**3GPP TSG RAN WG1 Meeting #104-e R1-21xxxxx**

**E-Meeting, January 25th – February 5th, 2021**

**Agenda Item: 8.8.1.3**

**Source: Moderator (China Telecom)**

**Title: [104-e-NR-CovEnh-03] Email discussion on 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]. 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]*
* *Specify mechanism(s) to support Type A PUSCH repetitions for Msg3 [RAN1]*

This contribution is a summary of the following email discussion:

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

* 1st check point: Jan 28
* 2nd check point: Feb 2
* 3rd check point: Feb 4

1. Summary of contributions

## 2.1 Conditions to keep power consistency and phase continuity

Based on WID, RAN4 will investigate the conditions to keep power consistency and phase continuity to enable joint channel estimation over multiple PUSCH transmissions. Although RAN1 needs to wait for RAN4’s reply, the initial assessment on the conditions are summarized. This information can be used as a reference to discuss other issues.

Some companies (OPPO, vivo, Intel, LG, CMCC, Qualcomm, Sharp) provided some initial assessment on the conditions as follows:

* The followings should be kept among multiple PUSCH transmissions to enable joint channel estimation
  + Same transmission power
  + Same frequency domain resource allocation
  + Same DMRS antenna ports
  + Same codebook
  + Same Tx spatial parameters
  + Same TA
  + No time gap between two adjacent PUSCH transmissions. Or the gap between multiple transmissions should be short enough. No DL portions in two PUSCH transmissions.

Similar issue was discussed for DMRS sharing between sTTIs in LTE. The reply from RAN4 [R4-1704089] is copied below:

*Q1: If there is any RF impacts that would degrade sPUSCH demodulation performance when having shared DMRS symbols in between 2 sTTIs but using different output power levels?*

*A1: To guaranty performance, both sTTIs should have same ouput power when sharing DMRS symbols.*

*Q2: If there is any RF impacts that would degrade sPUSCH demodulation performance when having shared DMRS symbols in between 2 sTTIs but using differentbadnwidth allocations?*

*A2: To guaranty performance, both sTTIs should have the same centre frequency, the same RB allocation and the same system bandwidth when sharing DMRS symbols.*

*Q3: If there is any RF impacts that would degrade sPUSCH demodulation performance when allocating DMRS symbol(s) non-contiguously in time?*

*A3: DMRS symbol could be shared in between 2 non-contiguous (in time) sTTI if the gap is equal to up to 2 sTTIs. There should not be any power change and have the same centre frequency, the same RB allocation and the same system bandwidth in between such non-contiguous sTTIs. When such non-contiguous sTTI would be scheduled, BS should indicate UE to keep its PLL ON to limit power consumption impact.*

Some companies (vivo, LG) mentioned the following cases may have impact on transmission power.

* CA/DC
* pre-coder cycling
* PRACH transmission on the PCell
* PUCCH transmission with HARQ-ACK information and/or SR or PUSCH transmission with HARQ-ACK information
* PUCCH transmission with CSI or PUSCH transmission with CSI
* PUSCH transmission without HARQ-ACK information or CSI
* SRS transmission, with aperiodic SRS having higher priority than semi-persistent and/or periodic SRS, or PRACH transmission on a serving cell other than the PCell

One company (Ericsson) observes at least in some conditions, a receiver can correct for a wideband phase error between repetitions of an uplink channel in different slots, such that the performance is relatively close to where the ideal relative phase is known. The use of wideband relative phase estimation to facilitate cross-slot channel estimation seems promising at least when the UE can’t adequately maintain relative phase between slots.

## 2.2 Use cases for joint channel estimation

Many contributions mentioned the use cases for joint channel estimation. There are five main use cases summarized based on companies’ contributions.

* Use case 1: back-to-back PUSCH transmissions within one slot.
* Use case 2: non-back-to-back PUSCH transmissions within one slot with the maximum gap of x-symbols between two adjacent 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 with the maximum gap of y-symbols between two adjacent PUSCH transmissions.
* Use case 5: PUSCH transmissions across non-consecutive slots with the maximum gap of z-slots between two adjacent PUSCH transmissions.

