**3GPP TSG RAN WG1 #107-e R1-21xxxxx**

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

**Agenda Item: 8.8.1.3**

**Source: Moderator (China Telecom)**

**Title: [107-e-NR-R17-CovEnh-03] Email discussion regarding joint channel estimation for PUSCH**

**Document for: Discussion**

1. Introduction

In RAN #90 e-meeting, a new Rel-17 work item on NR coverage enhancements was approved [1] and was revised in [2]. The objective of this work item is to specify enhancements for PUSCH, PUCCH and Msg3 PUSCH for both FR1 and FR2 as well as TDD and FDD.

The detailed objectives are as follows.

* *Specification of PUSCH enhancements [RAN1, RAN4]*
  + *Specify the following mechanisms for enhancements on PUSCH repetition type A [RAN1]*
    - *Increasing the maximum number of repetitions up to a number to be determined during the course of the work.*
    - *The number of repetitions counted on the basis of available UL slots.*
  + *Specify mechanism(s) to support TB processing over multi-slot PUSCH [RAN1]*
    - *TBS determined based on multiple slots and transmitted over multiple slots.*
  + *Specify mechanism(s) to enable joint channel estimation [RAN1, RAN4]*
    - *Mechanism(s) to enable joint channel estimation over multiple PUSCH transmissions, based on the conditions to keep power consistency and phase continuity to be investigated and specified if necessary by RAN4 [RAN1, RAN4]*
      * *Potential optimization of DMRS location/granularity in time domain is not precluded*
    - *Inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation [RAN1]*
* *Specification of PUCCH enhancements [RAN1, RAN4]*
  + *Specify signaling mechanism to support dynamic PUCCH repetition factor indication [RAN1]*
  + *Specify mechanism to support DMRS bundling across PUCCH repetitions [RAN1, RAN4]*
    - *When applicable, based on similar mechanism(s) for enabling joint channel estimation for PUSCH*
* *Specify mechanism(s) to support Type A PUSCH repetitions for Msg3 [RAN1, RAN2]*

This contribution is a summary of the following email discussion.

[107-e-NR-R17-CovEnh-03] Email discussion regarding joint channel estimation for PUSCH – Jianchi (China Telecom)

* 1st check point: November 15
* Final check point: November 19

1. Summary of contributions

## 2.1 Conditions to keep power consistency and phase continuity

Based on the LSs between RAN1 and RAN4 [3]-[10], the conditions for UE to keep power consistency and phase continuity among PUSCH transmissions for different scenarios can be summarized as follows:

**Back-to-back transmissions with zero gap in-between adjacent transmissions**

In order to maintain phase continuity, the following conditions should be met:

* Modulation order does not change.
* RB allocation in terms of length and frequency position should not be changed, and intra-slot and inter-slot frequency hopping is not enabled within a repetition bundle.
* No change on transmission power level of its own CC, i.e., no change on the power control parameters specified in TS 38.213, and also when own CC is not impacted by other concurrent CC(s) that are configured for inter-band CA or DC for same UE with dynamic power sharing and no change in any configured CC s that are part of configured intra-band uplink CA or DC.
* No UL beam switching for FR2 UE occurs.
* Applying the same TPMI precoder across PUSCH transmissions.
* TA adjustment and UE uplink timing autonomous adjustments cause the phase to change. RAN4 is still investigating the full impacts of the detailed scenarios, and will provide a final view about this at the next RAN4 meeting.

**Non-back-to-back transmission with non-zero gap in-between adjacent transmissions**

For non-back-to-back transmission with non-zero gap in-between adjacent transmissions, RAN4 concluded that at least following additional condition also need to be met in addition to the conditions for Back-to-back transmissions:

* No downlink reception in-between the PUSCH or PUCCH repetition in the same band for TDD case.
  + The “downlink reception” means downlink symbols with actual DL transmission from gNB to UE and/or DL monitoring with the assumption that UE is receiving information.
  + Regarding whether “downlink reception” include downlink symbols without actual DL transmission from gNB to UE and without DL monitoring, it would be helpful if RAN1 could provide more information on the exact scenario.
  + Phase discontinuity tolerance LLS is ongoing in RAN4 study and conditions of whether the phase continuity can be maintained in TDD case that has downlink reception in-between the PUSCH or PUCCH repetition could be revisited in future meeting with consideration of phase discontinuity tolerance. RAN4 is also still checking whether there are any optional UE antenna configurations where a UE could overcome this problem and still gain from using the feature.
* In scenario of no more than X un-scheduled OFDM symbols in-between the PUSCH or PUCCH repetition (e.g., X = 0, 1, 2, …, 14), RAN4 confirms the feasibility of phase continuity and power consistency for non-zero un-scheduled gap case for a gap less than 14 symbols when UE is not required to meet the existing off power requirements. RAN4 has further agreed that the 13-symbol is the maximum length for the gap for all SCS, and that the 14-symbol or 1ms will not be discussed in RAN4 anymore for un-scheduled gap in Rel-17 [8].
* In scenario of other UL channels in-between PUCCH or PUSCH repetitions, e.g., SRS or other PUCCH, at least if the other scheduled signals/channels during the non-zero gap have the same settings in antenna port, allocated number and locations of PRBs transmitted, and PAPR and average power, e.g., PUSCH/PUCCH part of repetitions and SRS has same PAPR and average power, it is feasible to maintain the phase continuity and power consistency across the repetitions. RAN4 has agreed that it is not considered for UE to transmit other channels in the gap with different settings.
* RAN4 has not agreed detailed requirement for phase continuity and plans to revisit the above agreement in the scenario of other UL signals/channels in the gap once the requirement is defined. Therefore, RAN4 would like to ask RAN1 what are the consequences if phase continuity cannot be maintained in that scenario?

In [10], RAN1 provide the following information to RAN4 on the scenario when “downlink reception” from UE point of view includes downlink symbols without actual DL transmission from gNB to UE and UE is not assumed to do DL monitoring:

* In RAN1 understanding, regarding to the “downlink reception”, there are actually three scenarios:
  + Scenario 1: downlink or flexible symbols with actual DL transmission from gNB to UE, with/without DL monitoring occasion configured.
  + Scenario 2: downlink or flexible symbols without actual DL transmission from gNB to UE, but with DL monitoring occasion configured.
  + Scenario 3: downlink or flexible symbols without DL monitoring occasion configured.

RAN1 further respectfully asks RAN4 to provide answer to the following question.

* Question 1: In additional to scenario 1 and 2, does the “downlink reception” in RAN4 reply LS R4-2103393 (“No downlink reception in-between the PUSCH or PUCCH repetition in the same band for TDD case”) further include scenario 3?

In [11], RAN1 provides the answer to RAN4:

* If phase continuity cannot be maintained in the case of UL transmissions of other signals/channels in the repetition gap, then DM-RS symbols transmitted before and after the transmission of such other signals/channels cannot be part of the same bundle from UE perspective. A new DMRS bundle may or may not start after the other UL signals/channel transmission in the repetition gap. Details are still under discussion in RAN1.

**The maximum duration**

In the latest LS from RAN4 [9], RAN4 replied RAN1’s questions related to the maximum duration and provided further agreement for the gap between PUSCH/PUCCH transmissions, details are listed as follows:

|  |  |
| --- | --- |
| **RAN1’s questions** | **RAN 4’s answers** |
| For joint channel estimation, is there a maximum duration during which UE is able to maintain power consistency and phase continuity under certain tolerance level? If any, how long is it? | Yes, there is a maximum duration but RAN4 has not agreed how many slots it is. |
| What factors determine the maximum duration? | RAN4 has agreed that TA adjustment should be avoided across the PUSCH/PUCCH transmissions (i.e., from start of first transmission until the end of last transmission) for joint channel estimation. RAN4 is still investigating other factors impact in more detail. |
| Whether the maximum duration should be the same for different cases for both PUSCH and PUCCH? | Yes. |
| Whether the maximum duration is dependent on the modulation order of transmission, e.g., QPSK, 16QAM, 64QAM? | Considering the scenario of coverage extension, RAN4 recommends to only focus on modulation orders not higher than QPSK, i.e., focus on QPSK (PUCCH and PUSCH), Pi/2 BPSK (PUCCH and PUSCH), BPSK (PUCCH). RAN4 is still discussing whether maximum duration depends on modulation order for the above modulation schemes. |
| Whether the maximum duration is dependent on UL waveform (DFT-s-OFDM vs. OFDM)? | No. |
| Besides the factors listed above, whether or not the maximum duration is further dependent on UE capabilities (e.g., multiple possible values for a given set of factor(s)), and if so, whether the UE should report such a duration. | Still under discussion in RAN4. |

## 2.2 Use cases for joint channel estimation

RAN1 has identified the potential use cases for joint channel estimation for PUSCH.

* Use case 1: back-to-back PUSCH transmissions within one slot.
* Use case 2: non-back-to-back PUSCH transmissions within one slot.
  + Use case 2a: no uplink transmission in the middle of two PUSCH transmissions
  + Use case 2b: other uplink transmissions in the middle of two PUSCH transmissions
* Use case 3: back-to-back PUSCH transmissions across consecutive slots.
* Use case 4: non-back-to-back PUSCH transmissions across consecutive slots.
  + Use case 4a: no uplink transmission in the middle of two PUSCH transmissions
  + Use case 4b: other uplink transmissions in the middle of two PUSCH transmissions
* Use case 5: PUSCH transmissions across non-consecutive slots.
  + Use case 5a: no uplink transmission in the middle of two PUSCH transmissions
  + Use case 5b: other uplink transmissions in the middle of two PUSCH transmissions

Note: RAN1 assumes “back-to-back PUSCH transmission” has zero gap in-between adjacent PUSCH transmissions.

Note: intervening “other uplink transmissions” can be either on the same component carrier or a different component carrier.

In the past RAN1 meetings, it was discussed whether joint channel estimation can be applied to the above uses cases. In addition, during online discussion of RAN1 #106-e meeting, according to the guidance from Chair there would be no further discussion for transmissions with different TBs. Based on the discussion and agreements so far, the situation is summarized in the following table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Use cases | Repetition type A for the same TB | Repetition type B for the same TB | Transmissions with different TBs | TBoMS |
| 1: B2B PUSCH transmission within one slot | / | Support | Not support | / |
| 2: Non-B2B PUSCH transmission within one slot | / | Not support | Not support | / |
| 3: B2B PUSCH transmissions across consecutive slots | Support | Support | **No further discussion** | Support |
| 4: Non-B2B PUSCH transmissions across consecutive slots | Support  (4a) | Support  (4a) | **No further discussion** | Support  (4a) |
| TBD  (4b) | TBD  (4b) | TBD  (4b) |
| 5: PUSCH transmissions across non-consecutive slots | Not support | Not support | Not support | Not support |

Thus, only Use case 4b remains to be discussed.

### 2.2.2 Use case 4b

For Use case 4b (other uplink transmissions in the middle of two PUSCH/PUCCH transmissions), there exist two sub-cases and companies’ views on the sub-cases are summarized as follows:

* **Use case 4b-1**: other UL transmission in the middle of two PUSCH/PUCCH transmissions has the same setting with PUSCHs.

