna ports** for UL transmission in Band B+ Number of **antenna ports** for UL transmission in Band C |
| Case 1 | 2T+0T+0T | 2P+0P+0P, 1P+0P+0P |
| Case 2 | 0T+2T+0T | 0P+2P+0P, 0P+1P +0P |
| Case 3 | 0T+0T+2T | 0P+0P+2P, 0P+0P+1P |

**Proposal 2: For Rel-18 UL Tx switching across 4 bands each supporting maximum 2Tx chain, the mapping between Tx chains and UL transmission antenna ports for inter-band UL CA Option 1 with and without SUL band is defined as follows.**

|  |  |  |
| --- | --- | --- |
|  | Number of **Tx chains** for Band A+ Number of **Tx chains** for Band B+ Number of **Tx chains** for Band C+ Number of **Tx chains** for Band D | Number of **antenna ports** for UL transmission in Band A+ Number of **antenna ports** for UL transmission in Band B+ Number of **antenna ports** for UL transmission in Band C+ Number of **antenna ports** for UL transmission in Band D |
| Case 1 | 2T+0T+0T+0T | 2P+0P+0P+0P, 1P+0P+0P+0P |
| Case 2 | 0T+2T+0T+0T | 0P+2P+0P+0P, 0P+1P +0P+0P |
| Case 3 | 0T+0T+2T+0T | 0P+0P+2P+0P, 0P+0P+1P+0P |
| Case 4 | 0T+0T+0T+2T | 0P+0P+0P+2P, 0P+0P+0P+1P |

**Proposal 3: For inter-band UL CA Option 1, if Tx switching across 3 or 4 bands is configured, the switching period is only applicable when the UL transmissions are switched between different bands.****Proposal 5: For Rel-18 UL Tx switching across 3 bands each supporting maximum 2Tx chain, the mapping between Tx chains and UL transmission antenna ports for inter-band UL CA Option 2 is defined as follows.*** **If there is(are) SUL band(s) within band A, B, C, D, subset of the cases applies.**

|  |  |  |
| --- | --- | --- |
|  | Number of **Tx chains** for Band A+ Number of **Tx chains** for Band B+ Number of **Tx chains** for Band C | Number of **antenna ports** for UL transmission in Band A+ Number of **antenna ports** for UL transmission in Band B+ Number of **antenna ports** for UL transmission in Band C |
| Case 1 | 2T+0T+0T | 2P+0P+0P, 1P+0P+0P |
| Case 2 | 0T+2T+0T | 0P+2P+0P, 0P+1P+0P |
| Case 3 | 0T+0T+2T | 0P+0P+2P, 0P+0P+1P |
| Case 4 | 1T+1T+0T | 1P+0P+0P, 1P+1P+0P, 0P+1P+0P |
| Case 5 | 1T+0T+1T | 1P+0P+0P, 1P+0P+1P, 0P+0P+1P |
| Case 6 | 0T+1T+1T | 0P+1P+0P, 0P+1P+1P, 0P+0P+1P |

**Proposal 6: For Rel-18 UL Tx switching across 4 bands each supporting maximum 2Tx chain, the mapping between Tx chains and UL transmission antenna ports for inter-band UL CA Option 2 is defined as follows.*** **If there is(are) SUL band(s) within band A, B, C, D, subset of the cases applies.**

