**3GPP TSG RAN WG1 #107-e R1-2112539**

**e-Meeting, November 11th – 19th, 2021**

**Agenda item:** 7.2.11

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

**Title:** Summary on [107-e-AI7.2.11-NR-UEFeature-Others-01]

**Document for:** Discussion and Decision

1. Introduction

This contribution summarizes the following email discussion/approval in RAN1#107-e meeting.

**[107-e-AI7.2.11-NR-UEFeature-Others-01] Email discussion/approval on UE features for others by Nov 18th – Hiroki (DOCOMO)**

* **Introduce a new UE capability indicating 4Tx UL MIMO coherence per band per band combination (no impact on Rel-16 UL Tx switching)**

1. Discussion on other UE features
   1. UE feature for UL MIMO coherence

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| 2-13 | PUSCH codebook coherency subset | Supported codebook coherency subset type | 2-12 | *pusch-TransCoherence* | *MIMO-ParametersPerBand* | n/a | n/a |  | Optional with UE capability  Candidate value set: {non-coherent, partial/non-coherent, full/partial/non-coherent} |

Following proposal is made in a contribution.

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| [8] | The UL coherence depends on the UE transmitter architecture. More precisely, it depends on whether a common oscillator signal is applied for up-conversion in the different Tx chains or not.    The same UL MIMO coherence capability in a given band likely does not hold across different band combinations even for the same band. For example, the UE may use a different set of antennas for the UL transmission for a given band in one band combination compared to the antennas used for the same band in a different band combination. A common example for this is that the UE may support 4Tx UL MIMO in one band when no UL CA is configured but the same UE may fall back to 2Tx UL MIMO only in the exact same band when UL CA is configured. Note that this was the very reason why the supported number of UL MIMO layers is signaled per band per combination. Obviously, a UE that can support coherent 2Tx UL MIMO may fall into any of the three coherence categories for 4Tx UL MIMO (i.e. it can be either coherent, partial coherent, or non-coherent for 4Tx UL MIMO). The latter is the case, for example, if the 1st and 2nd chains are associated with a common oscillator, while the 3rd and 4th chains are not.  Due to this consideration, the UL MIMO coherence capability needs to be signaled per band per band combination.  Unfortunately, the current specification doesn’t correctly capture this.  The LS from RAN4 is trying to solve the coherence issue when the UE reports and is configured with UL Tx switching. Although we agree that the capability for coherence with UL Tx switching should be per-band and per-band combination, we believe there is a more fundamental issue, as explained above, regardless of the configuration of UL Tx switching. Hence, we think that RAN1 should agree to introduce UL coherence as a per band per band combination capability before making any further decision on UL Tx switching.  **Proposal: A new UE capability indicating UL MIMO coherence per band per band combination is introduced (regardless of UL Tx switching)** |

Following comments are provided during preparation phase email discussion.

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| Company | Comment |
| Apple | We are supportive of the proposal |
| ZTE | We are ok to discuss this issue. However, the relationship between this potential new FG and the legacy UE feature and how this new FG can address the RAN4 issue should be clearly clarified. |
| DOCOMO | We are ok to discuss this issue. However, the late introduction of new capability for Release 16 should be carefully discussed and justified with considering capability signaling overhead increase. |
| Huawei, HiSilicon | It was proposed and discussed in RAN1#106e when a RAN4 LS on UL Tx switching was discussed. The proposal is **not in line** with the RAN4 LS (R1-2106431) and CR R4-2109582. Thus it was not agreed for UL Tx switching. We feel repeated discussion for UL Tx switching should be avoided. Additionally, only 2Tx UL MIMO is involved with UL Tx switching, however, the concern from the proponent seems only about 4Tx UL MIMO according to proponent’s tdoc. For the case of a UE supporting only 2Tx UL MIMO, there is no potential issue since only up to 2 RF chain are driven by a common oscillator and any splitting of 2Tx driving has become 1Tx-1Tx driving which is no UL MIMO any more. We don’t see any connection between the proposal and UL Tx switching.  In short, the proposal is not in line with RAN4 agreements R1-2106431 and R4-2109582, in order to avoid repeated discussion with UL Tx switching capable of 2Tx only and focus on the only potential issue, we suggest to clarify the scope to,  **[107-e-AI7.2.11-NR-UEFeature-Others-01] Email discussion/approval on UE features for others**   * **Introduce a new UE capability indicating 4Tx UL MIMO coherence per band per band combination (no impact on Rel-16 UL Tx switching)** |
| Intel | Agree to discuss the issue. |
| Qualcomm (late comment) | We have concerns on the change to 4Tx-only in the following proposal.  **[107-e-AI7.2.11-NR-UEFeature-Others-01] Email discussion/approval on UE features for others by Nov 18th – Hiroki (DOCOMO)**   * **Introduce a new UE capability indicating 4Tx UL MIMO coherence per band per band combination (no impact on Rel-16 UL Tx switching)**   I guess some companies may have misunderstood our motivation. We could list our technical consideration below:  *A UE that can support coherent 2Tx UL MIMO may fall into any of the three coherence categories for 4Tx UL MIMO (i.e. it can be either coherent, partial coherent, or non-coherent for 4Tx UL MIMO).*  If we don’t have this per band per band combination capability, the UE would have report the lowest coherence capability among all the band combinations and likely miss the coherence benefit if it only supports coherence within limited band combinations.  Given this consideration, we think it’s necessary to introduce this new UE capability.  On the release consideration, we think the best option is Rel-16 as we can solve this issue for both with and without UL Tx switching together. However, if the majority wants to introduce this in Rel-17, we can live with this.  In that case, we need a separate Rel-16 solution for UL Tx switching only. We can agree with the RAN4 solution for that.  Going forward, both solutions would exist in Rel-17. With the expectation that the UE doesn't set inconsistent values, we don't see a problem with that. |