**Support**: Nokia, NSB, TCL, CTC, xiaomi

**Not support**: LG, HW, HiSilicon, ZTE, Qualcomm, Ericsson, Sharp, CATT, WILUS, Panasonic

* **Use case 4b-2**: other UL transmission in the middle of two PUSCH/PUCCH transmissions has different settings than PUSCHs.

**Not support**: Nokia, NSB, vivo, CTC, xiao mi, CMCC, Sharp, LG, HW, HiSilicon, ZTE, Intel, Qualcomm, Ericsson, Sharp, CATT, WILUS, Panasonic

In RAN1 #106b-e, four options were discussed to handle Use case 4b-2 as follows:

* Option 1: Adapt the settings of the other UL transmission to make it be the same as PUSCHs.
* Option 2: Multiplex the data of the other UL transmission on PUSCH, if any.
* Option 3: Drop the other UL transmission with different settings.
* Option 4: Transmit the other UL transmission with different settings and break the phase continuity.

Based on the discussion in RAN1 #106b-e and contributions in RAN1#107-e, two companies (vivo, Panasonic) support Option 3 while majority companies (vivo, Panasonic, HW, HiSilicon, xiaomi, CTC, CATT, CMCC, Samsung, TCL, Lenovo, Motorola Mobility, Intel, Qualcomm, Panasonic, Sony) support Option 4.

### 2.2.4 Use case for UL CA

One company (ZTE) analyzes the benefit of using two carriers w/ Tx switching over single carrier under UL CA scenario. As shown in the following figure, there are two inter-band carriers with unaligned frame boundary. This is one main important deployment scenario and supported in Rel-16. It is also pointed out that the phase continuity can be kept for CA at least when PUSCH is only transmitted in one carrier at a given time.



Fig. Tx switching with unaligned frame boundary for CA

## 2.3 Time domain window for joint channel estimation

In RAN1 #104b-e meeting, a time domain window (TDW) was agreed to be specified, during which **UE is expected to** maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements. In RAN1 #105-e meeting, the maximum duration is defined to facilitate the discussion (whether it is specified is up to RAN4), during which **UE is able** to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements. In RAN1 #106-e meeting, a working assumption for the framework of TDW was achieved.

### 2.3.1 Configured time domain window

#### Issue #1: The window length *L* of the configured TDW

#### Issue #1-1: The maximum value of L

During past RAN1 meetings, it has been extensively discussed whether the maximum value of the window length *L* of the configured TDW(s) can be longer than the maximum duration during which UE is able to maintain power consistency and phase continuity. In RAN1 #106b-e, it was further discussed whether default value of *L* should be defined and the following agreement was achieved:

|  |
| --- |
| **Agreement:**  Down-select one of the following options in this meeting:  **Option 1**:   * The maximum value of window length *L* of the configured TDW should not exceed the maximum duration, which is reported as UE capability as the duration where UE is able to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.   **Option 1’:**   * The maximum value of window length L of the configured TDW should not exceed the maximum duration, which is reported as UE capability as the duration where UE is able to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.   + - If L is not configured, default behavior should be defined, e.g., the configured TDW length is equal to all repetitions   **Option 3’**:   * Whether the window length *L* of the configured TDW can be longer than maximum duration is subject to UE capability.   + If UE is capable of *L* being longer than maximum duration,     - The maximum value of the window length *L* of the configured TDW is the duration of all repetitions.       * FFS: whether *L* cannot be other values other than the duration of all repetitions, if it is longer than the maximum duration.     - If *L* is longer than the maximum duration, UE does not expect dynamic events.       * FFS: details of dynamic events |

It was further discussed on above options via email and it seems companies tend to converge on option 1’:

|  |
| --- |
| **Option 1’-a:**   * The maximum value of window length L of the configured TDW should not exceed the maximum duration, which is reported as UE capability as the duration where UE is able to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.   + - If L is not configured, the default value ~~and default behavior are~~ is to be discussed, with default value not exceeding the maximum duration.   **Option 1’-b:**   * The maximum value of window length L of the configured TDW should not exceed the maximum duration, which is reported as UE capability as the duration where UE is able to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.   + - If L is not configured, the default value and default behavior are to be discussed, ~~with~~ where default value may or may not exceed~~ing~~ the maximum duration. |

Companies’ views on the above options are summarized as follows:

**Companies supporting Option 1**: Spreadtrum, NTT DOCOMO, LG, ZTE, CATT(1st), Intel, InterDigital, Qualcomm, MediaTek, vivo

**Companies supporting Option 1’**: CTC, CMCC, Sharp, LG, Lenovo, Motorola Mobility, Nokia, NSB, OPPO, Apple, Panasonic, xiaomi, Samsung, Sierra Wireless, HW, HiSilicon, CATT(2nd) , Qualcomm, WILUS, Ericsson

**Companies supporting Option 1’-a**: Panasonic, xiaomi, Samsung, Sierra Wireless, HW, HiSilicon, CATT(2nd) , Qualcomm, WILUS, Ericsson, CMCC

**Companies supporting Option 1’-b**: CTC, Sharp, Nokia, NSB, OPPO, Apple

**Apple** proposes to update Option 1’ and Option 3’ as:

|  |
| --- |
| **Updated Option 1’:**   * The maximum value of window length L of the configured TDW should not exceed the maximum duration, which is reported as UE capability as the duration where UE is able to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.   + - If L is not configured, default behavior should be defined, ~~e.g., the configured TDW length is equal to all repetitions~~ i.e., TDW length and starting position of the TDW adapt to UL slots in UL/DL configuration.   **Updated Option 3’:**   * Whether the window length L of the configured TDW can be longer than maximum duration is subject to UE capability. * If UE is capable of *L* being longer than maximum duration, the maximum duration is consider as an event * The maximum value of the window length *L* of the configured TDW is the duration of all repetitions. * ~~FFS: whether~~ *~~L~~* ~~cannot be other values other than the duration of all repetitions, if it is longer than the maximum duration.~~ The TDW length and starting position of the TDW adapt to UL slots in UL/DL configuration. * ~~If~~ *~~L~~* ~~is longer than the maximum duration, UE does not expect dynamic events.~~ * ~~FFS: details of dynamic events~~ |

Nokia: The issue of error propagation, if any, could be handled by the gNB using at least one of the following options:

* If the gNB anticipates that there is a chance of missing DCI, it may configure a short configured TDW size L such that the impact of error propagation is minimized.
* The gNB may try to detect the dynamic event and know whether the actual TDWs are determined without or with the dynamic event by the UE and perform JCE accordingly.
* The gNB may apply a conservative approach by performing JCE only on the PUSCHs repetitions that are not impacted by the error propagation.

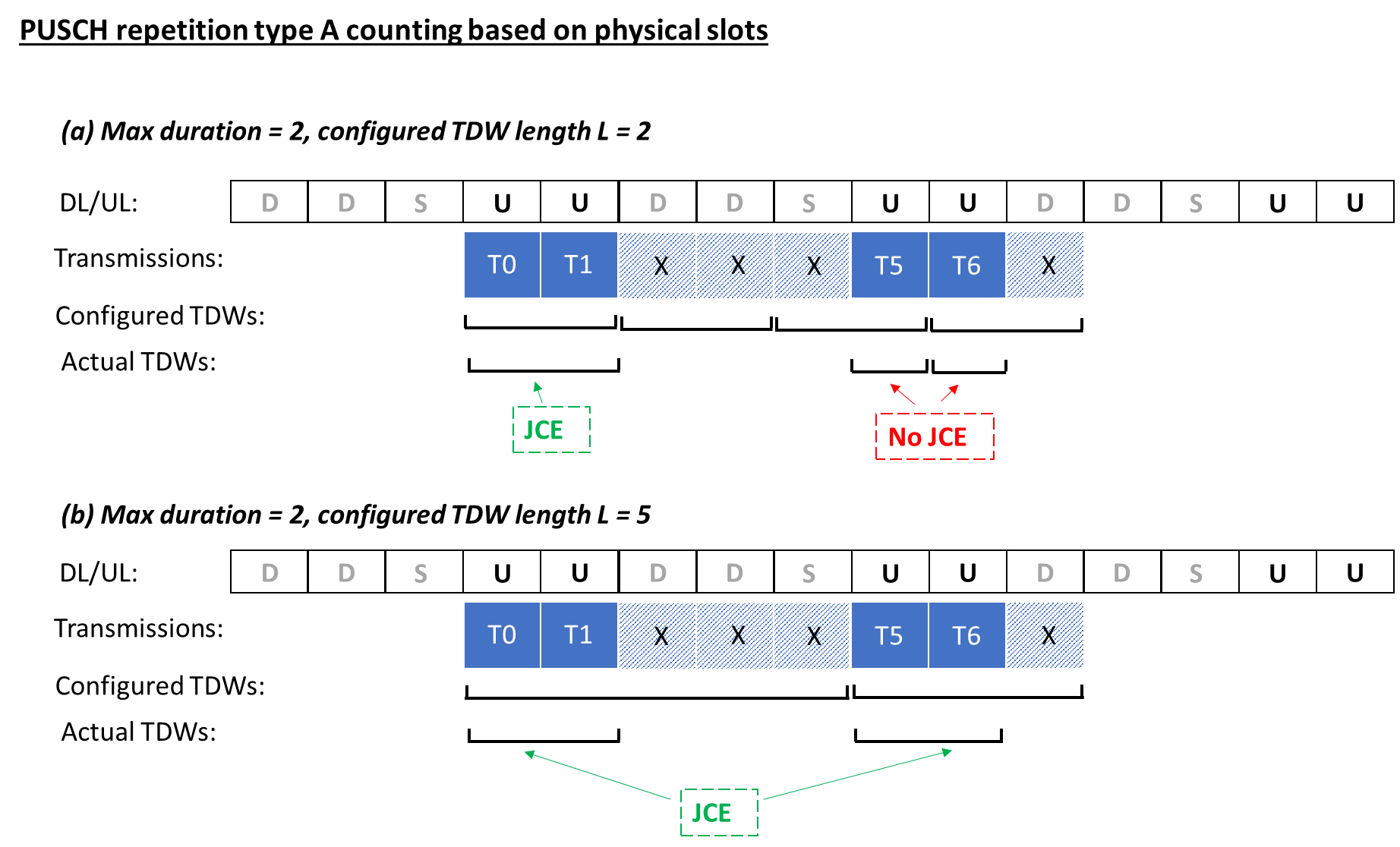
**Ericsson:** When L is not configured the value of L is set to the lesser of the maximum duration and the duration of the PUSCH repetition.

**Ericsson** analyzes the probability of length of actual TDWs and have the following observations.

* Whether L is larger than the maximum duration may not have a big impact on ATDW length
  + Allowing L > max duration can increase the probability of longer window lengths
  + Careful choice of L can also increase the probability of longer window lengths
  + The choice L does not affect smaller window sizes, at least when both L and the max duration is a significant fraction of the number of repetitions.