|  |  |  |
| --- | --- | --- |
|  | Number of **Tx chains** for Band A+ Number of **Tx chains** for Band B+ Number of **Tx chains** for Band C+ Number of **Tx chains** for Band D | Number of **antenna ports** for UL transmission in Band A+ Number of **antenna ports** for UL transmission in Band B+ Number of **antenna ports** for UL transmission in Band C+ Number of **antenna ports** for UL transmission in Band D |
| Case 1 | 2T+0T+0T+0T | 2P+0P+0P+0P, 1P+0P+0P+0P |
| Case 2 | 0T+2T+0T+0T | 0P+2P+0P+0P, 0P+1P+0P+0P |
| Case 3 | 0T+0T+2T+0T | 0P+0P+2P+0P, 0P+0P+1P+0P |
| Case 4 | 0T+0T+0T+2T | 0P+0P+0P+2P, 0P+0P+0P+1P |
| Case 5 | 1T+1T+0T+0T | 1P+0P+0P+0P, 1P+1P+0P+0P, 0P+1P+0P+0P |
| Case 6 | 1T+0T+1T+0T | 1P+0P+0P+0P, 1P+0P+1P+0P, 0P+0P+1P+0P |
| Case 7 | 1T+0T+0T+1T | 1P+0P+0P+0P, 1P+0P+0P+1P, 0P+0P+0P+1P |
| Case 8 | 0T+1T+1T+0T | 0P+1P+0P+0P, 0P+1P+1P+0P, 0P+0P+1P+0P |
| Case 9 | 0T+1T+0T+1T | 0P+1P+0P+0P, 0P+1P+0P+1P, 0P+0P+0P+1P |
| Case 10 | 0T+0T+1T+1T | 0P+0P+1P+0P, 0P+0P+1P+1P, 0P+0P+0P+1P |

**Proposal 7: For inter-band UL CA Option 2, if Tx switching across 3 or 4 bands is configured, the switching period is applicable in the following cases:*** **If the current state of Tx chains is 2Tx on one band and 0Tx on other bands, the next UL transmission has a 2-port transmission on at least one carrier on one of other bands.**
* **If the current state of Tx chains is 2Tx on one band and 0Tx on other bands, the next UL transmission has simultaneous 1-port transmission on two bands each on at least one carrier.**
* **If the current state of Tx chains is 2Tx on one band and 0Tx on other bands, the next UL transmission only has a 1-port transmission on at least one carrier on one of other bands.**
* **If the current state of Tx chains is 1Tx on one band and 1Tx on another band, the next UL transmission has a 2-port transmission on at least one carrier on a band.**
* **If the current state of Tx chains is 1Tx on one band and 1Tx on another band, the next UL transmission has simultaneous 1-port transmission on two bands each on at least one carrier, at least one of the next transmitting two bands is different than the two current 1Tx bands.**
* **If the current state of Tx chains is 1Tx on one band and 1Tx on another band, the next UL transmission only has a 1-port transmission on at least one carrier on a third band.**
 |
| [8] | **Proposal 12: For inter-band UL CA option 1 with 3 or 4 carriers, the mapping between UL transmission ports and Tx chains can be supported as follows.****Mapping between UL transmission ports and Tx chains for inter-band UL CA option 1 with 3 carriers**

|  |  |  |
| --- | --- | --- |
|  | **Number of Tx chains** **(carrier 1 + carrier 2 + carrier 3)** | **Number of antenna ports for UL transmission**  **(carrier 1 + carrier 2 + carrier 3)** |
| **Case 4** | **0T+0T+2T** | **{0P+0P+2P},{0P+0P+1P}** |
| **Case 5** | **0T+2T+0T** | **{0P+2P+0P},{0P+1P+0P}** |
| **Case 6** | **2T+0T+0T** | **{2P+0P+0P},{1P+0P+0P}** |

**Mapping between UL transmission ports and Tx chains for inter-band UL CA option1 with 4 carriers**

|  |  |  |
| --- | --- | --- |
|  | **Number of Tx chains (carrier 1 + carrier 2 + carrier 3 + carrier 4)** | **Number of antenna ports for UL transmission (carrier 1 + carrier 2+ carrier 3 carrier 4)** |
| **Case 7** | **0T+0T+0T+2T** | **{0P+0P+0P+2P},{0P+0P+0P+1P}** |
| **Case 8** | **0T+0T+2T+0T** | **{0P+0P+2P+0P},{0P+0P+1P+0P}** |
| **Case 9** | **0T+2T+0T+0T** | **{0P+2P+0P+0P},{0P+1P+0P+0P}** |
| **Case 10** | **2T+0T+0T+0T** | **{2P+0P+0P+0P},{1P+0P+0P+0P}** |