Based on the above, following proposal can be discussed in RAN1#107-e meeting. There would be other possible alternatives as below. Considering the preparation phase discussion, we can start with Alt.1.

Alt.1: As in FL proposal#1, a new per-FS coherence capability for 4Tx only is introduced in Rel-16. It would not have any impact to UL Tx switching for 2Tx.

Alt.2: As Qualcomm’s “best option”, a new per-FS coherence capability is introduced in Rel-16 to solve both the issue with and without UL Tx switching. But this alt was concerned by Huawei as this was already discussed but not agreed at RAN1#106-e.

Alt.3: As Qualcomm’s alternative, a new per-FS coherence capability is introduced in Rel-17. In this case, this can avoid any impact to UL Tx switching issue in R1-2106431 as it is for Rel-16 while the new coherence capability is for Rel-17.

### **FL proposal#1**

* **Introduce a new UE capability indicating 4Tx UL MIMO coherence per band per band combination**
  + **Note: This introduction does not have any impact on UL Tx switching issue in R1-2106431**

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| 22. NR Others | [22-12] | [PUSCH codebook coherency subset for 4Tx UL MIMO] | [Supported codebook coherency subset type for 4Tx UL MIMO]   * Candidate value set: {non-coherent, partial/non-coherent, full/partial/non-coherent} |  | Yes | N/A |  | Per FS | N/A | N/A | N/A |  | Optional with capability signalling |

Companies are encouraged to check above FL proposal and to provide feedback if any in below. If you cannot accept the FL proposal, please put your company name after “Cannot accept the proposals” below and please provide your alternative proposal (in your comment) which could be acceptable to all in your consideration.

Cannot accept the proposal:

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| Company | Comment |
| Apple | We are supportive of introducing per FS UE capability for MIMO coherency  However, we fail to see why we need to limit this to 4 Tx UL MIMO only. In fact, the numbe of UL MIMO Tx, more accurately, the maximum UL MIMO layers that UE can support is reported per FSPC (per CC per band per BC), which is to account for the UE RF/BB processing sharing between different component carriers per band per BC.  For a hypothetical case when UE supports non-coehrent 4Tx UL MIMO in BC of {B1}, UE may support coherent 2Tx UL MIMO in B1 and non-coherent 2Tx UL MIMO in B2 in BC of {B1, B2}. In other words, a particular band can belong to different BC, based on what the other bands UE needs to support together with the target band in a BC, following UE capability can vary   * Maximum UL MIMO laywer can support (i.e., the number of Tx UL MIMO) * The UL MIMO coherency   We already have per FSPC UE capability for the first bullet, it is very nature to support per FS UL MIMO coherency. In fact, the better or least ambiguous solution is to also introduce per FSPC UL MIMO coherency.  In summary,  We prefer to remove the restriction of “4Tx UL MIMO” in the newly proposed FG. |
| Qualcomm | We support to introduce a new UE capability on UL MIMO coherence per band per band combination.  However, we have concerns on the change to 4Tx-only in the proposal.  This should be a generic capability without limitation to the Tx numbers.  UE may support 2Tx or 4 Tx in the same band in different band combinations which is a well-accepted principle. But there is no reason to believe that the UE's coherence capability would be the same for 4 Tx as it is for 2 Tx. A UE that can support coherent 2Tx UL MIMO may fall into any of the three coherence categories for 4Tx UL MIMO (i.e. it can be either coherent, partial coherent, or non-coherent for 4Tx UL MIMO).  If we don’t have this per band per band combination capability, the UE would have to report the lowest coherence capability among all the band combinations and likely miss the coherence benefit if it only supports coherence within limited band combinations.  Given this consideration, we think it’s necessary to introduce this new UE capability.  On the release consideration, we think the best option is Rel-16 as we can solve this issue for both with and without UL Tx switching together. However, if the majority wants to introduce this in Rel-17, we can live with this.  In that case, we need a separate Rel-16 solution for UL Tx switching only. We can agree with the RAN4 solution for that.  Going forward, both solutions would exist in Rel-17. With the expectation that the UE doesn't set inconsistent values, we don't see a problem with that. |
| vivo | We are supportive to introduce this UE feature, as explained by Apple and Qualcomm this should not be restricted to 4Tx only. |
| OPPO | We support to introduce new UE capability signalling of MIMO coherence per band per band combination. Similar view as Apple/QC/vivo, it should be also applicable for 2-port UL MIMO. The main reason is that for different band combinations, UE may support UL MIMO with up to 2 or up to 4 layers |
| Moderator (NTT DOCOMO) | Thanks for the feedbacks.  The moderator understands that at least four companies (provided feedbacks so far) support to introduce the proposed per-FS UL MIMO coherence capability without restriction on 4Tx i.e., Alt.2 or 3.  It will be appreciated if companies provided their preferred alternative (with or without restriction on 4Tx, introduced in Rel-16 or Rel-17) with reasons. |
| ZTE | Regarding the introduced release of this new FG, we would prefer to introduce it in Rel-17. Since Rel-16 has been freezed for almost two years, it would impact the existing implementation if this new FG is introduced in Rel-16 at this late stage.  Regarding the 2Tx or 4Tx, we don’t have a strong view. But RAN1 needs to calrify the relationship between the new per-band per BC FG and legacy per-band FG. For example if UE reports “non-coherent” in the legacy per-band FG and report “coherent” in the per-band per BC FG for the same band, then how to interprete this? |
| DOCOMO | We support to introduce a new UE capability to report UL MIMO coherence per band per FS. We also prefer to remove 4Tx limitation and prefer not to limit the case only for Tx switching.  On the release for the introduction, we are fine with either Rel-16 or Rel-17. |
| Huawei, HiSilicon | More clarifications are required. As we mentioned, there is similar discussion in RAN4, but no any change on UE capability in the RAN4 agreements. It’s clear that changing the UE capability will impact UE implementation even the structure. Till now, we are not clear the benefits and necessity on the changing the UE capability in practical deployment. So, we require to clarify which common case in the PRACTICAL DEPLOYMENT requires the capability of coherency with per band per BC configurations?  Regarding the scope, we prefer to stick to the agreed scope for the following reasons,   * Assuming band A and band B, categorized into 4 kinds of UEs,   + UE Type#1: single band: Band A 4Tx, Band B 2Tx, UL CA BC {Band A <=2Tx, Band B 2Tx}   + UE Type#2: single band: Band A 2Tx, Band B 2Tx, UL CA BC {Band A 2Tx, Band B 2Tx}   + UE Type#3: Band A 2Tx, Band B 2Tx, UL CA BC {Band A 1Tx, Band B 1Tx}   + UE Type#4: Band A 2Tx, Band B 1Tx, UL CA BC {Band A 1Tx, Band B 1Tx} * Only UE Type#1 and Type#2 are capable of 4Tx concurrent transmissions (either at one band or at two bands simultaneously), but UE Type#3 and UE Type#4 are only capable of 2Tx concurrent transmissions * Based on the discussions, no company shows any issues for Type#3 and #4. We don’t feel they are in scope. * No company shows any issue for Type#2 either. No oscillator splitting is needed in this case, the oscillators for UL-CA 2Tx-2Tx are simply the same ones as that for each single band. Therefore, we don’t feel it is in scope, or please proponents clarify the reason. * For UE#Type 1, according to propoents’ comments, oscillator splitting seems to occur where one oscillator drives 2Tx with coherent property while the other oscillator drvies the other 2Tx. As a result, it seems probable that the UE is capable of coherent 2Tx on single band A or on the band A of UL CA BC, but is not capable of coherent 4Tx on single band A. If this is the only motivation, then the scope is surely about a UE that is capable of 4Tx at least at one band and its UE capability on a BC containing the band is discussed. |