**Ericsson** discusses the issue of possible segment of UL slots for TDD and have the following observations.

* Requiring L ≤ max duration can in principle prevent JCE over some TDD back-to-back slots, if PUSCH repetition type A counting based on physical slots is used.
* It seems such issues can be avoided by instead using PUSCH repetition type A counting based on available slots and/or by supporting max duration ≥ 5 slots.
  + Hence, L > max duration is not needed to support specific TDD configurations, and its complications can be avoided.





**Qualcomm:**

Default UE behaviour when is not configured, or when exceeds the duration of PUSCH Type A repetitions is specified as follows. Let max duration indicated by the UE be and let the number of PUSCH/PUCCH repetitions be . To differentiate between the configured value of and the actual value of , denote the parameters as and . Assume all parameters are in units of slots.

Case (i) value of is not configured i.e., is not available:

1. In this case, set .

Case (ii) value of L is configured i.e., is available to the UE and :

1. If value of exceeds the total repetitions, i.e., ,
   1. in this case set .
2. Number of repetitions exceeds ,
   1. in this case, .

#### Issue #1-2: Configuration/Indication of L

In RAN1 #106b-e, following agreements were achieved for the configuration/indication of configured window length L:

|  |
| --- |
| **Agreement**   * For DG-PUSCH, Type1 CG-PUSCH and Type2 CG-PUSCH, the window length L of the configured TDW is at least configured by RRC. * FFS: For DG-PUSCH and Type2 CG-PUSCH, whether the window length *L* of the configured TDW can be indicated by DCI or indicated by TDRA table with one additional entry.   **Agreement**   * The window length L of the RRC configured TDW is configured separately for PUSCH and PUCCH.   + For PUSCH, *L* is configured per BWP. * FFS whether the window length L can be configured with each row in the TDRA table |

The remaining issue is whether the configured window length L can be configured/indicated dynamically by DCI or TDRA table. Companies’ views are summarized as follows:

**Companies supporting DCI indication:** Spreadtrum

**Companies supporting TDRA indication:** Panasonic, NTT DOCOMO

**Companies not supporting dynamic indication:** Nokia, NSB, Samsung, Lenovo, Motorola Mobility, HW, HiSilicon

NTT DOCOMO analyses the benefit of dynamic indication of L: for semi-static window length indication, only single value can be configured regardless of the number of allocated slots for one TB. This restriction cannot provide the desired window length based on time domain resource allocation. One example is illustrated in the following figure showing that dynamic window length indication makes it possible to balance the length of multiple TDWs or adjust the window length so that one TDW can cover the whole duration of repetitions.

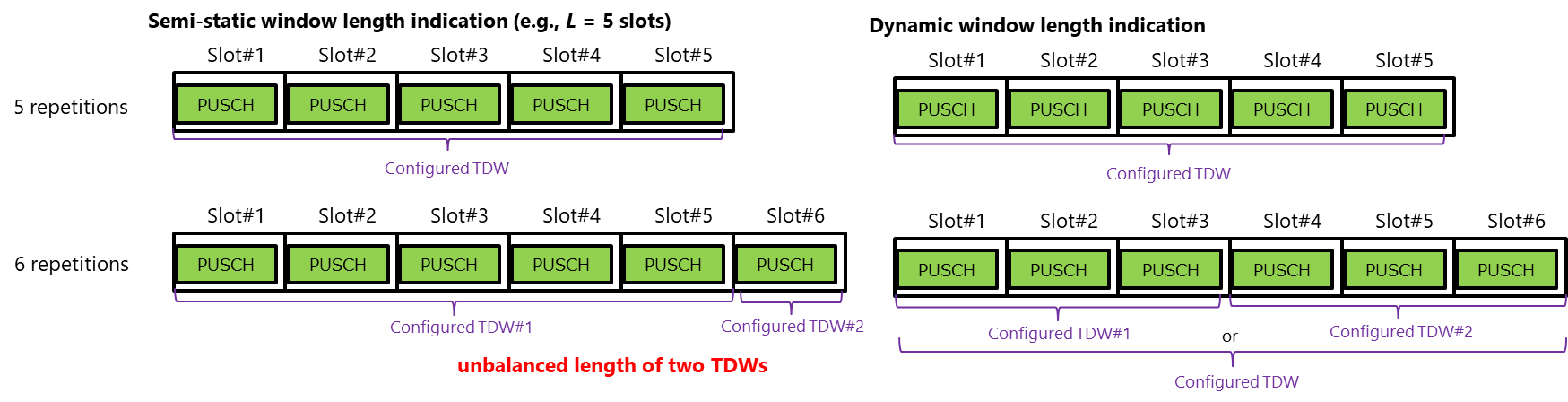


Fig. Comparison between semi-static window length indication and dynamic window length indication, when the number of allocated slots for PUSCH changes

#### Issue #1-3: Candidate values of L

Regarding the candidate value of L, LG proposes that the minimum value of L is 2. ZTE proposes the window length L of the configured TDW can be set to any integer value that is larger than 1 and no larger than the maximum duration.

#### Issue #1-4: Counting of L based on available slots

Nokia proposes one issue to clarify: For configured TDWs determination of PUSCH repetition type A counting based on available slots, RAN1 to further clarify that the configured time domain window length L is counted on available slots.

### 2.3.2 Actual time domain window

#### Issue #2: The determination of actual TDW

#### Issue #2-1: The start/end of the actual TDW

In RAN1 #106b-e, the following working assumption was achieved for the start/end of the actual window:

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| --- |
| **Working assumption:**   * The start of the first actual TDW is the first ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for the first PUSCH transmission in an available slot within the configured TDW. * The end of the actual TDW is   + the last ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for the last PUSCH transmission in an available slot within the configured TDW if the actual TDW reaches the end of the last PUSCH transmission within the configured TDW.   + the last ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ of the PUSCH transmission right before the event if an event occurs that violates power consistency and phase continuity, and the PUSCH transmission is in an available slot. * For UE capable of restarting DM-RS bundling, the start of the new actual TDW is the first ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for PUSCH transmission after the event violates power consistency and phase continuity, and the PUSCH transmission is in an available slot. |

**Spreadtrum** proposes to update the working assumption as:

|  |
| --- |
| **Working assumption:**   * The start of the first actual TDW is the first symbol ~~(at least determined by TDRA table)~~ for the first PUSCH transmission in an available slot within the configured TDW.   + Determined by TDRA table   + Starting symbol of a slot   + Starting symbol after an event * The end of the actual TDW is   + the last symbol ~~(at least determined by TDRA table)~~ for the last PUSCH transmission in an available slot within the configured TDW if the actual TDW reaches the end of the last PUSCH transmission within the configured TDW.     - Determined by TDRA table     - Ending symbol of a slot   + the last symbol (at least determined by TDRA table) of the PUSCH transmission right before the event if an event occurs that violates power consistency and phase continuity, and the PUSCH transmission is in an available slot.   + For UE capable of restarting DM-RS bundling, the start of the new actual TDW is the first symbol (at least determined by TDRA table) for PUSCH transmission after the event violates power consistency and phase continuity, and the PUSCH transmission is in an available slot. |

**WILUS**: If a collision occurs between DL reception/monitoring occasion and dynamically scheduled PUSCH in the set of symbols of the slot within the configured TDW, the DL reception/monitoring can be considered as not the event to determine the start of the actual TDW as illustrated in the following figure.

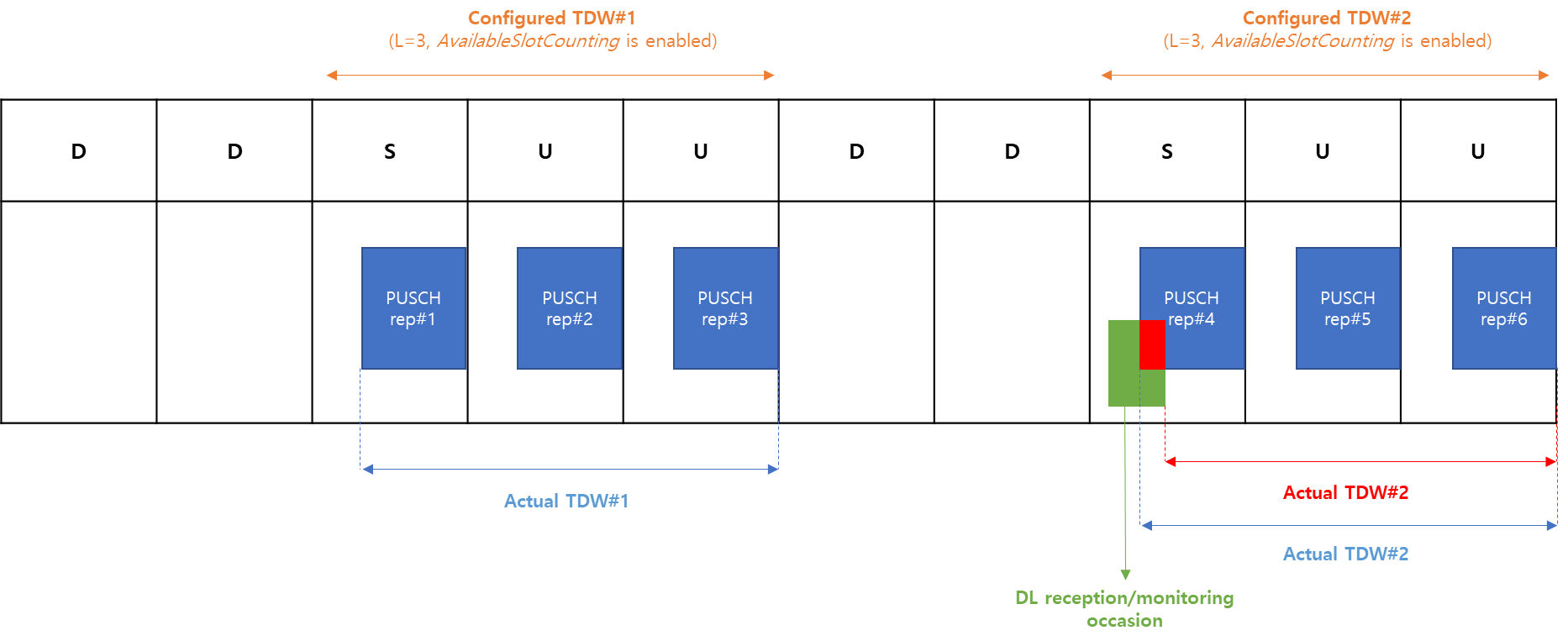


Fig. Actual TDW determination if a collision occurs between DL reception/monitoring occasion and PUSCH.