In addition, some companies mentioned number of TBs, repetition type, type of grant. The details for each use case are summarized as follows. Some companies also mentioned TB processing over multi-slot PUSCH.

* Use case 1: back-to-back PUSCH transmissions within one slot.
  + Repetition type B for one TB
    - Scheduled by dynamic grant
    - Scheduled by configured grant
  + Different TBs for PUSCH transmissions
    - Scheduled by dynamic grants
    - Scheduled by configured grants
    - Scheduled by both dynamic grants and configured grants
* Use case 2: non-back-to-back PUSCH transmissions within one slot with the maximum gap of x symbols between two adjacent PUSCH transmissions.
  + Repetition type B for one TB
    - Scheduled by dynamic grant
    - Scheduled by configured grant
  + Different TBs for PUSCH transmissions
    - Scheduled by dynamic grants
    - Scheduled by configured grants
    - Scheduled by both dynamic grants and configured grants
* Use case 3: back-to-back PUSCH transmissions across consecutive slots.
  + Repetition type A for one TB
    - Scheduled by dynamic grant
    - Scheduled by configured grant
  + Repetition type B for one TB
    - Scheduled by dynamic grant
    - Scheduled by configured grant
  + Different TBs for PUSCH transmissions
    - Scheduled by dynamic grants
    - Scheduled by configured grants
    - Scheduled by both dynamic grants and configured grants
  + One TB over multi-slots
* Use case 4: non-back-to-back PUSCH transmissions across consecutive slots with the maximum gap of y symbols between two adjacent PUSCH transmissions.
  + Repetition type A for one TB
    - Scheduled by dynamic grant
    - Scheduled by configured grant
  + Repetition type B for one TB
    - Scheduled by dynamic grant
    - Scheduled by configured grant
  + Different TBs for PUSCH transmissions
    - Scheduled by dynamic grants
    - Scheduled by configured grants
    - Scheduled by both dynamic grants and configured grants
  + One TB over multi-slots
* Use case 5: PUSCH transmissions across non-consecutive slots with the maximum gap of z-slots between two adjacent PUSCH transmissions.

## 2.3 Time-domain window for joint channel estimation

Many contributions mentioned a time window for joint channel estimation should be determined during which UE is required to maintain power consistency and phase continuity among PUSCH transmissions.

* Size of time domain window
  + Repetition type A
    - Equal to the number of repetitions
    - Smaller than the number of repetitions
  + Repetition type B
    - Equal to the number of nominal/actual repetitions
    - Smaller than the number of nominal/actual repetitions
  + Different TBs for PUSCH transmissions
  + One TB over multi-slots
    - Equal to the number of slots
    - Smaller than the number of slots
* Signaling for time domain window
  + Implicit signaling
    - E.g., derived from number of repetition
    - Samsung
  + Explicit signaling
    - Cell specific or UE specific?
    - Option 1: Configurable by gNB
      * Semi-static: InterDigital, Samsung, Nokia, NSB
      * Dynamic: Potevio
      * DOCOMO
    - Option 2: Reported by UE
      * Sierra Wireless
    - Option 3: Configurable by gNB based on UE capability reporting
      * Support: vivo

One company (Intel) mentioned there can be two types of time domain window for joint channel estimation:

* Sliding window
* Fixed window

One company (InterDigital) proposed a grant-type dependent index which indicates PUSCH(s) to bundle.

One company (Qualcomm) proposed UE signals a bundling indication in the PUSCH transmission. The indication can indicate whether the PUSCH transmission is coherent with respect to the previous PUSCH transmission or whether the PUSCH transmission is coherent with respect to the next PUSCH transmission

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

Based on WID, inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation is to be specified. 20 companies (ZTE, OPPO, Huawei, HiSilicon, CATT, vivo, Potevio, Intel, LG, China Telecom, Lenovo, Motorola Mobility, CMCC, Samsung, Apple, Qualcomm, Sharp, WILUS, Nokia, NSB) support it, while one company (Sierra Wireless) proposed to wait for RAN4’s response on phase continuity before agreeing to specify inter-slot bundling for frequency hopping as it may not be needed.