| Ericsson | The discussion of UE capability here mixes capabilities a bit. The examples discussed where a subset of Tx antennas can support coherence is not the same as indicating a number of layers per band, since different Tx chains are needed to support multiple layers, whereas coherence applies to a given number of Tx chains. So we don’t think that the FSPC indication of layers naturally implies that FSPC should be supported for coherence capability.  Then, as we have commented before, determining what combination of capabilities to configure for the UE is actually pretty painful for the gNB. In order for the network to select what to configure for MIMO, we have to check all band combinations for combinations of MIMO layers on pcell/scells, DL/UL, etc. Furthermore, it is not clear how common the example UE architecture under discussion will be, and the gains of 2 Tx coherent over 2 or 4 Tx non-coherent operation supported by this UE are not likely to be dramatic, so we wonder if the gains will be large enough and available enough in networks to be really beneficial. Again, we can certainly understand the desire from a UE product perspective, and would like to be supportive. However, managing/configuring these highly grained UE capabilities is quite complicated, and further increasing this by adding another parameter to this effectively exponential search complexity should be thoroughly justified.  On 2 vs. 4 Tx, presuming that the benefit to the network from such partially coherent UEs is indeed significant and such UEs are sufficiently available, then we think this use case is relevant to 2 Tx capability. |
| Nokia, NSB | We tend to agree with ZTE that any new capability introduced from now on should apply to Rel-17, as Rel-16 has been frozen for a long time already. In any case, we need to be really parcimonious on the features that are defined per FS or per FSPC, as those imply significant extra complexity for the network, not to mention the added signaling overhead. Further clarifications are needed for such new capability in any case before we can agree on introducing it or not. |
| Moderator (NTT DOCOMO) | Thanks for the feedbacks.  Based on the feedbacks so far, we need to have more discussion on following points.  Q1: whether the new per-FS capability should be introduced or not  At least five companies are supportive, while some companies asked more justification. The proponent and/or supporting companies are encouraged to provide feedback on above Huawei, Ericsson and Nokia comments.  Q2: whether the new per-FS capability if introduced should be only for 4 Tx or not  At least six companies prefer not to have such restriction, while one company strongly argued to have the restriction. The proponent and/or supporting companies are encouraged to provide feedback on above Huawei comment.  Q3: whether the new per-FS capability if introduced should be Rel-16 or Rel-17  At least the proponent prefers Rel-16 introduction while at least two companies prefer Rel-17 introduction. More companies’ feedbacks on this point are appreciated.  Q4: how to clarify the relationship with legacy per-band capability  One company raised this question. Since the motivation of the proposed new per-FS capability is to solve potential under-reporting issue, it would be possible that the UE reports e.g., non-coherent for a band (via legacy capability) while the UE also reports e.g., full/partial/non-coherent for the same band with a specific band combination (via new capability if introduced). The moderator thinks that even if the new capability is introduced, the UE needs to report the legacy one considering legacy BS which can only read the legacy capability, and the new BS can understand UE’s capability based on the new capability i.e., for the specific band combination case where the new capability is provided, the legacy capability is ignored. The proponent and/or supporting companies are encouraged to provide feedback on the question from ZTE. |
| Apple | Q1: whether the new per-FS capability should be introduced or not  We support to introduce per-FS capability  Regarding the question from infra-vendor including Huawei, Ericsson and Nokia, NW is always allowed to downgrade the UE coherency operation. In other words, if NW does not want to handle the new capability or does not believe in the performance benefit or cannot handle the complexity, NW can always downgrade UE to non-coherent UE or based on what we report as legacy capability (per band). In other words, the specification is written largely to regulate UE behaviour. Even though, it is not our preference, but we believe 3GPP provides NW enough flexibility. But we do fully understand the concern raised by companies including Ericsson and Nokia, on the difficulties of UE capability reporting  Since we are discussing UE capability, the priority is to allow UE to report its capability. How NW handles it is largely implementation based as long as NW does not violate the UE capability  Q2: whether the new per-FS capability if introduced should be only for 4 Tx or not  We prefer not to limit to 4 Tx.  2 Tx is the typical commercial deployment, it will be useless for a long time if we limit this to 4 Tx. Furthermore, as we explained, the issues still exist for 2 Tx since UE cannot have independently RF and hardware component for every single band in RAN4  Q3: whether the new per-FS capability if introduced should be Rel-16 or Rel-17  We prefer Rel-16, but we are flexible if companies, especially infra-vendor, have concern.  Q4: how to clarify the relationship with legacy per-band capability  We do not think there is an issue, the principle is that, if UE reports it supports something, it means UE supports it.  In other words,   * Per band per BC, if two capability reporting indicates different things, for example one is coherent, the other one is non-coherent, UE supports both, essentially the one with higher capability, i.e., coherent * If new per-FS capability is not reported, capability follows the legacy capability for backward compatibility.   In general, with the above principle in mind, maybe companies who have concern can give detailed example for clarification since we cannot think of any case that has ambiguity. |