#### Issue #2-2: Events that violate power consistency and phase continuity

In RAN1 #106b-e, the following agreement was achieved for events that violate power consistency and phase continuity.

|  |
| --- |
| **Agreement**   * Support at least the following events that violate power consistency and phase continuity.   + Dropping/cancellation based on Rel-15/16 collision rules.   + FFS: Rel-17 collision rules.   + DL slot or DL reception/monitoring based on semi-static DL/UL configuration for unpaired spectrum.   + FFS: Other UL transmission in between PUSCH/PUCCH transmissions.   + Gap between two PUSCH/PUCCH transmissions exceeds 13 symbols.   + FFS: Transmission parameters need to be changed due to network-indicated operations, including: Tx power, UL beam/TPMI, and RB allocation.   + FFS: TPC command.   + FFS: TA adjustment.   + FFS: The actual TDW reaches the maximum duration.   + FFS: Frequency hopping.   + FFS: Precoder cycling.   + FFS: other events.   + FFS: whether events are semi-static events or dynamic events.   + FFS: the time duration of an event. |

Regarding the FFS parts, companies’ views are summarized as follows:

|  |  |  |
| --- | --- | --- |
| **Potential events** | **Support as an event** | **Not support as an event** |
| Rel-17 collision rules | Ericsson |  |
| Other UL transmission in between two successive PUSCH/PUCCH transmissions has **different settings** than PUSCHs | Nokia, NSB, vivo, CTC, xiaomi, CMCC, Sharp, LG, HW, HiSilicon, ZTE, Intel, Qualcomm, Ericsson, Sharp, CATT, WILUS, Panasonic |  |
| Other UL transmission in between two successive PUSCH/PUCCH transmissions has the **same setting** with PUSCHs | LG, HW, HiSilicon, ZTE, Qualcomm, Ericsson, Sharp, CATT, WILUS, Panasonic | Nokia, NSB, TCL, CTC, xiaomi |
| Action of TPC commands | Spreadtrum, ZTE | vivo, OPPO, Panasonic, CTC, xiaomi, CMCC, Samsung, HW, HiSilicon, CATT, InterDigital, Nokia, NSB, Sharp, NTT DOCOMO, Intel, Ericsson, LG |
| Action of TA commands | Spreadtrum, HW, HiSilicon, ZTE，CATT(1st) | Samsung, vivo, Panasonic, CTC, xiaomi, CMCC, Apple, Sharp, CATT(2nd), InterDigital, NTT DOCOMO, Intel, Ericsson |
| The actual TDW reaches the maximum duration | It depends on whether L can be larger than maximum duration. | |
| Frequency hopping | Spreadtrum, xiaomi, Sharp, ZTE, InterDigital, Ericsson, Nokia, NSB, CTC, LG, Qualcomm | vivo, CMCC, Samsung, HW, HiSilicon, NTT DOCOMO |
| Precoder cycling | Nokia, NSB | Sharp, CMCC, CATT, Ericsson |

For changing of transmission parameters and precoder cycling, companies’ views are summarized as follows:

**Transmission parameters need to be changed due to network-indicated operations, including: Tx power, UL beam/TPMI, and RB allocation.**

**Support as an event:** vivo, Spreadtrum, xiaomi, Sharp, ZTE, Intel, Qualcomm

**Not support as an event:** CMCC, Ericsson

**Nokia**: This event type would need further discussion in RAN1. At least, it is unclear what is the network-indicated operation for Tx power and what is the difference with TPC command. In addition, the difference between UL beam/TPMI and precoder cycling is unclear. Moreover, for PUSCH repetition type A (and also PUSCH repetition type B and TBoMS), it is unclear why RB allocation is changed across PUSCH repetitions.

**LG**: Discuss prioritizations for transmission power reductions with joint channel estimation.

**Precoder cycling**

**Sharp:** For precoder cycling, the UE should not implicitly change precoder for PUSCH repetitions within at least the actual TDW because the gNB cannot identify that.

**Ericsson:** In our understanding, a UE can use precoder cycling according to implementation for PUSCHs/PUCCHs that are not bundled together. This can be when DMRS bundling is not configured or between different frequency hopping positions. The gNB will not be aware of such cycling. Therefore, precoder cycling should not be an event.

**CMCC:** The precoding cycling is transparent to gNB. And precoding cycling should not be considered as an event.

Apart from the above discussion, there are two additional issues to be discussed:

**Whether events are semi-static events or dynamic events?**

This issue is related to Issue #2-3. Companies (Nokia, NSB, vivo, OPPO, CTC, xiaomi, Sierra Wireless, Sharp, HW, HiSilicon, ZTE, CATT, LG) supporting Option 1 for Issue #2-3 support to differentiate semi-static events and dynamic events.

**Ericsson:** if L>max duration is not supported, it is already sufficient to define what conditions are events, without labeling them as semi-static or dynamic events.

**Apple:** Actual time domain window is determined in the order of event triggered by semi-static signaling, then event triggered by dynamic signaling.

**The time duration of an event**

**LG:** define either time duration of events or UE should report the start of actual time domain window after the event.

**Ericsson:** there is no need to further define the duration of an event beyond the working assumption on actual TDW determination.

**Other considerations:**

**Samsung**: Support the same RV within time domain window (at least for PUSCH repetitions Type A).

**Intel**: The events that violate power consistency and phase continuity may further include:

* If a PUSCH overlaps with PUCCH and UCI is multiplexed on the PUSCH repetition.
* If a UE needs to transmit another uplink channel/signal in a different carrier simultaneously.

**Sony** proposes to categorize the events into 4 subgroups, as:

1. **Events that can be handled by a UE**, relate to configurations that are not time critical and can be applied outside an active TDW or actual TDW. The specification impact relates to UE behavior.
2. **Scheduled events**, relate to events when both the UE and the gNB side is aware of the occurrence. Each time they happen a new TDW/actual TDW will be started. The specification impact is that scheduled events needs to be listed.
3. **UE capability conditioned events**, similar as for the scheduled events, both the UE and the gNB are aware of them and if the UE needs to restart a TDW/actual TDW is up to the UE capability. The specification impact is both the definition of the capability and, the conditioned behavior.
4. **Isolated events**, relates to events the UE need to perform instantaneously but where the gNB is not aware. If such events are present and how to be handled is not clear.

#### Issue #2-3: UE capability of restarting DMRS bundling

In RAN1 #106 b-e meeting the following agreement was achieved for UE capability of restarting DMRS bundling:

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| **Agreement**  Down-select one of the following options:   * **Option 1:** If DM-RS bundling is supported, UE is mandatory to support restarting DM-RS bundling due to semi-static events. UE capability of restarting DMRS bundling is applied only to dynamic events. * **Option 2:** UE capability of restarting DMRS bundling is applied to both semi-static events and dynamic events. |

Companies’ views are summarized as follows:

**Companies supporting Option 1**: Nokia, NSB, vivo, OPPO, CTC, xiaomi, Sierra Wireless, Sharp, HW, HiSilicon, ZTE, CATT, LG

**Companies supporting Option 2**: Spreadtrum, Panasonic, CMCC, Lenovo, Motorola Mobility, MediaTek

**Sierra Wireless**: There have been no agreements made WRT which events are considered semi-static vs dynamic events. Thus, assuming semi-static event are events which are known before the start of the transmission and dynamic events are only known after the start of the transmission then we support Option 1.

**Nokia**: RAN1 to clarify whether the UE capability of restarting DM-RS bundling is applicable per configured TDW or across all configured TDW.

**LG**: If UE is mandatory to support restarting DM-RS bundling due to semi-static event, working assumptions in RAN1#106-e and RAN1#106b-e should be revisited to describe the start of the other actual time domain window.

## 2.4 Inter-slot frequency hopping with inter-slot bundling

In RAN1 #104b-e meeting, two options were agreed to be down selected about the bundle size of inter-slot frequency hopping with inter-slot bundling.

* Option 1: The bundle size (time domain hopping interval) equals to the time domain window size.
* Option 2: The bundle size (time domain hopping interval) can be different from the time domain window.

In RAN1 #106b-e, the following agreement was made.

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| **Agreement:**  For the interaction between inter-slot frequency hopping and DMRS bundling for PUCCH/PUSCH repetitions, a UE perform the “hopping intervals determination”, “configured TDW determination”, and “actual TDW determination” in a sequential ordering. One option of the following options is to be selected.   * Option 1: “hopping intervals determination” -> “configured TDW determination” -> “actual TDW determination” * Option 2: “configured TDW determination” -> “hopping intervals determination” -> “actual TDW determination” * Option 4: “configured TDW determination” -> “actual TDW determination” and “hopping intervals determination”   Note: option 1 and 2 assume a hopping interval can be different than an actual TDW. Option 4 assumes a hopping interval is the same as an actual TDW. |

The above three options are illustrated below:



Fig.1 Illustration of the configured hopping interval smaller than the window length of the configured TDWs for option 1



Fig.2 Illustration of the configured hopping interval larger than the window length of the configured TDWs for option 1



Fig.3 Illustration of the hopping interval equal to the window length of the configured TDWs for option 2



Fig.4 Illustration of the hopping intervals equal to the window length of the actual TDWs for option 4

**FL comments:** This issue is discussed under AI 8.8.2.

## 2.5 TPC command

In RAN1#106bis-e meeting, the handling of TPC command was discussed extensively [12]. During the discussion, accumulated TPC commands and absolute TPC commands were discussed separately as follows.

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| **Accumulate TPC commands:**   * The action of TPC commands does not constitute an event that violates power consistency and phase continuity.   + If UE is configured to accumulate TPC commands, down select one of the following options.     - Option 1: If UE receives TPC commands that would take into effect during an actual TDW, UE accumulates TPC commands without taking effect during the current actual TDW. TPC commands take effect after the current actual TDW.     - Option 2: If UE receives TPC commands that would take into effect during a configured TDW, UE accumulates TPC commands without taking effect during the current configured TDW.   **Absolute TPC commands:**   * If UE is not configured to accumulate TPC commands, down select one of the following alternatives.   + Alt 1: the last TPC command that would take effect within a configured TDW supersedes all previous TPC commands that take effect within that configured TDW and only the last TPC command is applied by the UE.     - FFS: no more than 1 TPC command is expected to take effect during a configured TDW.   + ~~Alt 2: no more than 1 TPC command is expected to take effect during a configured TDW.~~   + Alt 3: the last TPC command that would take effect within an actual TDW supersedes all previous TPC commands that take effect within that actual TDW and only the last TPC command is applied by the UE.     - FFS: no more than 1 TPC command is expected to take effect during an actual TDW.   + ~~Alt 4: no more than 1 TPC command is expected to take effect during an actual TDW.~~   + Alt 5: The UE applies TPC commands after a configured TDW. It is left to UE implementation which TPC commands to apply from those that would take effect within the configured TDW.   + Alt 6: The UE applies TPC commands after an actual TDW. It is left to UE implementation which TPC commands to apply from those that would take effect within the actual TDW. |

For accumulate TPC commands, companies’ views are summarized as follows:

**Companies supporting Option 1**: vivo, OPPO, Panasonic, CTC, xiaomi, CMCC, Samsung, HW, HiSilicon, CATT, InterDigital, LG

**Companies supporting Option 2**: Nokia, NSB, Sharp, NTT DOCOMO, Intel, Ericsson

For absolute TPC commands, companies’ views are summarized as follows:

**Companies supporting Alt 1**: Sharp

**Companies supporting Alt 3**: vivo, OPPO, CMCC, Samsung, HW, HiSilicon

**Companies supporting Alt 4**: CATT

**Companies supporting Alt 5**: Ericsson

**Other considerations**

**Apple**: Clarify power control for PUSCH repetition first, then determine whether new power control mechanism is introduced for DMRS bundling.