Based on WID and the majority view, FL thinks there is no need to further discuss whether inter-slot frequency hopping with inter-slot bundling should be specified.

If a time domain window is defined, there can be three options for the size of time domain hopping interval:

* Option 1: Smaller than the size of time domain window
  + LG
* Option 2: Equal to the size of time domain window
  + CATT, LG, Lenovo, Motorola Mobility, Panasonic, Sharp
* Signaling for time domain hopping interval
  + Cell specific or UE specific?
  + Implicit signaling
    - E.g., derived from number of repetition, time domain window, available resources
    - Support: ZTE, CATT, vivo, Intel, Samsung
  + Explicit signaling
    - Semi-static: ZTE, Intel, LG, Samsung, WILUS
    - Dynamic: ZTE, Potevio, WILUS

One company (Potevio) mentioned inter-nominal repetition frequency hopping with inter-nominal repetition bundling.

## 2.5 Optimization of DMRS location/granularity in time domain

12 companies (OPPO, Huawei, HiSilicon, InterDigital, China Telecom, Lenovo, Motorola Mobility, CMCC, Samsung, DOCOMO, Nokia, NSB) support optimization of DMRS location in time domain

9 companies (ZTE, OPPO, Huawei, HiSilicon, CATT, vivo, China Telecom, CMCC, Samsung) support optimization of DMRS granularity in time domain.

* Use cases for optimization of DMRS location in time domain
  + Repetition type A
  + Repetition type B
  + Different TBs for PUSCH transmission
  + One TB over multi-slots
* Location for DMRS
  + DMRS equally spaced among PUSCH transmissions
    - OPPO, Lenovo, Motorola Mobility, DOCOMO, Nokia, NSB
  + Located in special slots
    - Huawei, HiSilicon, InterDigital, China Telecom, CMCC, DOCOMO
  + DMRS for orphan symbol
    - Samsung
* Use cases for optimization of DMRS granularity in time domain
  + Repetition type A
    - Support: ZTE
  + Repetition type B
    - Samsung
  + Different TBs for PUSCH transmission
  + One TB over multi-slots
* Granularity for DMRS:
  + Different DMRS density for different PUSCH transmissions
    - OPPO, Huawei, HiSilicon, CATT, vivo, China Telecom
  + No DMRS for some PUSCH transmissions
    - OPPO, Huawei, HiSilicon, Samsung

## 2.6 Signaling to trigger joint channel estimation

Some companies (Nokia, NSB) mentioned signalling to trigger joint channel estimation.

* Option 1: separate signalling to enable or disable joint channel estimation.
* Option 2: joint signalling with other parameters, e.g., time domain window, to enable or disable joint channel estimation.

This issue can be discussed later.

## 2.7 Others

Special slot for TDD

* PUSCH transmission in special slots for repetition type A
  + China Telecom, CMCC

Orphan symbol

* PUSCH transmission for orphan symbol
  + Samsung

1. Email discussion (1st round)

## 3.1 Use cases for joint channel estimation

* Use case 1: back-to-back PUSCH transmissions within one slot.
* Use case 2: non-back-to-back PUSCH transmissions within one slot with the maximum gap of x-symbols between two adjacent 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 with the maximum gap of y-symbols between two adjacent PUSCH transmissions.
* Use case 5: PUSCH transmissions across non-consecutive slots with the maximum gap of z-slots between two adjacent PUSCH transmissions.

Companies are encouraged to provide views on the categorization of the above use cases.