**Proposal 13: For inter-band UL CA option 2 with 3 or 4 carriers, the mapping between UL transmission ports and Tx chains can be supported as follows.****Mapping between UL transmission ports and Tx chains for inter-band UL CA option 2 with 3 carriers**

|  |  |  |
| --- | --- | --- |
|  | **Number of Tx chains** **(carrier 1 + carrier 2 + carrier 3)** | **Number of antenna ports for UL transmission (carrier 1+ carrier 2 + carrier 3)** |
| **Case 1** | **0T+1T+1T** | **{0P+0P+1P}, {0P+1P+0P}, {0P+1P+1P}** |
| **Case 2** | **1T+0T+1T** | **{0P+0P+1P},{1P+0P+0P}, {1P+0P+1P}** |
| **Case 3** | **1T+1T+0T** | **{0P+1P+0P},{1P+0P+0P},{1P+1P+0P}** |
| **Case 4** | **0T+0T+2T** | **{0P+0P+2P},{0P+0P+1P}** |
| **Case 5** | **0T+2T+0T** | **{0P+2P+0P},{0P+1P+0P}** |
| **Case 6** | **2T+0T+0T** | **{2P+0P+0P},{1P+0P+0P}** |

Mapping between UL transmission ports and Tx chains for inter-band UL CA option 2 with 4 carriers

|  |  |  |
| --- | --- | --- |
|  | **Number of Tx chains (carrier 1 + carrier 2 + carrier 3 + carrier 4)** |  **Number of antenna ports for UL transmission (carrier 1 + carrier 2 + carrier 3 + carrier 4)** |
| **Case 1** | **0T+0T+1T+1T** | **{0P+0P+0P+1P},{0P+0P+1P+0P},{0P+0P+1P+1P}** |
| **Case 2** | **0T+1T+0T+1T** | **{0P+0P+0P+1P},{0P+1P+0P+0P},0P+1P+0P+1P}** |
| **Case 3** | **0T+1T+1T+0T** | **{0P+0P+1P+0P},{0P+1P+0P+0P},{0P+1P+1P+0P}** |
| **Case 4** | **1T+1T+0T+0T** | **{0P+1P+0P+0P},{1P+0P+0P+0P},{1P+1P+0P+0P}** |
| **Case 5** | **1T+0T+1T+0T** | **{0P+0P+1P+0P},{1P+0P+0P+0P},{1P+0P+1P+0P}** |
| **Case 6** | **1T+0T+0T+1T** | **{0P+0P+0P+1P},{1P+0P+0P+0P},{1P+0P+0P+1P}** |
| **Case 7** | **0T+0T+0T+2T** | **{0P+0P+0P+2P},{0P+0P+0P+1P}** |
| **Case 8** | **0T+0T+2T+0T** | **{0P+0P+2P+0P},{0P+0P+1P+0P}** |
| **Case 9** | **0T+2T+0T+0T** | **{0P+2P+0P+0P},{0P+1P+0P+0P}** |
| **Case 10** | **2T+0T+0T+0T** | **{2P+0P+0P+0P},{1P+0P+0P+0P}** |

**Proposal 14: The mapping rule between Tx chains and antenna port for inter-band UL CA option1 (*SwitchedUL*)** **with 3 or 4 carriers can be reused for 1 SUL with 3 or 4 carriers scenario.****Proposal 16: For uplink Tx switching across up to 3 or 4 bands, if the UE is configured with option 2 (*DualUL*) and only two carriers are involved in Tx UL switching, the uplink Tx switching scheme in Rel-16/Rel-17 can be reused.****Proposal 17: For uplink Tx switching across up to 3 or 4 bands, if the UE is configured with option 2 (*DualUL*) and three carriers are involved in Tx UL switching; the following two cases shall be applied uplink switching period** * **Switching between “2-port transmission on first uplink carrier” and “1-port transmission on second uplink carrier and 1-port transmission on third uplink carrier”**
* **Switching between “1-port transmission on first uplink carrier and 1-port transmission on second uplink carrier” and “1-port transmission on first or second uplink carrier and 1-port transmission on third uplink carrier”.**

**Proposal 18: For uplink TX switching across up to 3 or 4 bands, if the UE is configured with option 2 (DualUL) and four carriers are involved in Tx UL switching; the following one case shall be applied uplink switching period,*** **Switching between “1-port transmission on first uplink carrier and 1-port transmission on second uplink carrier” and “1-port transmission on third uplink carrier 1-port transmission on fourth uplink carrier.”**