**LG**: Select one of the following alternatives for TPC command without accumulation when joint channel estimation is enabled.

* Alt. 1: TPC without accumulation is semi-static event with 1 slot time duration.
* Alt. 2: Enabling joint channel estimation implies enabling of TPC accumulation.

**Qualcomm**: A UE is not expected to receive TPC commands that take effect during a configured time domain window.

**Nokia/NSB:** for paired spectrum, wherein the reception/monitoring of a DL transmission does not break power consistency and phase continuity (at least no agreement in both RAN1 and RAN4 exists that prevents such scenario for paired spectrum), then the PDCCH carrying the DCI that contains TPC command could be considered as an event. However, if TPC command is applied in the next configured TDW instead of the next actual TDW, then it is not necessary to consider TPC command as an event, even for paired spectrum.

## 2.6 TA adjustment

In RAN1#106bis-e meeting, the handling of TA adjustment was discussed extensively. The latest FL’s proposals on this topic are as follows [12].

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| * The action of TA commands does not constitute an event that violates power consistency and phase continuity, down select one of the following options.   + Option 1: UE performs TA adjustment after the actual TDW if it receives any TA command indicating TA adjustment during the actual TDW.     - FFS: UE receives no more than 1 TA command whose action time falls within an actual TDW.   + Option 2: UE performs TA adjustment after the configured TDW if it receives any TA command indicating TA adjustment during the configured TDW.     - FFS: UE receives no more than 1 TA command whose action time falls within a configured TDW. |

**Companies supporting Option 1**: vivo, Panasonic, CTC, xiaomi, CMCC, Apple, Sharp, CATT(2nd), InterDigital

**Companies supporting Option 2**: NTT DOCOMO, Intel, Ericsson

**LG**:

**gNB indicated TA adjustment：**

Select one of the following options for the gNB indicated TA adjustment when joint channel estimation is enabled.

* Opt. 1: gNB indicated TA adjustment is semi-static event without time duration.
* Opt. 2: gNB indicated TA adjustment that taking effect during the configured or actual time domain window is applied right after the end of the time domain window.

To support above Opt. 2, select one of the following options for the multiple gNB indicated TA adjustment during a time domain window.

* Alt. 1: UE expects only single TA adjustment is indicated during the time domain window.
* Alt. 2: UE applies multiple TA adjustments right after the end of time domain window in the indicated order.
* Alt. 3: UE applies only single TA adjustment during the time domain window even multiple indicated.

**UE autonomous TA adjustment：**

UE should report the end of the actual time domain window when it is terminated by the UE autonomous TA adjustment.

Discuss whether the reduced slot due to TA adjustment is included in the time domain window or not.

**CATT**: 1st preference is that the action of TA command constitutes a dynamic event.

**Qualcomm**: A UE is not expected to receive TA commands indicating TA adjustment during a configured time domain window.

**Nokia/NSB:** The action of TA commands does not constitute an event that violates power consistency and phase continuity, down select one of the following options.

* Option 1: UE performs TA adjustment after the actual TDW if it receives any TA command indicating TA adjustment during the actual TDW.
  + FFS: in which actual TDW after the current actual TDW the TA adjustment is applied.
* Option 2: UE performs TA adjustment after the configured TDW if it receives any TA command indicating TA adjustment during the configured TDW.

## 2.7 JCE for PUSCH repetition type B and TBoMS

Companies (Nokia, NSB, CTC, Samsung) propose that the time domain window determination procedure agreed for PUSCH repetition type A is also applicable for PUSCH repetition type B and TBoMS.

Nokia proposes that the configured TDWs determination procedure for PUSCH repetition type A counting based on physical slots is applied for PUSCH repetition type B and the configured TDWs determination procedure for PUSCH repetition type A counting based on available slots is applied for TBoMS.

Panasonic thinks PUSCH repetition Type B cannot be supported as it does not reuse only those joint channel estimation specification enhancements defined to support repetition Type A considering that the terminology of "available slot" is not used for PUSCH repetition Type B specified in current Rel. 15/16.

InterDigital proposes to support joint channel estimation for TBoMS repetition. The DMRS bundling restarting behavior for actual TDW needs to be modified correspondingly. For joint channel estimation for TBoMS repetitions, the earliest actual TDW occurs at the first symbol of the next ToT (TBoMS transmission occasion) as illustrated in the following figure.



Figure. Joint channel estimation for TBoMS repetitions (N=4, m=3), actual TDW is denoted by “A-TDW”

## 2.8 Others

**Coherent transmission indication**

**LG**: The coherent transmission indication using DMRS resource (e.g., DMRS port, DMRS phase) should be reported at least for the end of the actual time domain window due to the dynamic event.

**Qualcomm**: UE signals a bundling indication in the UCI multiplexing with PUSCH transmission to indicate whether a PUSCH transmission is coherent with respect to the other PUSCH transmission. The motivation of the coherent transmission indication is due to the fact that some events on the UE side may impact the phase continuity but such change may not be known to the gNB. These events may include: frequency error correction, timing correction, RF calibration, antenna virtualization and etc.

**Phase drifting**

**CMCC**: The impact of phase drifting to the performance of joint channel estimation under a large number of consecutive slots should be studied.

**PTRS:**

**InterDigital:** Support to include PTRS in a DMRS bundle. Parameters of PTRS in the DMRS bundle depend on duration of the time window, SCS, bandwidth for PUSCH, and MCS used with DMRS bundling.

**Qualcomm:** Support different criteria for activation of PTRS or its density for the case of joint channel estimation.

1. Email discussion (1st round)

## 3.1 Use cases for joint channel estimation

**Use case 4b:**

**Proposal 1:**

* For non-back-to-back PUSCH/PUCCH transmissions across consecutive slots, the other uplink transmission in the middle of two PUSCH/PUCCH transmissions constitutes an event that violates power consistency and phase continuity.

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| **Companies** | **Comments** |
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## 3.2 Time domain window

**Proposal 2: Confirm the following working assumption**

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| **Working assumption:**  For joint channel estimation for PUSCH repetition type A of PUSCH repetitions of the same TB, all the repetitions are covered by one or multiple consecutive/non-consecutive configured TDWs.   * Each configured TDW consists of one or multiple consecutive physical slots. * The window length *L* of the configured TDW(s) can be explicitly configured with a single value ~~and~~ *~~L~~* ~~is no longer than the maximum duration~~.   + FFS: The maximum value of *L* ~~is the duration of all repetitions~~   + FFS: Solutions to error propagation issue if ~~for~~ *L* is longer than the maximum duration is to be discussed further.   + FFS: The window length *L* is configured per UL BWP * The start of the first configured TDW is the first PUSCH transmission   + FFS: The first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission. * The start of other configured TDWs can be implicitly determined prior to first repetition.   + FFS: The configured TDWs are consecutive for paired spectrum/SUL band   + FFS: The start of the configured TDWs for unpaired spectrum is implicitly determined based on semi-static DL/UL configuration. * The end of the last configured TDW is the end of the last PUSCH transmission.   + FFS: The end of the configured TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission. * Within one configured TDW, one or multiple actual TDWs can be implicitly determined:   + The start of the first actual TDW is the first PUSCH transmission within the configured TDW.     - FFS: The first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission.   + After one actual TDW starts, UE is expected to maintain the power consistency and phase continuity until one of the following conditions is met, then the actual TDW is ended.     - The actual TDW reaches the end of the last PUSCH transmission within the configured TDW.       * FFS: The end of the actual TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission.     - An event occurs that violates power consistency and phase continuity       * FFS: The events may include e.g., a DL slot based on DL/UL configuration for unpaired spectrum, the actual TDW reaches the maximum duration, DL reception/monitoring occasion for unpaired spectrum, high priority transmission, frequency hopping, precoder cycling.       * FFS: The end of the actual TDW is the last available slot/symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.   + If the power consistency and phase continuity are violated due to an event, whether a new actual TDW is created is subject to UE capability of supporting restarting DMRS bundling.     - If UE is capable of restarting DM-RS bundling, one new actual TDW is created after the event,       * FFS: The start of the new actual TDW is the first available slot/symbol for PUSCH transmission after the event.     - If UE is not capable of restarting DM-RS bundling, no new actual TDW is created until the end of the configured TDW.     - FFS: UE capability of restarting DMRS bundling is applied only to dynamic event or not   Note 1: A ‘configured TDW’ refers to a time domain window whose length can be configured to ‘L’ and whose start and end is determined as described above.  Note 2: An ‘actual TDW’ refers to a time domain window during whose entire duration the DM-RS bundling is actually applied. An ‘actual TDW’ duration is always less than or equal to the ‘configure TDW’ duration.  Note 3: Whether the terms ‘configured TDW’ and ‘actual TDW’ are revised to other terms and if such terminology is used in specifications is to be further discussed. |

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| **Companies** | **Comments** |
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### 3.2.1 Configured TDW

#### Issue #1: The window length *L* of the configured TDW

#### Issue #1-1: The maximum value of L

**FL comments:** Based on the discussion in RAN1 #106b-e, companies tend to converge on option 1’. In addition, based on the guideline in R1-2111193, default values are primarily important for cases where the NW has not yet provided a (UE-specific) configuration. In other cases, it can help clarify what the UE does when a parameter or feature is not configured. Thus, let’s focus on the discussion on option 1’. There are two sub-options for option 1’. To make each option clearer, they are modified as follows.

**Option 1’-a:**

* If L is configured, the maximum value of window length L of the configured TDW should not exceed the maximum duration, which is reported as UE capability as the duration where UE is able to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.
* If L is not configured, the default value of L = min (maximum duration, duration of all PUSCH repetitions)

**Option 1’-b:**

* If L is configured, the maximum value of window length L of the configured TDW should not exceed the maximum duration, which is reported as UE capability as the duration where UE is able to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.
* If L is not configured, the default value of L is the duration of all PUSCH repetitions.

Pros and cons for each options are summarized below.

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| --- | --- | --- |
|  | Pros | Cons |
| **Option 1’-a** | Error propagation is restricted within one configured TDW. | May cause segment of UL slots for counting based on physical slots for TDD. |
| **Option 1’-b** | Can achieve best performance if no dynamic events | May have error propagation across configured TDWs in case of dynamic events. |

Companies are encouraged to provide further views on the above two options.

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| **Companies** | **Comments** |
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#### Issue #1-2: Configuration/Indication of L

**FL comments:** It seems the majority do not support dynamic indication of the window length L of the configured TDW.

**Proposal 3:**

* Dynamic indication of the window length *L* of the configured TDW by DCI or indicated by TDRA table with one additional entry is not supported.

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| **Companies** | **Comments** |
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#### Issue #1-3: Candidate values of L

**FL comments:** The candidate values of L depend on the maximum duration. Based on RAN4 discussion, RAN4 is studying the impact of enabling up to 32 slots for maximum duration and other numbers beyond 32 slots are not analyzed in RAN4.

**Proposal 4:**

* The candidate values of the window length *L* of the configured TDW can be any integer value that is larger than 1 and no larger than the maximum duration.
* FFS: candidate values if *L* can be larger than the maximum duration.