**Note that whether joint channel estimation can be applicable is a separate issue.**

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | All the Use cases 1/2/3/4/5 can be used for joint channel estimation, especially case 1/3. |
| Sharp | All use cases can be supported unless no DL reception is configured between two PUSCHs. Some other restrictions (e.g., same power, same precoder, same FDRA, etc.) can be also discussed. |
| Apple | We consider the use case 1/3 are feasible, use case 2/4/5 is up to RAN4’s feedback. |
| ZTE | Though whether joint channel estimation can be applicable is a separate issue, it is still be better to further discuss this after receiving RAN4 reply. If the conditions defined in RAN4 only allows some use cases, e.g., back-to-back cases, then it would waste RAN1 time to discuss other use cases in this meeting. |
| CATT | At least use case 1/3 can apply joint channel estimation. Other use cases should wait for RAN4’s feedback. |
| Samsung | In general, we are fine with all cases. However, it is questionable on the needs to distinguish the cases of within one slot and consecutive slots. Also, the maximum gap of x/y/z-symbols can be more discussed and RAN4 input would be required to determine the phase continuity. |
| Panasonic | The categorization of the above use cases is fine. |
| InterDigital | Use case 1,2,3,4,5 can be considered. Case 3 and 4 can be described by PUSCH transmissions in consecutive slots by setting y=0 or y>0, respectively. Similarly, case 1 and 2 can be described by PUSCH transmission in one slot by setting x=0 or x>0, respectively. |
| Intel | At least case1 and 3 can be considered as a starting point for study. It would be good that we can check RAN4 input first. |
| vivo | In our view, use case 1 and use case 3 can be feasible for joint channel estimation. Other use cases can be discussed after RAN4 feedback. |
| Nokia/NSB | If the requirements for joint channel estimation are satisfied for the above use cases, then all of the above use cases can be supported. At this stage, we need inputs from RAN4 on the requirements for joint channel estimation before further discuss on use cases. |
| CMCC | At least the use case 1 and 3 could be feasible for joint channel estimation. Others could be discussed after RAN4’s feedback. But use case 1 may not be the typical scenario requiring the coverage enhancement. Use case 3 could be prioritized if necessary. |
| Lenovo, Motorola Mobility | Use case 1 and 3 should be supported for joint channel estimation. For other use cases, we can discuss further depending up on RAN 4 input |
| Qualcomm | Support only use case 3. Use case 1 is not relevant for a cell-edge UE --- a cell edge UE is likely to use all 14 symbols for PUSCH transmission. Remaining use cases appear to be infeasible. |
| Sierra Wireless | Use case 1,2,3,4,5 can be considered now. RAN4 will come back with set of possible values for X, Y, Z. |
| Ericsson | Some of the use cases assume a maximum gap size. It is not immediately clear to us that there is a maximum gap that needs to be specified. So we might just say ‘gap’ rather than ‘maximum gap’ for now, since that allows non-contiguous bundling, but does not presume a maximum needs to be specified.  Use cases 1 and 2 do not seem like coverage limited cases, since the whole slot is not used. So it is not clear to us that they are in scope.  Use case 3 and 4: These back-to-back use cases seems quite relevant, especially for FDD.  Use case 5: Seems important to consider for TDD. |
| Huawei, HiSilicon | All above use cases are supported for joint channel estimation if no DL switching between 2 consecutive PUSCH transmissions. |
| Xiaomi | All the use cases can be considered. Especially, use case 1 and 3 can be considered with high priority. |
| LG | All 5 use cases can be used for joint channel estimation. |

**FL’s comments:**

**The intention of discussion on the categorization of the above use cases is to identify the potential use cases for joint channel estimation. This can facilitate the discussion on other issues. It does not actually mean whether or not joint channel estimation can be applicable to each use case, which depends on RAN4 decision. From FL perspective, RAN4 does not have all the potential use cases in mind. LS in R1-2009784 only mentioned back-to-back transmission and PUSCH repetition. FL thinks it’s necessary to send another LS on PUSCH to RAN4. Thus, FL would like to propose the following proposal.**

**Proposal:**

* 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 with the maximum gap of x-symbols between two adjacent 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 with the maximum gap of y-symbols between two adjacent PUSCH transmissions.
  + Use case 5: PUSCH transmissions across non-consecutive slots with the maximum gap of z-slots between two adjacent PUSCH transmissions.
* Send LS to RAN4, asking following questions:
  + Whether joint channel estimation can be applicable to the above uses cases?
  + Under what conditions UE can maintain power consistency and phase continuity for gNB to implement joint channel estimation for each use case?