**Proposal 19: All UL Tx switching cases are supported in R18 specification, and gNB can configure sub-set of switching cases according to reported UE capability.** |
| [9] | **Proposal 2*** For mapping between UL transmission ports and Tx chain:
	+ Consider Table 1 for Tx switching across 3 bands for CA Option 1 without or with SUL
	+ Consider Table 2 for Tx switching across 3 bands for CA Option 2 without SUL
	+ Consider Table 3 for Tx switching across 4 bands for CA Option 1 without or with SUL
	+ Consider Table 4 for Tx switching across 4 bands for CA Option 2 without SUL
 |
| [10] | ***Proposal 1: There should be no restrictions on the band pairs for Rel-18 UL Tx switching.*** |
| [11] | **Proposal 1. If dynamic UL Tx switching across 3 and 4 bands is supported, the following switching cases can be considered.*** **For UL Tx switching across 3 or 4 bands in inter-band UL Option 1 CA without SUL scenarios, the mapping between Tx chains and UL transmission antenna ports can be defined as in Table 1 and Table 2.**
* **For UL Tx switching across 3 or 4 bands in inter-band UL Option 2 CA without SUL scenarios, the mapping between Tx chains and UL transmission antenna ports can be defined as in Table 3 and Table 4.**
* **For UL Tx switching across 3 or 4 bands in inter-band UL CA with 1 SUL band, the mapping between Tx chains and UL transmission antenna ports can be defined as in Table 5 and Table 6.**
 |
| [17] | **Proposal 5: For Rel-18 switched UL scenario, whether switching cases where Tx chains are on the different bands are supported or not should be discussed.** |
| [18] | **Table 1 General switching cases for Rel-18**

|  |  |  |
| --- | --- | --- |
|  | Tx status of each band, may be contiguous CA of some band (Band A, B, C, D) |  |
| Case 1 | aT + bT + cT + dT  | Two out of {a, b, c, d} are “1” and the rest are “0” |
| Case 2 | aT + bT + cT + dT | One out of {a, b, c, d} is “1” or “2” and the rest are “0” |
| Case 3 | aT + bT + cT + dT | Another one of {a, b, c, d} is “1” or “2” and the rest are “0” |

**Proposal 2: Use the switching cases in Table 1 for Rel-18 UL Tx switching discussion.****Table 3 CA Option 1 mapping between Tx state and Tx layers**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Tx state of each band, may be contiguous CA of some band (Band A, B, C, D) |  | Transmission layers |
| Case 2 | aT + bT + cT + dT | The anchor band is “1” or “2” and the rest are “0” | Anchor band: ≥1 layer  |
| Case 3 | aT + bT + cT + dT | A non-anchor band is “1” or “2” and the rest are “0” | Non-anchor band: ≥1 layer |

**Proposal 4: Adopt Table 3 for CA Option 1 without SUL mapping between Tx state and Tx layers.****Table 5 CA Option 2 mapping between Tx state and Tx layers**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Tx state of each band, may be contiguous CA of some band (Band A, B, C, D) |  | Transmission layers |
| Case 1 | aT + bT + cT + dT  | The anchor and one non-anchor band are “1” and rest are “0” | Anchor band: 1 layerNon-anchor band: 1 layer |
| Case 2 | aT + bT + cT + dT | The anchor band is “1” or “2” and the rest are “0” | Anchor band: ≥ 1 layer  |
| Case 3 | aT + bT + cT + dT | The non-anchor band is “1” or “2” and the rest are “0” | Non-anchor band: ≥ 1 layer |

**Proposal 5: Adopt Table 5 for CA Option 2 without SUL mapping between Tx state and Tx layers.****Proposal 6: For inter-band UL CA Option 1 with SUL, adopt following for UL Tx switching among 3 or 4 bands.*** **Leverage CA Option 1 without SUL as baseline**
* **The anchor band should be identified among NUL bands. Direct switching is between anchor and non-anchor bands, and indirect switching between non-anchor bands.**
* **FFS: whether allowing direct switching between SUL and other NUL rather than its serving cell.**

**Table 7 CA Option 1 with SUL mapping between Tx state and Tx layers**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Tx state of each band, may be contiguous CA of one NUL band |  | Transmission layers |
| Case 2 | aT + bT + cT + dT | The anchor band is “1” or “2” and the rest are “0” | Anchor band: ≥1 layer  |
| Case 3 | aT + bT + cT + dT | A non-anchor band is “1” or “2” and the rest are “0” | Non-anchor band: ≥1 layer |