| DOCOMO | Q1: whether the new per-FS capability should be introduced or not  As in our previous comment, we are supportive to introduce the new per-FS UE capability.  We assume a UE reports the most conservative capability per band without the new UE capability. Even if it is capable of coherent MIMO based on a certain condition, it will report non-coherent if another condition where only non-coherent MIMO is possible is observed in a band. Thus, we assume UEs tend to report non-coherent in practical operations. By introducing this per-FS signaling, we believe much more opportunities will be unlocked to perform coherent MIMO.  We do understand the concern of NW-side complexity (and overhead on capability reporting), however, we think the new UE capability deserves such costs in terms of the advantage above.  Q2: whether the new per-FS capability if introduced should be only for 4 Tx or not  We prefer not to limit to 4Tx. We share Apple’s answer to Q2.  Q3: whether the new per-FS capability if introduced should be Rel-16 or Rel-17  We are open for either Rel-16 or Rel-17. We agree Rel-17 may be safer, but at this moment we do not see a significant issue to introduce this in Rel-16.  Q4: how to clarify the relationship with legacy per-band capability  It is obvious that Rel-15 per-band capability would always be necessary for UL MIMO coherence indication considering at least Rel-15 gNB can understand it only even if the per-FS capability is introduced. For the relationship with legacy per-band capability, we think the following can be considered:   * When the new per-FS capability is reported, a gNB, that is NOT capable of reading the new capability signaling, will follow the legacy per-band capability only * When the new per-FS capability is reported, a gNB, that is capable of reading the new capability signaling, can choose either of the following two approaches;   + gNB can follow the legacy per-band capability regarding UL MIMO coherence in the band in the BC, and gNB can ignore the new per-FS capability signaling.   + gNB can follow the new per-FS capability regarding UL MIMO coherence in the band in the BC, and gNB can ignore the legacy per-band capability signaling.   In summary, even if the new per-FS capability is introduced and reported, it will be up to gNB to follow either the legacy per-band capability signaling or the new per-FS capability signaling. |
| Intel | Thanks for the feedbacks.  Based on the feedbacks so far, we need to have more discussion on following points.  Q1: whether the new per-FS capability should be introduced or not  We are OK with new capability. We assume that Rel-15 capability should be pre-requisite to the new UE capability that should be reported for BC purpose.  Q2: whether the new per-FS capability if introduced should be only for 4 Tx or not  We think the enhancement may be applicable to 2Tx in case UE reports 4Tx for one of the bands in the band combination.  Q3: whether the new per-FS capability if introduced should be Rel-16 or Rel-17  If new capability supports only 4Tx, it should be Rel-17 capability  If new capability supports both 2Tx and 4Tx, it should be Rel-16 capability  Q4: how to clarify the relationship with legacy per-band capability  We don’t see any issue to support combination of Rel-15 and new UE capability. The Rel-15 capability would correspond to lower UE coherence capability that works for any band in the BC. New capability indicates higher coherence capability for some bands in the band combinations. If new capability is painful for some gNB, gNB can always rely on the Rel-15 capability. |
| Huawei, HiSilicon | We feel the key discussion point is a justification for per-FS capability, so that we listed four types of UEs to facilitate the discussion. We hope proponents could provide some justification with examples for type#2, 3 and 4 first, in order to better understand what is missing in current spec. With this understanding, we have the following answers to FL’s questions.  Q1: before answer this question, we ask for more justification with examples for UE type#2, 3 and 4, and clarification of which common case in the PRACTICAL DEPLOYMENT requires the capability of coherency with per band per BC configurations.  Q2: the same as Q1.  Q3: Rel-17 is preferred unless any critical issue is found.  Q4: Proponents seem to presume gNBs should explore both legacy UE capability and the new UE capability for all possible cases, which costs additionally complexity to network. Therefore, we would like to better understand the justification first as commented above, especially for UE type#2, 3 and 4. |
| Qualcomm | Q1: whether the new per-FS capability should be introduced or not  We share similar views as Apple that network would always have the flexibility to implement the scheduling based on UE’s capability report. The new UE capability offers an opportunity if network wants to check the UE’s coherence capability and schedule UE accordingly. The worst case (from UE perspective) is network ignore the UE reported new capability and always schedules based on the legacy per band capability.  Q2: whether the new per-FS capability if introduced should be only for 4 Tx or not  We prefer no limitation to the Tx numbers and introduce this capability for a generic case because the reasons in the 4Tx and 2Tx case are the same.  Q3: whether the new per-FS capability if introduced should be Rel-16 or Rel-17  We slightly prefer to introduce this in Rel-16, but we can live with Rel-17 capability if this is the majority view.  Q4: how to clarify the relationship with legacy per-band capability  The relationship is the same as for any other capability with different versions across releases. The UE will meet all the requirements represented by the reported Rel-15 capability. When the UE reported higher capability in the new Rel-16 (or Rel-17) capability version compared to the Rel-15 version then the UE will meet the higher requirement in those band combinations where the Rel-16 (or Rel-17) capability was included. This will fix the problem in all cases where the UE was forced to underreport its capability in Rel-16 due to the inadequate signalling granularity. |