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| LG Electronics | We are fine with FL’s comment and proposals. |
| Nokia/NSB | We are fine with the FL’s proposals in principle. However, it is too early at this stage to assume that there is a maximum gap between PUSCHs in the Use case 2 and Use case 4. The maximum gap, if any, can be studied and identified by RAN4. Therefore, we can ask this question to RAN4 instead of defining the directly there is a gap in the corresponding use cases. |
| InterDigital | We support the idea of sending the LS. It may be good to wait for the reply from RAN4 to send another LS so that we can reflect inputs from the RAN4 reply in the new RAN1 LS. |
| Lenovo, Motorola Mobility | We agree with FL’s views and proposal |
| Samsung | According to current RAN4 discussion, back-to-back PUSCH transmission may include non-zero gap in-between PUSCH transmissions (RAN4 is still discussing).   1. If RAN1 is clear enough that back-to-back PUSCH transmission means ‘zero gap’ in-between, let’s first agree to that term. If it include ‘non-zero gap’, we don’t need ‘non-back-to-back’ PUSCH transmissions. We think this is the pre-requisite for the remaining part of our discussion. 2. Rather than sending another LS, we suggest to wait for RAN4 response on previous RAN1 questions. |

**Although RAN1 needs to wait for RAN4’s reply regarding whether joint channel estimation can be applicable to the above use cases. It seems joint channel estimation can be applicable to use case 1 and use case 3 with high probability. We can start the discussion on use case 1/3, while hold on the discussion on use case 2/4/5.**

* Use case 1: back-to-back PUSCH transmissions within one slot.
  + Repetition type B for one TB
    - Scheduled by dynamic grant
    - Scheduled by configured grant
  + Different TBs for PUSCH transmissions
    - Scheduled by dynamic grants
    - Scheduled by configured grants
    - Scheduled by both dynamic grants and configured grants

Companies are encouraged to answer the following questions for use case 1.

* Q1: Whether joint channel estimation can be applicable to repetition type B for use case 1? If joint channel estimation is applied, whether PUSCH repetition type B can be scheduled by dynamic grant or configured grant?
* Q2: Whether joint channel estimation can be applicable to different TBs for PUSCH transmissions for use case 1? If joint channel estimation is applied, whether different TBs for PUSCH transmissions can be scheduled by dynamic grant or configured grant?