**Proposal 7: Adopt Table 7 for CA Option 1 with SUL mapping between Tx state and Tx layers.** |

Based on above, the situation can be summarized as below.

|  |
| --- |
| * Reuse R17 triggering mechanism of UL Tx switching (specified in S6.1.6.2 of TS 38.214) for Switched UL [2], [6]
	+ Switching period is only applicable when the UL transmissions are switched between different bands
* Reuse R17 triggering mechanism of UL Tx switching for Dual UL when only two bands are involved in a switching [8]
* New switching instances need to be specified for Dual ULwhen more than two bands are involved in a switching [2], [6], [8]
* Support all the switching cases such as 6 cases for 3 bands and 10 cases for 4 bands [3], [5], [6], [8], [9], [10], [11], [17]
	+ For Switched UL, only cases with 2T (3 cases for 3 bands and 4 cases for 4 bands) are supported [6], [8], [9], [11]
	+ Even for Switched UL, cases with 1T+1T may be supported e.g., when 2 ports transmission is not supported in some band(s) [3], [5], [17]
	+ Subset of switching cases can be configured by gNB according to the reported capability [8]
* Use the new generalized table for the switching cases in Rel-18 [18]
 |

It seems that many companies consider switching cases and triggering mechanisms based on Rel-16/17. However, if we consider some complexity reduction options such as option 1 and 2, possible switching cases may need to be considered case by case. The moderator would like to ask companies to provide feedback if any on the above summary and following potential FL proposal.

### **Proposed agreement 4.3**

* **If Rel-18 UL Tx switching for 3 or 4 bands is supported, following is considered as baseline.**
	+ **Existing conditions where the switching period is required can be reused for Rel-18 UL Tx switching with 3 or 4 bands when only two bands are involved in a switching**
	+ **New conditions where the switching period is required should be introduced for Rel-18 UL Tx switching with 3 or 4 bands when more than two bands are involved in a switching**
		- **At least for dual UL, following new conditions are considered**
			* **When the UE is to transmit a 1-port or 2-port transmission on one uplink carrier on one band (1st band) and if Tx chain state at the preceding uplink transmission is 1T + 1T each on a carrier on other different bands (2nd and 3rd band)**
			* **When the UE is to transmit a 1-port + 1-port transmission each on one uplink carrier on different bands (1st and 2nd band) and if Tx chain state at the preceding uplink transmission is 2T on a carrier on another band (3rd band)**
			* **When the UE is to transmit a 1-port + 1-port transmission each on one uplink carrier on one band (1st and 2nd band) and if Tx chain state at the preceding uplink transmission is 1T + 1T each on a carrier on other different bands (3rd and 4th band)**
		- **FFS for switched UL and/or for the case with complexity reduction option 1 or 2**

#### 1st round Feedback form for 4.3

|  |  |
| --- | --- |
| Company | Comment |
| ZTE | We are generally fine with this proposal.There are also some spec impacts for switched UL and SUL, e.g., ambiguity issue for them and how to determine the switching period. But these can be discussed separately. |
|  |  |
|  |  |

1. Discussions on other general aspects for Rel-18 multi-carrier UL Tx switching

## 5.1 Whether to specify UL Tx switching schemes across up to 3 or 4 bands in Rel-18

In contributions in AI 9.9.2, following observations and proposals were made regarding whether to specify UL Tx switching schemes across up to 3 or 4 bands in Rel-18.

|  |  |
| --- | --- |
| [2] | ***Observation 1:*** *For dynamic UL Tx switching among 4 bands, UL-CA Option 1 can bring average UPT gain up to 44.8% compared with Rel-17 UL Tx switching. However, UL-CA Option 2 has small additional average UPT gain compared with UL-CA Option 1.****Proposal 4:*** *UL-CA Option 1 should be specified because it has small specification impacts and provided most of potential performance gains.* |
| [9] | **Proposal 1*** Multi-carrier Tx switching across 3 or 4 bands is supported in Rel-18.
 |

Although not so many companies are proposing to agree on specifying Rel-18 UL Tx switching across 3 or 4 bands, most of companies submitting contributions may be fine to agree on it as they proposed many details on the Rel-18 UL Tx switching across 3 or 4 bands. Therefore, the moderator would like to ask companies to provide feedback if any on the above summary and following potential FL proposal.