| Moderator (NTT DOCOMO) | Thanks for the feedbacks.  Although there are multiple feedbacks on the moderator’s questions, it seems that the most important point i.e., justification for the new capability still needs further discussion.  Especially for following Huawei’s comment, could proponent/supporting companies provide feedback especially on whether UE Type#2/3/4 below requires the proposed capability?  ---   * Assuming band A and band B, categorized into 4 kinds of UEs,   + UE Type#1: single band: Band A 4Tx, Band B 2Tx, UL CA BC {Band A <=2Tx, Band B 2Tx}   + UE Type#2: single band: Band A 2Tx, Band B 2Tx, UL CA BC {Band A 2Tx, Band B 2Tx}   + UE Type#3: Band A 2Tx, Band B 2Tx, UL CA BC {Band A 1Tx, Band B 1Tx}   + UE Type#4: Band A 2Tx, Band B 1Tx, UL CA BC {Band A 1Tx, Band B 1Tx} * Only UE Type#1 and Type#2 are capable of 4Tx concurrent transmissions (either at one band or at two bands simultaneously), but UE Type#3 and UE Type#4 are only capable of 2Tx concurrent transmissions * Based on the discussions, no company shows any issues for Type#3 and #4. We don’t feel they are in scope. * No company shows any issue for Type#2 either. No oscillator splitting is needed in this case, the oscillators for UL-CA 2Tx-2Tx are simply the same ones as that for each single band. Therefore, we don’t feel it is in scope, or please proponents clarify the reason.   For UE#Type 1, according to propoents’ comments, oscillator splitting seems to occur where one oscillator drives 2Tx with coherent property while the other oscillator drvies the other 2Tx. As a result, it seems probable that the UE is capable of coherent 2Tx on single band A or on the band A of UL CA BC, but is not capable of coherent 4Tx on single band A. If this is the only motivation, then the scope is surely about a UE that is capable of 4Tx at least at one band and its UE capability on a BC containing the band is discussed.  --- |
| Samsung | Sorry for late comment. We don’t support this proposal.  We can share the similar view with Ericsson. This new UE capability (per FS) requires too much complexity to gNB side rather than the legacy UE capability (per band). And we cannot see the huge performance gain with full-coherent UL transmission while this UE capability requires large gNB complexity. |
| Apple | We do not fully follow the UE Type #1/2/3/4, especially in terms of coherency etc. But there are more than those 4 types UE. The UE capability design should be aiming at allowing UE to report its capability and provide UE with implementation flexibility. Let us give one example.  In a hypothetical setup where there are only   * Two bands: B1 and B2 * UE has 4 Tx (PA) to support B1 and B2: PA0, PA1, PA2, PA3 * UE can do only coherent PUSCH with PA0/PA1   So   * For BC with only B1: UE indicates UE support 4 layer PUSCH (use PA0/1/2/3 for B1)   + In this case, UE only support non-coherent PUSCH * For BC with only B2: UE indicates UE support 4 layer PUSCH (use PA0/1/2/3 for B2)   + In this case, UE only support non-coherent PUSCH * For BC with B1+B2: UE indicates UE support 2 layer PUSCH in B1 and 2 layer PUSCH in B2 ((use PA/2/3 for B1 and PA0/1 for B2)   + In this case, UE support non-coherent PUSCH in B1 and coherent PUSCH in B2   Now, let us look at B2   * When B2 is configured in a BC without B1:   + UE supports 4 layer non-coherent PUSCH * When B2 is configured in a BC with B1:   + UE supports 2 layer coherent PUSCH   As we explained before, that is the reason why we allow per FSPC maximum number of PUSCH layers. It is per CC per band per BC. However, currently, we only allow per band pusch-TransCoherence. This example shows that (1) we need per FS coherency report at least (2) It is also useful for 2 layer  I can also give other example, such as 2 coherent PA to support any band, but if there are two bands in a BC, we have to use another two non-coherent PA for B1 (coherent) + B2 (non-coherent) which can be more realistic since 4 Tx UE is not that common in the deployment, if there is any  Also, there is no NW complexity since NW can ignore the new UE capability if NW does not want to handle it. |
| Huawei, HiSilicon | Thank Apple for your reply. But it only confirms that the potential issue is only related to UE Type#1, but not to the other three types of UEs because your example is always with a UE capable of 4Tx on at least one band but UE Type#2, #3 and #4 do not.  With this, we reduplicate our previous comment below.   * *Only UE Type#1 and Type#2 are capable of 4Tx concurrent transmissions (either at one band or at two bands simultaneously), but UE Type#3 and UE Type#4 are only capable of 2Tx concurrent transmissions* * *Based on the discussions, no company shows any issues for Type#3 and #4. We don’t feel they are in scope.* * *No company shows any issue for Type#2 either. No oscillator splitting is needed in this case, the oscillators for UL-CA 2Tx-2Tx are simply the same ones as that for each single band. Therefore, we don’t feel it is in scope, or please proponents clarify the reason.*   We don’t feel this issue is related to any UE that is not capable of 4Tx on any band. Please kindly note that if a UE reports a BC for UL Tx switching, it is surely incapable of 4Tx on any band of the BC. As FL mentioned, RAN2 is still waiting for us to handle the CR for the RAN4 LS of UL Tx switching, we hope proponents could provide an example for UE Type#2, #3 and #4, or we should stick to the original scope with 4Tx only, and let RAN2 know no impact on the RAN4 LS and its corresponding RAN2 CR. |