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | Q1: Joint channel estimation can be applicable to repetition type B for use case 1. PUSCH repetition type B can be scheduled by dynamic grant or configured grant.  FFS the mixed grant case.  Q2: Joint channel estimation shall NOT be applicable to different TBs for PUSCH transmissions for use case 1 since the frequency domain resource allocation, the modulation order, the code rate for different TBs may be different, which will result in different PUSCH transmission power and make it impossible for joint channel estimation. |
| Sharp | Q1: Joint channel estimation can be applicable to repetition type B for use case 1. Dynamic and configured grant can be supported.  Q2: Joint channel estimation can be applicable to different TBs for PUSCH transmissions for use case 1. Dynamic and configured grant can be supported. Network can schedule two PUSCHs with the same power and the same FDRA. If coding rate is different, then the network can disable the delta MCS. |
| NTT DOCOMO | Q1. Joint channel estimation can be applicable to repetition type B. PUSCH repetition type B can be scheduled by either dynamic grant or configured grant. We could not find the reason to confine the scheduling ways when joint channel estimation is applied. |
| Apple | Q1: joint channel estimation could apply to PUSCH repetition type B with dynamic grant or configured grant.  Q2: joint channel estimation should only apply to same TB. If applying to different TB, it will cause lots of restrictions on the two TB scheduling, which make it impossible actually. |
| ZTE | Overall the discussion is contingent on RAN4 decision.  Q1: Agree with use case 1 for PUSCH repetition type B scheduled by CG or DG.  Q2: Agree with use case 2 for PUSCH repetition type B scheduled at least by CG or DG. For the last bullet, if the intention is one TB is scheduled by DG and another is by CG, we would be fine to consider this case as well as long as it can satisfy RAN4 conditions and has limited additional spec impacts compared use case 1. |
| CATT | Q1: Joint channel estimation can be applied to PUSCH repetition type B, no matter with dynamic grant or configured grant.  Q2: Theoretically, joint channel estimation can be applied to different TBs for PUSCH transmissions. Whether the power/phase/spatial/FDRA/gap satisfies the requirement(s) is another story, though it may be hard in practice. |
| Samsung | We are fine with repetition type B for one TB. However, different TBs for PUSCH transmissions would be challenging to maintain power consistency and phase continuity. |
| Panasonic | Q1: Joint channel estimation can be applicable to PUSCH repetition Type B for use case 1. Both DG PUSCH and CG PUSCH can be considered.  Q2: We think it is not required to consider joint channel estimation to different TBs for PUSCH transmissions because it would cause the limitation/scheduling restriction in order to keep phase continuity, such as same frequency resource allocation. |
| InterDigital | Q1 : Yes, type B repetition with configured or dynamic grant can be supported.  Q2 : Yes, different TB scheduled by configured or dynamic grant should be supported as long as conditions (e.g., same modulation order, same frequency domain resource allocation) for enabling joint channel estimation (e.g., phase/power continuity) are met. |
| Intel | Q1: it can be applied for PUSCH repetition type B.  Q2: it is not clear to us whether we need to consider multi-PUSCH scheduling. The main target is to improve the coverage, where repetition is needed. Our view is that multi-TB PUSCH is out of scope for joint channel estimation. |
| WILUS | Q1: It can be supported for PUSCH repetition Type B scheduled by either dynamic grant or configured grant. |
| vivo | For Q1, joint channel estimation can be applicable to repetition type B for use case 1. If PUSCH repetition type B is scheduled by either dynamic grant or configured grant separately, joint channel estimation can be applied.  For Q2, the transmission power of PUSCH is depended on TB size of PUSCH in current power control mechanism. If DMRS bundling also applies to PUSCH of different TBs, transmission power for each PUSCH transmission can not be adjusted accordingly, and it is not clear whether the coverage would be improved without proper transmission power control. Besides, the FDRA for different TBs may be different, the feasibility for DMRS bundling on PUSCHs with different FDRA is doubtful. |
| Nokia/NSB | Q1: Joint channel estimation can be applied for repetition type B for use case 1, for both DG and CG, as long as the requirements are satisfied.  Q2: Joint channel estimation can be applied for PUSCH transmissions with different TBs for use case 1. We share the same view with CATT that the requirements for joint channel estimation can be discussed separately. Therefore, if the gNB schedules two PUSCHs with different TBs and both PUSCHs satisfy the requirements, then joint channel estimation can be applied. This does not introduce additional scheduling restrictions as discussed by some companies because the gNB can freely schedule PUSCHs that do not satisfy the requirements then joint channel estimation is not expected in that case, but in case the gNB schedules PUSCHs with different TBs and same FDRA/transmit power then there is no reason why the UE does not guarantee phase continuity for joint channel estimation. |
| CMCC | Q1: Though joint channel estimation could benefit the repetition type B, the repetition type B is not the typical use scenario compared with full slot transmission/repetitions. And also the configured grant transmission should be deprioritized compared with dynamic grant.  Q2: joint channel estimation could be used between different TBs for PUSCH transmission, if the conditions are fulfilled, such as same precoding, power consistency, same frequency resource allocation and etc.  Joint channel estimation over CG and DG transmission is too complicated for the specification design and also could be a low probability use case. |
| Lenovo, Motorola Mobility | Q1: Yes, join channel estimation can be applied to PUSCH repetition type B for use case 1 (for both dynamic and configured grant)  Q2: Joint channel estimation could be applied to different TBs for PUSCH (for both dynamic and configured grant) |
| Qualcomm | * A1: We dont think use case 1 is relevant for a cell-edge UE. Further, Type B repetitions are only relevant in a URLLC context. We therefore don’t think it is necessary to extend support to type B repetitions. * A2: We dont think use case 1 is relevant for a cell-edge UE --- if coverage is limited, the gNB should first consider merging the two TB transmissions into a single transmission. No need to discuss further. |
| Sierra Wireless | Q1: Yes, joint channel estimation for Type B repetition is applicable for both dynamic and configured grant PUSCH transmissions although the degree of coverage improvement for JCE for type B is unclear.  Q2: Apply JCE across separately schedule TB is an unnecessary enhancement. This could only be done if the same frequency resources are used for both TB which is a corner case or puts a lot of scheduling constraints on gNB. |
| Ericsson | While it is not clear to us that use case 1 is applicable to coverage scenarios, if it is considered, repetition type B seems more likely to be supportable than different TBs. Different TBs may be more difficult to bundle, if they have to be at the same power, or in the same PRBs, etc. So we prefer to first discuss whether use case 1 is applicable, and if so to leave different TBs FFS for now. |
| Huawei, HiSilicon | Q1: Joint channel estimation can be applied for repetition type B for use case 1, for both DG and CG, as long as the RAN4 requirements are satisfied.  Q2: Joint channel estimation can be applied for different TB, as long as the RAN4 requirements are satisfied. There is no need of restricting joint channel estimation only for same TB. |
| Xiaomi | Q1: Joint channel estimation can be applicable to PUSCH repetition Type B for use case 1. And the repetition can be scheduled by dynamic grant or configured grant.  Q2: Given that it will cause so much scheduling restriction, it is better not do such joint channel estimation between different TBs. |
| LG | Q1: In technical perspective, channel estimation can be applied to repetition type B for use case 1. However, we don’t think coverage enhancement of repetition type B is in the work scope.  Q2: Since the same uplink Tx power, uplink transmission timing, PRB allocation, uplink Tx precoder, and UL spatial filter, etc are not guaranteed for different TBs for PUCH transmissions, joint channel estimation is not applicable in this case. |