### **Proposed working assumption 5.1**

* **Specify UL Tx switching schemes across up to 4 bands in Rel-18**

#### 1st round Feedback form for 5.1

|  |  |
| --- | --- |
| Company | Comment |
| MediaTek | Support |
| Qualcomm | As far as our concern on complexity issue could be solved, we are ok with FL’s proposal. |
| ZTE | We are supportive of this proposal considering the previous simulation results from companies. However, if companies want to introduce additional processing delay or interruption time, new simulations are needed to justify the potential performance gain. |

## 5.2 Whether to support Switched UL and/or Dual UL for UL Tx switching schemes across up to 3 or 4 bands in Rel-18

In contributions in AI 9.9.2, following observations and proposals were made regarding whether to support Switched UL and/or Dual UL for UL Tx switching schemes across up to 3 or 4 bands in Rel-18.

|  |  |
| --- | --- |
| [2] | ***Observation 1:*** *For dynamic UL Tx switching among 4 bands, UL-CA Option 1 can bring average UPT gain up to 44.8% compared with Rel-17 UL Tx switching. However, UL-CA Option 2 has small additional average UPT gain compared with UL-CA Option 1.****Observation 3:*** *For UL-CA Option 2, the following specification impacts need to be considered,** *Tx state ambiguity after Tx switching*
* *Switching ambiguity issue*
* *4 new switching instances, i.e. current UL transmission band(s) and the preceding band(s) involve 3 or 4 bands, should be specified*
* *Supporting only some concurrent UL transmission cases by UE reporting.*
* *Switching location configuration issue for 4 new switching instances*
* *Switching period issue for 4 new switching instances*

***Proposal 4:*** *UL-CA Option 1 should be specified because it has small specification impacts and provided most of potential performance gains.* |
| [3] | ***Proposal 1****: If Rel-18 UL Tx switching is supported, both inter-band CA Option 1 (switchedUL) and inter-band CA Option 2 (dualUL) are supported.* |
| [5] | Proposal 7: Option 1(*switchedUL*) and option 2 (*DualUL*) are both supported in Rel-18 Tx switching. |
| [13] | ***Proposal 6: For supporting NR Rel-18 UL Tx switching across 3 or 4 bands, support both options including switchedUL (option 1) and dual UL (option 2)*** |

Based on above, the situation can be summarized as below.

|  |
| --- |
| * Support at least Switched UL for UL Tx switching schemes across up to 3 or 4 bands in Rel-18? [2]
* Support both Switched UL and Dual UL for UL Tx switching schemes across up to 3 or 4 bands in Rel-18 [3], [5], [13]
 |

The moderator would like to ask companies to provide feedback if any on the above summary and following potential FL proposal.

### **Proposed working assumption 5.2**

* **If Rel-18 UL Tx switching for 3 or 4 bands is supported, both Switched UL and Dual UL are supported**

#### 1st round Feedback form for 5.2

|  |  |
| --- | --- |
| Company | Comment |
| MediaTek | Support |
| Qualcomm  | We support FL proposal. |
| ZTE | We support this proposal, which is aligned with the RANP guidance. |

## 5.3 Whether to support additional target scenarios for UL Tx switching schemes across up to 3 or 4 bands in Rel-18

In contributions in AI 9.9.2, following observations and proposals were made regarding whether to support additional target scenarios for UL Tx switching schemes across up to 3 or 4 bands in Rel-18.