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| **Companies** | **Comments** |
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#### Issue #1-4: Counting of L based on available slots

**FL comments:** From FL understanding, based on the working assumption, each configured TDW consists of one or multiple consecutive physical slots, regardless of the counting based on physical slots or available slots.

Companies are encouraged to provide views whether it is necessary to the configured time domain window length L is counted on available slots as proposed in R1-2110865.

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| **Companies** | **Comments** |
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### 3.3.2 Actual time domain window

#### Issue #2: The determination of actual TDW

#### Issue #2-1: The start/end of the actual TDW

**Proposal 5: Confirm the following working assumption**

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| **Working assumption:**   * The start of the first actual TDW is the first ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for the first PUSCH transmission in an available slot within the configured TDW. * The end of the actual TDW is   + the last ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for the last PUSCH transmission in an available slot within the configured TDW if the actual TDW reaches the end of the last PUSCH transmission within the configured TDW.   + the last ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ of the PUSCH transmission right before the event if an event occurs that violates power consistency and phase continuity, and the PUSCH transmission is in an available slot. * For UE capable of restarting DM-RS bundling, the start of the new actual TDW is the first ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for PUSCH transmission after the event violates power consistency and phase continuity, and the PUSCH transmission is in an available slot. |

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| **Companies** | **Comments** |
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#### Issue #2-2: Events that violate power consistency and phase continuity

**FL comments:** Regarding the change of transmission parameters, some companies think it is not necessary to discuss this type of event, since some parameters will not change while other parameters are covered by other events.

* Transmission parameters need to be changed due to network-indicated operations, including: Tx power, UL beam/TPMI, and RB allocation.

Companies are encouraged to answer the following questions.

Q1: Whether it is necessary to consider the change of transmission parameters as an event?

Q2: If the answer to Q1 is yes, which parameters should be considered while not covered by other events?

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| **Companies** | **Comments** |
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**FL comments:** Based on companies’ views, whether precoder cycling is used is up to UE implementation and it is transparent to gNB. UE should not change precoder within the actual TDW because the gNB cannot identify that.

**Proposal 6:**

* Precoder cycling does not constitute an event that violates power consistency and phase continuity.
* UE should not perform procoder cycling within the actual TDW.

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| **Companies** | **Comments** |
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**FL comments:** Regarding whether events are semi-static events or dynamic events, it depends on whether UE capability of restarting DMRS bundling is applied only to dynamic events. Companies are encouraged to provide views on how to differentiate semi-static events or dynamic events if the differentiation is necessary.

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| **Companies** | **Comments** |
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**FL comments:** Regarding the time duration of an event, Companies are encouraged to answer the following questions.

Q1: Is it necessary to define the time duration of an event?

Q2: If the answer to Q1 is yes, how to define the time duration of an event?

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| **Companies** | **Comments** |
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Any other comments about events?

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| **Companies** | **Comments** |
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#### Issue #2-3: UE capability of restarting DMRS bundling

**FL comments:** Regarding UE capability of restarting DMRS bundling, two options are discussed to be down selected. From FL understanding, as we have agreed that DL slot or DL reception/monitoring based on semi-static DL/UL configuration for unpaired spectrum is regarded as an event. For option 2, for UE not capable of restarting DMRS bundling, DMRS bundling cannot be supported after DL slot within the configured TDW. This seems a drawback of option 2.

* **Option 1:** If DM-RS bundling is supported, UE is mandatory to support restarting DM-RS bundling due to semi-static events. UE capability of restarting DMRS bundling is applied only to dynamic events.

**Support:** Nokia, NSB, vivo, OPPO, CTC, xiaomi, Sierra Wireless, Sharp, HW, HiSilicon, ZTE, CATT

* **Option 2:** UE capability of restarting DMRS bundling is applied to both semi-static events and dynamic events.

**Support:** Spreadtrum, Panasonic, CMCC, Lenovo, Motorola Mobility, MediaTek

Companies are encouraged to provide pros and cons of the above two options.

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| **Companies** | **Option 1** | **Option 2** |
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Companies are encouraged to provide comments on whether UE should be mandatory to support restarting DM-RS bundling at least due to some of the events, e.g., DL slot or DL reception/monitoring based on semi-static DL/UL configuration for unpaired spectrum?

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| **Companies** | **Comments** |
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## 3.3 TPC command

**FL comments:** In RAN 1#106b-e, we almost reached the consensus that the action of TPC commands does not constitute an event and down select one of the following options for accumulate TPC commands. Considering this is the last meeting before RAN1 freeze, let’s focus the discussion on the following two options.

* The action of TPC commands does not constitute an event that violates power consistency and phase continuity.
  + If UE is configured to accumulate TPC commands, down select one of the following options.
    - Option 1: If UE receives TPC commands that would take into effect during an actual TDW, UE accumulates TPC commands without taking effect during the current actual TDW. TPC commands take effect after the current actual TDW.
    - Option 2: If UE receives TPC commands that would take into effect during a configured TDW, UE accumulates TPC commands without taking effect during the current configured TDW.

Companies are encouraged to provide pros and cons of the above two options.

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| **Companies** | **Option 1** | **Option 2** |
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**FL comments:** Regarding absolute TPC commands. It seems no company supports Alt 6. Let’s focus the discussion on Alt 1, Alt 3 and Alt 5.

* If UE is not configured to accumulate TPC commands, down select one of the following alternatives.
  + Alt 1: the last TPC command that would take effect within a configured TDW supersedes all previous TPC commands that take effect within that configured TDW and only the last TPC command is applied by the UE.
    - FFS: no more than 1 TPC command is expected to take effect during a configured TDW.
  + ~~Alt 2: no more than 1 TPC command is expected to take effect during a configured TDW.~~
  + Alt 3: the last TPC command that would take effect within an actual TDW supersedes all previous TPC commands that take effect within that actual TDW and only the last TPC command is applied by the UE.
    - FFS: no more than 1 TPC command is expected to take effect during an actual TDW.
  + ~~Alt 4: no more than 1 TPC command is expected to take effect during an actual TDW.~~
  + Alt 5: The UE applies TPC commands after a configured TDW. It is left to UE implementation which TPC commands to apply from those that would take effect within the configured TDW.
  + ~~Alt 6: The UE applies TPC commands after an actual TDW. It is left to UE implementation which TPC commands to apply from those that would take effect within the actual TDW.~~

Companies are encouraged to provide pros and cons of the above options

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| **Companies** | **Alt 1** | **Alt 3** | **Alt 5** |
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## 3.4 TA adjustment

**FL comments:** In RAN 1#106b-e, the majority support that the action of TA commands does not constitute an event and down select one of the following options. Let’s focus on the discussion on the following two options.

* The action of TA commands does not constitute an event that violates power consistency and phase continuity, down select one of the following options.
  + Option 1: UE performs TA adjustment after the actual TDW if it receives any TA command indicating TA adjustment during the actual TDW.
    - FFS: UE receives no more than 1 TA command whose action time falls within an actual TDW.
  + Option 2: UE performs TA adjustment after the configured TDW if it receives any TA command indicating TA adjustment during the configured TDW.
    - FFS: UE receives no more than 1 TA command whose action time falls within a configured TDW.

Companies are encouraged to provide pros and cons of the above two options.

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| **Companies** | **Option 1** | **Option 2** |
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## 3.5 JCE for PUSCH repetition type B and TBoMS

**FL comments:** Based on the agreements, joint channel estimation (DM-RS bundling) is supported for PUSCH repetition type B and TBoMS. One issue raised about the configured TDW determination for PUSCH repetition type B and TBoMS is the counting method. There are two counting methods for PUSCH repetition type A, i.e., counting based on physical slots and counting based on available slots.

**Proposal 7:**

* The TDW determination procedure agreed for PUSCH repetition type A is applicable for PUSCH repetition type B and TBoMS.
  + The configured TDWs determination procedure for PUSCH repetition type A counting based on physical slots is applied for PUSCH repetition type B.
  + The configured TDWs determination procedure for PUSCH repetition type A counting based on available slots is applied for TBoMS.
* No additional specification enhancements for PUSCH repetition type B and TBoMS.

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| **Companies** | **Comments** |
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**FL comments:** Another issue is whether DM-RS bundling and TDW determination can be applied to repetition of TBoMS.

**Proposal 8:**

* DM-RS bundling for repetition of TBoMS is supported.
* The TDW determination procedure agreed for PUSCH repetition type A is applicable for repetition of TBoMS.

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| **Companies** | **Comments** |
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1. Agreements at RAN1#106b-e

**Agreement:**

* For PUSCH repetition type A counting based on physical slots
  + The start of the first configured TDW is the first physical slot for the first PUSCH transmission.
  + The end of the last configured TDW is the last physical slot for the last PUSCH transmission.
* For PUSCH repetition type A counting based on available slots
  + The start of the first configured TDW is the first available slot for the first PUSCH transmission.
  + The end of the last configured TDW is the last available slot for the last PUSCH transmission.
  + Note: The determination of available slots for PUSCH repetition Type A is defined in AI 8.8.1.1.

**Conclusion:**

* Joint channel estimation over PUSCH transmissions across non-consecutive slots is not supported in Rel-17.

**Agreement:**

Down-select one of the following options in this meeting:

**Option 1**:

* The maximum value of window length *L* of the configured TDW should not exceed the maximum duration, which is reported as UE capability as the duration where UE is able to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.

**Option 1’:**

* The maximum value of window length L of the configured TDW should not exceed the maximum duration, which is reported as UE capability as the duration where UE is able to maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.
  + - ~~If L is not configured, the configured TDW length is equal to all repetitions~~
    - If L is not configured, default behavior should be defined, e.g., the configured TDW length is equal to all repetitions

**Option 3’**:

* Whether the window length *L* of the configured TDW can be longer than maximum duration is subject to UE capability.
  + If UE is capable of *L* being longer than maximum duration,
    - The maximum value of the window length *L* of the configured TDW is the duration of all repetitions.
      * FFS: whether *L* cannot be other values other than the duration of all repetitions, if it is longer than the maximum duration.
    - If *L* is longer than the maximum duration, UE does not expect dynamic events.
      * FFS: details of dynamic events

**Agreement**

* For DG-PUSCH, Type1 CG-PUSCH and Type2 CG-PUSCH, the window length L of the configured TDW is at least configured by RRC.
* FFS: For DG-PUSCH and Type2 CG-PUSCH, whether the window length *L* of the configured TDW can be indicated by DCI or indicated by TDRA table with one additional entry.

**Agreement**

* The window length L of the RRC configured TDW is configured separately for PUSCH and PUCCH.
  + For PUSCH, *L* is configured per BWP.
* FFS whether the window length L can be configured with each row in the TDRA table

**Agreement**

* For PUSCH repetition type A counting based on physical slots
  + The configured TDWs are consecutive, where the start of other configured TDWs is the first physical slot right after the last physical slot of a previous configured TDW.
* For PUSCH repetition type A counting based on available slots
  + The configured TDWs are determined based on available slots, where start of a configured TDWs is the ~~next~~ first available slot after the ~~conclusion~~ last available slot of a previous configured TDW.
  + Note: The determination of available slots for PUSCH repetition Type A is defined in AI 8.8.1.1.