| Qualcomm | The Huawei comments make the assumption there are such UE types, such as Type #1, #2, and so on. That in turn makes the assumption that the UE has all components dedicated to bands. While indeed certain components, like PAs, filters, are dedicated to bands, the RF components that matter for MIMO coherence, LOs, upconverters, RF drivers, are not. The UE has a 'bank' of such components and they are assigned to bands as needed for different band combinations. Therefore, such categorization of UE types as Huawei suggests may not make sense. The UE may assign one upconvererter/RF driver to a band in a band combination that is capable for 2Tx coherence but it may use different ones with separate LOs still for 2Tx for the same band in another band combination, depending on what resources the other band(s) in the band combination need, or whether there is LTE configured or not and so on. Whenever the 2Tx goes through different chains employing different LOs, there is no coherence, but when the band uses the path with common LOs, it can have coherence. These changes will occur depending on the band combination.  Regarding the impact on gNB complexity, we understand the concern that the gNB may have to do a comparison of different band combination options and choose a CA configuration according to some metric. Although the gNB doesn't actually have to do this, i.e. it could just select a band combination first and apply whatever capability is reported for that band combination, we understand the concern. But at the same time, forcing the UE to under-report is making the gNB to always end up with the worst possible choice. Cannot see any benefit in that. Changing the capability structure is not going to change the UE design or the underlying UE capabilities. There seems to be a bit of a naivete in thinking that non-coherent UE design can be forced to be coherent by restricting the reporting granularity. Obviously, in the vast majority of cases, this will work in the opposite direction. The reduced granularity will force the UE to under-report.  UL MIMO coherence has been in particular slow to take off, we are puzzled by the insistence by quite a few companies on keeping hurdles in the way of commercialization. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks!  The proponent provided justification for the new per-FS capability even for UE with 2 Tx.  The moderator’s understanding based on the feedback so far is summarized as below.   * UE has some components not dedicated to bands, such as LOs, upconverters, RF drivers. The UE may assign such components to a band in a band combination for coherent 2 or 4 Tx, while the UE may assing different ones to the same band in different band combination for 2 or 4 Tx depending on required resources for other band(s) in the band combination and in such case it will be non-coherent. * If the UE has above possible implementation, currently the UE needs to perform “under-reporting” for UL MIMO coherence capability i.e., reporting “non-coherent” for the band since it is per band capability even though the UE can actually support coherent 2 or 4 Tx for the band in case of specific band combination. Maybe due to this issue, UL MIMO coherence has not been widely used in practice. * If we will introduce new per-FS (per band per band combination) UL MIMO coherence capability, UE can report the support of UL MIMO coherence for a band in a band combination which can be different from the report for the same band in different band combination. Even in such case, it is of course up to gNB how to configure CA band combination and UL MIMO for each band in the band combination, but some companies raised concern on gNB complexity to take per-FS capability report from UE into account for determining band combination and UL MIMO configurations. * Supporting companies prefer to introduce the new per FS capability in Rel-16, but they seem to be flexible also for Rel-17 introduction, while there are several companies prefer to introduce it in Rel-17 as Rel-16 has been frozen for a long time already. If the new per FS capability is introduced in Rel-17, there will be no impact to RAN2 endorsed CRs for the RAN4 LS of UL Tx switching. * Regarding the relationship with legacy per band capability, companies’ understandings seem to be aligned that it is same as for any other capability with different versions across releases. Anyway, there are legacy gNBs not capable of understanding the new capability and they just take the legacy capability into account. As described above, the new gNB capable of understanding the new capability can make a decision based on legacy capability and/or new capability, i.e., it is up to gNB.   Based on the above understanding, the moderator would like to suggest to agree on the following updated proposal. **Updated FL proposal#1**  * **Introduce a new per-FS UE capability indicating UL MIMO coherence in Rel-17**   + **Note: This introduction does not have any impact on UL Tx switching issue in R1-2106431, and it will be informed to RAN2 in the LS to be sent with Rel-16 updated UE features list**   + **Detailed capability signalling design can be discussed in Rel-17 UE features agenda (for others)**   Reasons for the updates are followings.   * Given the concerns on the introduction of new capability for Rel-16 at this timing and gNB complexity aspects, even if we introduce it for Rel-16, it may not be widely implemented to Rel-16 gNB. The introduction for Rel-17 can be a good compromise. * In addition, any impact to RAN2 endorsed CRs for the RAN4 LS of UL Tx switching can also be avoided in this case (i.e., Rel-17 introduction). It can be informed to RAN2/4 via LS to be sent with updated Rel-16 RAN1 NR UE features list as the information relates to Rel-16. * Based on the explanations from proponent companies, restriction to 4 Tx only seems not necessary. But as it can be further discussed in Rel-17 UE features agenda if necessary as it is now proposed to introduce it in Rel-17.   All interested companies are encouraged to check the above updated FL proposal and to provide feedback only if the company has formal objection to the proposal or small editorial modification suggestion. If there is a company having a formal objection with a reason, we would need to make following conclusion at least for Rel-16 so that RAN2 can proceed their endorsed CRs for UL Tx switching, while as clarified during the preparation phase email discussion, how to reply to RAN4 LS on UL Tx switching (R1-2106431) can be discussed based on the companies’ contributions in future meeting.  Alternative conclusion:   * RAN1 did not reach a consensus to introduce a new per-FS capability indicating UL MIMO coherence in Rel-16 |