|  |  |
| --- | --- |
| [2] | ***Observation 2:*** *For UL Tx switching among 3 or 4 bands, UL-CA Option 1 with or without SUL has minor specification impacts by reusing existing Rel-16/17 mechanism.****Proposal 1:*** *Reuse the R17 triggering mechanism of UL Tx switching specified in S6.1.6.2 of TS 38.214 for UL-CA Option 1 for dynamic UL Tx switching across 3 or 4 bands.****Proposal 2:*** *Current CA framework can be directly reused in UL Tx switching among 3 or 4 bands for the scenarios with or without SUL, where the current CA framework is that the same UE behaviors across serving cells are applied irrespective of FDD/TDD/SUL band, e.g. UL Tx chain sharing across cells, and the UE behavior between SUL and paired NUL within a serving cell refers to the UE behaviors specified on the context of one serving cell.* ***Proposal 3:*** *The following three scenarios are confirmed within the scope for Rel-18 UL Tx switching:** *Inter-band UL-CA Option 1 without SUL band*
* *Inter-band UL-CA Option 1 for {SUL band + corresponding NUL band} + 1 or 2 other NUL band(s)*
* *Inter-band UL-CA Option 1 for {SUL band + corresponding NUL band} + {SUL band + corresponding NUL band}*
 |
| [8] | **Proposal 15: From RAN1 perspective, following SUL configurations will not introduce extra switching cases for Rel-18 UL Tx switching. Whether it is supported or not depends on RAN4.*** **{SUL band + corresponding NUL band} + {SUL band + corresponding NUL band}.**
* **Simultaneous transmission across 2 bands in {SUL band + corresponding NUL band} + 1 or 2 other NUL band(s) (excluding simultaneous transmission between SUL and corresponding NUL).**
 |
| [11] | **Proposal 1. If dynamic UL Tx switching across 3 and 4 bands is supported, the following switching cases can be considered.*** **For UL Tx switching across 3 or 4 bands in inter-band UL CA with 1 SUL band, the mapping between Tx chains and UL transmission antenna ports can be defined as in Table 5 and Table 6.**
* **For UL Tx switching across 4 bands in inter-band UL CA with 2 SUL bands, the mapping between Tx chains and UL transmission antenna ports can be defined as in Table 7 and Table 8.**
 |
| [18] | **Proposal 1: Following RAN#96 guidance, RAN1 #110bis only focus inter-band UL CA Option 1 and 2 without SUL, and inter-band UL CA Option 1 with 1 SUL, and does not discuss other additional scenarios before further guidance.** |
| [20] | **Proposal 7: Postpone the discussion on the UL Tx Switching with a SUL cell in a CA configuration until after UL Tx Switching for 3 or 4 bands in the CA configuration has gained more maturity** |

Based on above, the situation can be summarized as below.

|  |
| --- |
| * Support Switched UL for {SUL band + corresponding NUL band} + {SUL band + corresponding NUL band} [2], [11]
	+ Whether to support or not depends on RAN4 while no extra switching case exists from RAN1 perspective [8]
* Support Dual UL for {SUL band + corresponding NUL band} + {SUL band + corresponding NUL band} [11]
	+ Whether to support or not depends on RAN4 while no extra switching case exists from RAN1 perspective [8]
* Support Dual UL for inter-band UL CA with 1 SUL band [11]
	+ Whether to support or not depends on RAN4 while no extra switching case exists from RAN1 perspective [8]
* Additional target scenarios should not be discussed before further guidance from RAN [18]
* Postpone the discussion on scenarios with SUL in a CA configuration until after maturity for scenarios without SUL in a CA configuration [20]
 |

Based on the discussion and situation at RAN#97-e, the moderator thinks that additional target scenarios should not be discussed before completing the design for current target scenarios. The moderator would like to ask companies to provide feedback if any on the above summary and proposals in the contributions.

#### 1st round Feedback form for 5.3

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | We support FL proposal to follow RAN#96 guidance, RAN1 #110bis only focus inter-band UL CA Option 1 and 2 without SUL, and inter-band UL CA Option 1 with 1 SUL, and does not discuss other additional scenarios before further guidance. |
|  |  |
|  |  |

## 5.4 Clarifications on UL Tx switching among bands with intra-band CA

In contributions in AI 9.9.2, following observations and proposals were made regarding clarifications on UL Tx switching among bands with intra-band CA.

|  |  |
| --- | --- |
| [6] | **Proposal 10: For Rel-18 UL Tx switching across up to 3 or 4 bands, the same number of Tx chain is applied to intra-band UL carriers in one band.** |
| [11] | * **For UL Tx switching across 3 or 4 bands in intra-band two contiguous aggregated carriers within one non-SUL band scenarios, the mapping between UL transmission ports and Tx chains can be similar to Rel-17 2Tx-2Tx switching between 1 carrier on Band A and 2 contiguous carriers on Band B.**
 |
| [13] | ***Proposal 5: For supporting NR Rel-18 UL Tx switching across 3 or 4 bands, RAN 1 should agree to support only up to 1 band with up to 2 contiguous carriers*** |

It seems proposals for the clarification on intra-band CA are straightforward. Therefore, the moderator would like to ask companies to provide feedback if any on the above proposals in contributions and following potential FL proposal.