**Working assumption:**

* The start of the first actual TDW is the first ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for the first PUSCH transmission in an available slot within the configured TDW.
* The end of the actual TDW is
  + the last ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for the last PUSCH transmission in an available slot within the configured TDW if the actual TDW reaches the end of the last PUSCH transmission within the configured TDW.
  + the last ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ of the PUSCH transmission right before the event if an event occurs that violates power consistency and phase continuity, and the PUSCH transmission is in an available slot.
* For UE capable of restarting DM-RS bundling, the start of the new actual TDW is the first ~~available~~ symbol (at least determined by TDRA table) ~~in available slot~~ for PUSCH transmission after the event violates power consistency and phase continuity, and the PUSCH transmission is in an available slot.

**Agreement**

* For back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following case:
  + Over back-to-back PUSCH transmissions for one TB processed over multiple slots
    - It’s subject to UE capability
    - if it reuses only those joint channel estimation specification enhancements defined to support repetition Type A

**Agreement**

* For non-back-to-back PUSCH transmissions across consecutive slots (no uplink transmission in the middle of two PUSCH transmissions), support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following case:
  + Over non-back-to-back PUSCH transmissions for one TB processed over multiple slots
    - It’s subject to UE capability
    - if it reuses only those joint channel estimation specification enhancements defined to support repetition Type A

**Agreement**

Down-select one of the following options:

* **Option 1:** If DM-RS bundling is supported, UE is mandatory to support restarting DM-RS bundling due to semi-static events. UE capability of restarting DMRS bundling is applied only to dynamic events.
* **Option 2:** UE capability of restarting DMRS bundling is applied to both semi-static events and dynamic events.

**Agreement**

* Support at least the following events that violate power consistency and phase continuity.
  + Dropping/cancellation based on Rel-15/16 collision rules.
  + FFS: Rel-17 collision rules.
  + DL slot or DL reception/monitoring based on semi-static DL/UL configuration for unpaired spectrum.
  + FFS: Other UL transmission in between PUSCH/PUCCH transmissions.
  + Gap between two PUSCH/PUCCH transmissions exceeds 13 symbols.
  + FFS: Transmission parameters need to be changed due to network-indicated operations, including: Tx power, UL beam/TPMI, and RB allocation.
  + FFS: TPC command.
  + FFS: TA adjustment.
  + FFS: The actual TDW reaches the maximum duration.
  + FFS: Frequency hopping.
  + FFS: Precoder cycling.
  + FFS: other events.
  + FFS: whether events are semi-static events or dynamic events.
  + FFS: the time duration of an event.

**Agreement**

* Introduce two RRC parameters to indicate enabling of DM-RS bundling and the window length of the configured TDW respectively.

**Agreement**

* Introduce a new RRC parameter for when UE restarts a PUSCH bundling window

1. Agreements at RAN1#106-e

**Agreement: Confirm the following working assumption.**

**Working assumption:**

* For non-back-to-back PUSCH transmissions (at least for the case of the same TB) across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following cases:
  + Over non-back-to-back PUSCH transmissions (of the same TB) for repetition type A scheduled by dynamic grant or configured grant.
  + Over non-back-to-back PUSCH transmissions (of the same TB) for repetition type B scheduled by dynamic grant or configured grant, if it reuses only those joint channel estimation specification enhancements defined to support repetition Type A.
    - FFS: additional specification enhancements on top of that defined to support repetition Type A
    - Only for single layer transmissions
    - Subject to UE capability
  + FFS: Over non-back-to-back PUSCH transmissions with different TBs
  + FFS: Over non-back-to-back PUSCH transmissions for TBoMS
  + For the non-back-to-back PUSCH transmissions, it is defined as at least when there is no UL transmission between the two successive PUSCH transmissions
  + Subject to UE capability with details FFS (e.g., separate vs. joint capability for type A & type B, w.r.t. OFF power requirements, etc.)
* FFS: Joint channel estimation over non-back-to-back PUSCH transmissions with other uplink transmissions between the two successive PUSCH transmissions across consecutive slot.

**Conclusion**

* Optimization of DMRS location in time domain for PUSCH is not considered for joint channel estimation in Rel-17.

**Agreement**

* Joint channel estimation for PUSCH transmissions and the time domain window are jointly enabled or disabled via RRC configuration for a UE.
  + Note: Enabling/disabling of joint channel estimation for PUSCH transmissions means enabling/disabling of DMRS bundling for PUSCH transmissions under the condition of power consistency and phase continuity.

**Agreement**

**Make down-selection between the following two alternatives:**

* Alt 1: UE is not expected to receive TPC commands during the current time domain window.
* Alt 2: UE receives and accumulates TPC commands without taking effect during the current time domain window.

**Agreement**

* UE should not perform TA adjustment during the time domain window.
  + FFS: UE does not expect to receive TA command to indicate TA adjustment during the TDW.
  + FFS: UE ignores any TA command which indicates TA adjustment during the TDW.
  + FFS: UE performs TA adjustment after the TDW if it receives any TA command indicating TA adjustment during the TDW.

**Working assumption:**

For joint channel estimation for PUSCH repetition type A of PUSCH repetitions of the same TB, all the repetitions are covered by one or multiple consecutive/non-consecutive configured TDWs.

* Each configured TDW consists of one or multiple consecutive physical slots.
* The window length *L* of the configured TDW(s) can be explicitly configured with a single value ~~and~~ *~~L~~* ~~is no longer than the maximum duration~~.
  + FFS: The maximum value of *L* ~~is the duration of all repetitions~~
  + FFS: Solutions to error propagation issue if ~~for~~ *L* is longer than the maximum duration is to be discussed further.
  + FFS: The window length *L* is configured per UL BWP
* The start of the first configured TDW is the first PUSCH transmission
  + FFS: The first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission.
* The start of other configured TDWs can be implicitly determined prior to first repetition.
  + FFS: The configured TDWs are consecutive for paired spectrum/SUL band
  + FFS: The start of the configured TDWs for unpaired spectrum is implicitly determined based on semi-static DL/UL configuration.
* The end of the last configured TDW is the end of the last PUSCH transmission.
  + FFS: The end of the configured TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission.
* Within one configured TDW, one or multiple actual TDWs can be implicitly determined:
  + The start of the first actual TDW is the first PUSCH transmission within the configured TDW.
    - FFS: The first available slot/symbol, or the first physical slot/symbol for the first PUSCH transmission.
  + After one actual TDW starts, UE is expected to maintain the power consistency and phase continuity until one of the following conditions is met, then the actual TDW is ended.
    - The actual TDW reaches the end of the last PUSCH transmission within the configured TDW.
      * FFS: The end of the actual TDW is the last available slot/symbol, or the last physical slot/symbol for the last PUSCH transmission.
    - An event occurs that violates power consistency and phase continuity
      * FFS: The events may include e.g., a DL slot based on DL/UL configuration for unpaired spectrum, the actual TDW reaches the maximum duration, DL reception/monitoring occasion for unpaired spectrum, high priority transmission, frequency hopping, precoder cycling.
      * FFS: The end of the actual TDW is the last available slot/symbol of the PUSCH transmission right before an event such that the power consistency and phase continuity are violated.
  + If the power consistency and phase continuity are violated due to an event, whether a new actual TDW is created is subject to UE capability of supporting restarting DMRS bundling.
    - If UE is capable of restarting DM-RS bundling, one new actual TDW is created after the event,
      * FFS: The start of the new actual TDW is the first available slot/symbol for PUSCH transmission after the event.
    - If UE is not capable of restarting DM-RS bundling, no new actual TDW is created until the end of the configured TDW.
    - FFS: UE capability of restarting DMRS bundling is applied only to dynamic event or not

Note 1: A ‘configured TDW’ refers to a time domain window whose length can be configured to ‘L’ and whose start and end is determined as described above.

Note 2: An ‘actual TDW’ refers to a time domain window during whose entire duration the DM-RS bundling is actually applied. An ‘actual TDW’ duration is always less than or equal to the ‘configure TDW’ duration.

Note 3: Whether the terms ‘configured TDW’ and ‘actual TDW’ are revised to other terms and if such terminology is used in specifications is to be further discussed.

1. Agreements at RAN1#105-e

Agreement**:**

* Joint channel estimation over non-back-to-back PUSCH transmissions within one slot is not supported.

Agreement:

* Definition of **the maximum duration**: a maximum time duration during which **UE is able to** maintain power consistency and phase continuity subject to power consistency and phase continuity requirements.
* FFS whether or not such a definition is necessary for RAN1 specifications.
  + Note: whether such a definition is to be specified in RAN4 specifications is up to RAN4.
* FFS the maximum duration may be reported by UE.
* Note: it is understood that for a UE, the maximum duration is no less than the time domain window duration

Agreement:Send LS to RAN4 asking the following questions

* For joint channel estimation, is there a maximum duration during which UE is able to maintain power consistency and phase continuity under certain tolerance level? If any, how long is it?
  + What factors determine the maximum duration?
  + Whether the maximum duration should be the same for different cases for both PUSCH and PUCCH?
  + Whether the maximum duration is dependent on the modulation order of transmission, e.g., QPSK, 16QAM, 64QAM?
  + Whether the maximum duration is dependent on UL waveform (DFT-s-OFDM vs. OFDM)?
  + Whether the maximum duration is band specific?
  + Besides the factors listed above, whether or not the maximum duration is further dependent on UE capabilities (e.g., multiple possible values for a given set of factor(s)), and if so, whether the UE should report such a duration

Agreement:

* Optimization of DMRS granularity in time domain for PUSCH is not considered for joint channel estimation in Rel-17.

Agreement:

* For back-to-back PUSCH transmissions within one slot, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following cases:
  + Over back-to-back PUSCH transmissions (of the same TB) for repetition type B scheduled by dynamic grant or configured grant, if it reuses only those joint channel estimation specification enhancements defined to support repetition Type A with consecutive slots
    - FFS: additional specification enhancements on top of that defined to support repetition Type A
    - Only for single layer transmissions
    - Subject to UE capability
* Joint channel estimation over back-to-back PUSCH transmissions with different TBs within one slot is not supported.

**Working assumption:**

* For non-back-to-back PUSCH transmissions (at least for the case of the same TB) across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following cases:
  + Over non-back-to-back PUSCH transmissions (of the same TB) for repetition type A scheduled by dynamic grant or configured grant.
  + Over non-back-to-back PUSCH transmissions (of the same TB) for repetition type B scheduled by dynamic grant or configured grant, if it reuses only those joint channel estimation specification enhancements defined to support repetition Type A.
    - FFS: additional specification enhancements on top of that defined to support repetition Type A
    - Only for single layer transmissions
    - Subject to UE capability
  + FFS: Over non-back-to-back PUSCH transmissions with different TBs
  + FFS: Over non-back-to-back PUSCH transmissions for TBoMS
  + For the non-back-to-back PUSCH transmissions, it is defined as at least when there is no UL transmission between the two successive PUSCH transmissions
  + Subject to UE capability with details FFS (e.g., separate vs. joint capability for type A & type B, w.r.t. OFF power requirements, etc.)
* FFS: Joint channel estimation over non-back-to-back PUSCH transmissions with other uplink transmissions between the two successive PUSCH transmissions across consecutive slot.