Based on the discussion above, following updated FL proposal is provided.

### **Updated FL proposal#1**

* **Introduce a new per-FS UE capability indicating UL MIMO coherence in Rel-17**
  + **Note: This introduction does not have any impact on UL Tx switching issue in R1-2106431, and it will be informed to RAN2 in the LS to be sent with Rel-16 updated UE features list**
  + **Detailed capability signalling design can be discussed in Rel-17 UE features agenda (for others)**

All interested companies are encouraged to check the above updated FL proposal and to provide feedback only if the company has formal objection to the proposal or small editorial modification suggestion.

|  |  |
| --- | --- |
| Company | Comment |
| DOCOMO | We support the Updated FL proposal#1. |
| Huawei, HiSilicon | We see the necessity of the Note, and it should be informed to RAN2.  But this proposal for Rel-17 is not OK at this stage. Reading the discussions, the per-FS UE capability has never been justified for a UE capable of only 2 concurrent Tx (at least UE Type#3 and #4), even a simple example for a UE incapable of any 4Tx has not been provided. The example provided by Qualcomm’s latest reply is only about a UE with 4 concurrent Tx chains and the UE is configured with 2Tx + Y Tx, otherwise there is no need of “*depending on what resources the other band(s) in the band combination need*”  The issue is not only about Rel-16 v.s. Rel-17, but more about its justification.  @Qualcomm, the UE types we listed are representing potential UE capability reporting, without any further assumption. For example, UE Type#3 means for a UE, 2Tx is reported on Band A and Band B (single band), and the UE also reports UL CA band combination with 1Tx on Band A and 1Tx on Band B. Again, could you please provide an example for this UE Type#3 that an issue is identified?  UE Type#3: Band A 2Tx, Band B 2Tx, UL CA BC {Band A 1Tx, Band B 1Tx} |
| Moderator (NTT DOCOMO) | Thank you very much for the feedbacks.  It is the moderator’s understanding that Huawei/HiSilicon’s concern is provided for applicability to 2 Tx vs 4 Tx only. In other words, no concern/objection seem to be provided for the proposal in case of targeting UEs capable of 4 Tx (“UE with 4 concurrent Tx chains and the UE is configured with 2Tx + Y Tx”).  As described in the previous moderator’s comment, it is the moderator’s intention that “*Based on the explanations from proponent companies, restriction to 4 Tx only seems not necessary. But it can be further discussed in Rel-17 UE features agenda if necessary as it is now proposed to introduce it in Rel-17.*”  So, is it ok for Huawei/HiSilicon if such further discussion point is explicitly captured in the proposal?   * **Introduce a new per-FS UE capability indicating UL MIMO coherence in Rel-17**   + **Note: This introduction does not have any impact on UL Tx switching issue in R1-2106431, and it will be informed to RAN2 in the LS to be sent with Rel-16 updated UE features list**   + **Detailed capability signalling design can be discussed in Rel-17 UE features agenda (for others) including whether the new capability is only for UE capable of 4 Tx** |
| Samsung | First of all, based on a new UE capability signaling (per FS) to support full-coherent TPMI more accurately in case of UL CA, we are wondering how much performance gain we can get. Without checking performance gain based on a new UE capability signaling (per FS), we have strong concern to introduce a new UE capability which can incur huge complexity for gNB. Although after checking the performance gain, if the gain seems marginal, we don’t want to introduce a new UE capability which affects a critical complexity increase in gNB side.  Second, instead of introducing a new UE capability which makes a large complexity for gNB, we can consider to support NCB based transmission or virtualization method for the UE that can support FPTX. With these possible alternatives, we can achieve coherent UL transmission (with NCB based transmission or virtualization). Because there are several alternative methods to support coherent UL transmission, we don't think that a new UE capability should be introduced. |
| Moderator (NTT DOCOMO) | Thank you very much for the feedback.  Regarding the concern on gNB complexity, the moderator believes that companies already provided answers that it is anyway up to gNB whether/how to take per-FS capability report into account. Therefore, the moderator thinks it should not be a reason to block the proposal as long as at least there are several companies would like to use the proposed capability in practice.  Regarding the performance gain of per FS capability introduction, it is straightforward that it makes coherent UL MIMO precoders available for the band in band combination. Since 3GPP decided to introduce such coherent UL MIMO precoders to achieve certain gain over non-coherent precoders, the moderator thinks it should not be a reason to block the proposal.  Regarding the alternative i.e., to use NCB based transmission, although it would be true that it can also achieve coherent UL transmission, we already have both CB based and NCB based transmission and there should be a demand to use CB based approach for coherent UL transmission. Anyway, CB based vs NCB based would not be the discussion point here.  So, please elaborate more on the reasons if the proposal is not acceptable. |

1. Conclusion

TBD

Reference

[1] R1-2112185 Discussion on UL MIMO Coherence capability Qualcomm Incorporated

[2] R1-2112463 Summary on Rel-16 NR UE features related discussion Moderator (NTT DOCOMO, INC.)

[3] R1-2108426 Updated RAN1 UE features list for Rel-16 NR after RAN1#106-e Moderators (AT&T, NTT DOCOMO, INC.)