### **Proposed agreement 5.4**

* **For Rel-18 UL Tx switching across up to 3 or 4 bands, the same number of Tx chains is applied to intra-band UL carriers in one band similar to Rel-17**
	+ **Up to two Intra-band contiguous aggregated carriers can be within only one non-SUL band out of 3 or 4 bands**

#### 1st round Feedback form for 5.4

|  |  |
| --- | --- |
| Company | Comment |
| MediaTek | We are not sure if there is a need for RAN1 agreement given that similar thing was agreed in RAN#96.

|  |
| --- |
| RAN provides following guidance to RAN1/2/4.* If Rel-18 UL Tx switching is supported,
	+ RAN1/2/4 shall focus on defining necessary mechanisms and requirements for UL Tx switching across 3 or 4 different bands in Q3 2022
		- Inter-band UL-CA Option 1 (i.e., switched UL) and Option 2 (i.e., dual UL) without SUL band
		- Inter-band UL CA Option 1 (i.e., switched UL) for {SUL band + corresponding NUL band} + 1 or 2 other NUL band(s)
			* UL CA framework where UL CA is performed between NULs according to current RAN4 specifications should not be changed
			* Note: switching across any band in this scenario is not precluded
		- Intra-band two contiguous aggregated carriers within one non-SUL band out of 3 or 4 bands
	+ Further check additional scenarios in RAN#97e, e.g.,
		- {SUL band + corresponding NUL band} + {SUL band + corresponding NUL band}
		- Simultaneous transmission across 2 bands in {SUL band + corresponding NUL band} + 1 or 2 other NUL band(s) (excluding simultaneous transmission between SUL and corresponding NUL)
	+ Mechanisms/requirements should not introduce restrictions on what were already supported in current specifications for UL Tx switching
 |

 |
| Qualcomm | We support FL proposal. |
| ZTE | We support this proposal.  |

## 5.5 Other proposals

In contributions in AI 9.9.2, following other proposals were made.

|  |  |
| --- | --- |
| [11] | **Proposal 4. Multiple PUCCH cells can be configured for Rel-18 UL Tx switching across 3 or 4 bands.** |
| [12] | **Proposal #8: Consider additional UL Tx switching conditions to handle the case when simultaneous UL transmissions occur on more than 2 bands (e.g. based on the priority of the transmitted UL channels).** |
| [13] | ***Observation 1: When UL Tx switching is triggered for PUCCH carrying HARQ-ACK, the margin provided by the PDSCH symbols plus PDSCH processing timeline is not sufficient to perform the triggered switching for the scenarios when (also shown in Table):**** ***the scheduling DCI and corresponding PDSCH are overlapping***
* ***and/or reported switching gap value is higher***
* ***and/or higher numerology is applied***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **μ** | **N1** | **N1 + 4****(** | **N2** | **N2 +** **(** |
|  |  |  |  | **35μs** | **140μs** | **210μs** |
| 0 | 8 | **12** | 10 | 11 | 12 | **13** |
| 1 | 10 | **14** | 12 | 13 | **16** | **18** |
| 2 | 17 | **21** | 23 | **25** | **31** | **35** |

***Proposal 7: For supporting NR Rel-18 UL Tx switching, RAN1 should consider supporting switching gap to the PDSCH processing timeline**** ***FFS whether switching gap applied to only specific PDSCH scheduling scenarios***
 |

The moderator would like to ask companies to provide feedback if any on the above proposals in contributions.

#### 1st round Feedback form for 5.5

|  |  |
| --- | --- |
| Company | Comment |
|  |  |
|  |  |
|  |  |

1. Summary of proposals

TBD

1. Conclusion

TBD