Agreement:

* Joint channel estimation for PUSCH transmissions is enabled or disabled via RRC configuration for a UE
  + FFS: whether additional dynamic signaling is needed to enable/disable joint channel estimation for PUSCH transmissions
  + Note: the enabling of such a feature is subject to certain prerequisites
  + FFS RRC parameter details (including explicit vs. implicit configuration)
* FFS For joint channel estimation for PUSCH, the time domain window is not explicitly enabled or disabled separately from joint channel estimation.

Note: Enabling/disabling of joint channel estimation for PUSCH transmissions means enabling/disabling of DMRS bundling for PUSCH transmissions under the condition of power consistency and phase continuity.

Agreement:

For joint channel estimation for PUSCH repetition type A of PUSCH repetitions of the same TB, down select one of the following alternatives for the time domain window.

* Alt 1: All the repetitions are covered by one single time domain window
  + The start of the window is the first PUSCH transmission
  + FFS: how to handle non-consecutive physical slots for UL transmission, e.g., due to DL/UL configuration for unpaired spectrum
  + FFS: frequency hopping and precoder cycling
* Alt 2: All the repetitions are covered by one or multiple time domain windows
  + For the start of each window,
    - The start of the first window is the first PUSCH transmission.
    - FFS: how to determine the start of other windows, e.g., whether multiple windows are consecutive or non-consecutive, whether the start of the window depends on DL/UL configuration for unpaired spectrum
  + For the length of each window,
    - FFS Each window consists of at least two adjacent physical slots for UL transmission.
    - The length of each window is no longer than the maximum duration.
    - FFS: how to determine the length of each window
    - FFS: whether the length of each window depends on DL/UL configuration for unpaired spectrum
  + FFS: how to handle non-consecutive physical slots for UL transmission, e.g., due to DL/UL configuration for unpaired spectrum.
  + FFS: frequency hopping and precoder cycling
* Other alternatives are not precluded.

1. Agreements at RAN1#104b-e

Agreements:

* For joint channel estimation, specify a time domain window during which a UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.
  + FFS how the time domain window is determined (e.g., via explicit configuration and/or implicitly derived) and whether or not to have the possibility of enabling/disabling the time domain window
  + FFS the units the time domain window (e.g. repetitions, slots, and/or symbols)
    - FFS : association between the potential use case(s) and units of the time window
  + FFS: single or multiple time domain windows
* FFS: relation with UE capability
* FFS: whether the term "time domain window" is used in the specification or replaced by other technical terms
* FFS whether or not to further consider impacting of timing advance

**Agreements:**

* A new DMRS pattern equally spaced among PUSCH transmissions is not considered for joint channel estimation in Rel-17.

**Agreements:**

* For inter-slot frequency hopping with inter-slot bundling, down select on the following two options:
  + Option 1: The bundle size (time domain hopping interval) equals to the time domain window size.
  + Option 2: The bundle size (time domain hopping interval) can be different from the time domain window size.
    - FFS: Whether the bundle size (time domain hopping interval) is explicitly configured or implicitly determined.
    - FFS: Whether/How the bundle size (time domain hopping interval) is defined separately for FDD and TDD.
    - FFS: relation between the bundle size (time domain hopping interval) and the time domain window size

**Conclusion:**

* For optimization of DMRS granularity in time domain with joint channel estimation, the proponents are encouraged to provide more simulation results in next meeting

**Agreements:**

* For the time domain window for joint channel estimation, down select on the following two options:
  + Option 1: The unit of the time domain window is defined separately for the following PUSCH transmissions:
    - PUSCH repetition type A
    - PUSCH repetition type B, if agreed
    - TBoMS, if agreed
    - Different TB, if agreed
  + Option 2: The unit of the time domain window is the same for the following PUSCH transmission:
    - PUSCH repetition type A
    - PUSCH repetition type B, if agreed
    - TBoMS, if agreed
    - Different TB, if agreed

**Agreement:**

* For back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following cases:
  + Over back-to-back PUSCH transmissions (of the same TB) for repetition type B scheduled by dynamic grant or configured grant, if it reuses only those joint channel estimation specification enhancements defined to support repetition Type A.
    - FFS: additional specification enhancements on top of that defined to support repetition Type A
    - Only for single layer transmissions
    - Subject to UE capability
  + FFS: Over back-to-back PUSCH transmissions with different TBs

1. Agreements at RAN1#104e

**Agreements**:

* Following potential use cases are considered for joint channel estimation for PUSCH:
  + Use case 1: back-to-back PUSCH transmissions within one slot.
  + Use case 2: non-back-to-back PUSCH transmissions within one slot.
  + Use case 3: back-to-back PUSCH transmissions across consecutive slots.
  + Use case 4: non-back-to-back PUSCH transmissions across consecutive slots.
  + Use case 5: PUSCH transmissions across non-consecutive slots.

Note: RAN1 assumes “back-to-back PUSCH transmission” has zero gap in-between adjacent PUSCH transmissions.

Agreements:

* For back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation at least for the following case:
  + Over back-to-back PUSCH transmissions (of the same TB) for repetition type A scheduled by dynamic grant or configured grant
  + FFS details (including possible other cases)

Agreements:

* For joint channel estimation, ~~define~~ a time domain window is introduced to facilitate further discussion, during which UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.
  + FFS: whether the window should be specified
  + FFS: the length of the time domain window is defined by a set of repetitions/slots/symbols
  + FFS: single or multiple time domain windows
* FFS: relation with UE capability
* FFS: the time domain window may or may not be configured ~~or specified~~.
* FFS: whether the term "time domain window" is used in the specification or replaced by other technical terms
* FFS: Whether the window is determined by the power consistency and phase continuity requirements and/or by other factors is to be decided.

Agreements:

* Companies are encouraged to study optimization of DMRS granularity in time domain with joint channel estimation, including:
  + Use cases
  + Simulations results
  + Enhanced schemes, e.g.,
    - Different DMRS density for different PUSCH transmissions
    - No DMRS for some PUSCH transmissions
  + If applicable, impact of dynamic changes, e.g., cancellation of a repetition and companies report the evaluation method.
* Companies are encouraged to study optimization of DMRS location in time domain with joint channel estimation, including:
  + Use cases
  + Simulations results
  + Enhanced schemes, e.g.,
    - DMRS equally spaced among PUSCH transmissions
    - DMRS located in special slots
    - Orphan symbol上 used for DMRS
  + If applicable, impact of dynamic changes, e.g., cancellation of a repetition and companies report the evaluation method.
* Note: the simulation assumptions for DM-RS in TR 38.830 are used as baseline for performance evaluation on optimization of DMRS location/granularity in time domain.
  + Take into account impairments such as frequency offset, and report corresponding parametrization together with the results. Further discuss impairment details.

**Working assumption:**

* For back-to-back PUSCH transmissions across consecutive slots, support necessary design aspects (under the condition of power consistency and phase continuity) to enable joint channel estimation for the following case:
  + Over back-to-back PUSCH transmissions for ~~TB processing~~ one TB processed over multiple slots
    - It’s subject to UE capability

Agreements:

* For joint channel estimation.
  + Take into account the residual frequency error, e.g., +/- 0.1 ppm as upper bound.
  + Companies can report other values and frequency error model.

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4. 3GPP R1-2009784, “LS on PUCCH and PUSCH repetition”, Qualcomm, RAN1#103-e, October 26th – November 13th, 2020.
5. 3GPP R4-2103393, “Reply on LS on PUCCH and PUSCH repetition”, Qualcomm, RAN4#98-e, January 25th – February 5th, 2021.
6. 3GPP R4-2105417, “Reply LS on PUCCH and PUSCH repetition”, Qualcomm, RAN4#98b-e, April 12th – 20th April, 2021.
7. 3GPP R1-2104119, “Reply LS on PUCCH and PUSCH repetition”, Qualcomm, RAN1#104bis-e, April 12th – April 20th, 2021.
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9. 3GPP R4-2107880, “Reply LS on PUCCH and PUSCH repetition”, Qualcomm, RAN4#99-e, May 2021.
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11. 3GPP R1-2108458, “Reply LS on PUCCH and PUSCH repetition”, Qualcomm, RAN1#106-e, August 16th – 27th, 2021.
12. 3GPP R1-2110642, “Reply LS on PUCCH and PUSCH repetition”, Qualcomm, RAN1#106b-e, October 11th – 19th, 2021.
13. 3GPP R1-2110569, “Summary of email discussion on joint channel estimation for PUSCH”, China Telecom (moderator), RAN1#106b-e, October 11th – 19th, 2021.
14. R1-2110791 Discussion on joint channel estimation for PUSCH Huawei, HiSilicon
15. R1-2110865 Joint channel estimation for PUSCH coverage enhancements Nokia, Nokia Shanghai Bell
16. R1-2110920 Discussion on joint channel estimation for PUSCH ZTE
17. R1-2111029 Remaining issues on joint channel estimation for PUSCH vivo
18. R1-2111108 Discussion on joint channel estimation for PUSCH Spreadtrum Communications
19. R1-2111205 Discussion on joint channel estimation for PUSCH TCL Communication Ltd.
20. R1-2111273 Discussion on joint channel estimation for PUSCH CATT
21. R1-2111330 Consideration on Joint channel estimation for PUSCH OPPO
22. R1-2111425 Discussion on joint channel estimation for PUSCH Panasonic Corporation
23. R1-2111428 Remaining issues on joint channel estimation for PUSCH China Telecom
24. R1-2111429 FL Summary of joint channel estimation for PUSCH Moderator (China Telecom)
25. R1-2111509 Discussion on joint channel estimation for PUSCH Intel Corporation
26. R1-2111586 Discussion on joint channel estimation for PUSCH Xiaomi
27. R1-2111622 Discussion on joint channel estimation for PUSCH CMCC
28. R1-2111681 On events for Joint Channel Estimation for PUSCH Sony
29. R1-2111753 Joint channel estimation for PUSCH Samsung
30. R1-2111794 Joint channel estimation for PUSCH InterDigital, Inc.
31. R1-2111841 Design Considerations for Joint channel estimation for PUSCH Sierra Wireless. S.A.
32. R1-2111889 Discussion on joint channel estimation for PUSCH Apple
33. R1-2111950 Enhancements for joint channel estimation for multiple PUSCH Lenovo, Motorola Mobility
34. R1-2111980 Discussions on joint channel estimation for PUSCH LG Electronics
35. R1-2112021 Joint channel estimation for multiple PUSCH transmission Sharp
36. R1-2112037 Remaining Issues for Joint Channel Estimation for PUSCH Ericsson
37. R1-2112121 Joint channel estimation for PUSCH NTT DOCOMO, INC.
38. R1-2112232 Joint channel estimation for PUSCH Qualcomm Incorporated
39. R1-2112317 Discussion on Joint channel estimation over multi-slot MediaTek Inc.
40. R1-2112391 Discussion on joint channel estimation for PUSCH WILUS Inc.