**FL’s comments:**

**It seems the majority support joint channel estimation over back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant. While for different TBs, there are different understandings, further discussion is needed. Thus, FL would like to propose the following proposal.**

**Proposal:**

* For back-to-back PUSCH transmissions within one slot, if power consistency and phase continuity can be maintained.
  + Joint channel estimation over back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant is supported.
  + FFS: whether joint channel estimation over back-to-back PUSCH transmissions with different TBs can be supported.

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| LG Electronics | We should clarify whether PUSCH transmissions for repetition type B is a scope of CE WI. |
| Nokia/NSB | We are fine with the FL’s proposal. |
| InterDigital | We support the FL’s proposal. In WID, it is stated as follows “Mechanism(s) to enable joint channel estimation over multiple PUSCH transmissions…”. Thus joint channel estimation should be applicable to type B repetitions if phase/power continuity conditions are met. We are ok to discuss the different TB scenario. |
| Lenovo, Motorola Mobility | We support the proposal |

* Use case 3: back-to-back PUSCH transmissions across consecutive slots.
  + Repetition type A for one TB
    - Scheduled by dynamic grant
    - Scheduled by configured grant
  + Repetition type B for one TB
    - Scheduled by dynamic grant
    - Scheduled by configured grant
  + Different TBs for PUSCH transmissions
    - Scheduled by dynamic grants
    - Scheduled by configured grants
    - Scheduled by both dynamic grants and configured grants
  + One TB over multi-slots

Companies are encouraged to answer the following questions for use case 3.

* Q1: Whether joint channel estimation can be applicable to repetition type A for use case 3? If joint channel estimation is applied, whether PUSCH repetition type A can be scheduled by dynamic grant or configured grant?
* Q2: Whether joint channel estimation can be applicable to repetition type B for use case 3? If joint channel estimation is applied, whether PUSCH repetition type B can be scheduled by dynamic grant or configured grant?
* Q3: Whether joint channel estimation can be applicable to different TBs for PUSCH transmissions for use case 1? If joint channel estimation is applied, whether different TBs for PUSCH transmissions can be scheduled by dynamic grant or configured grant?
* Q4: Whether joint channel estimation can be applicable to one TB over multi-slots for use case 3?

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | Q1: Joint channel estimation can be applicable to repetition type A for use case 3. PUSCH repetition type A can be scheduled by dynamic grant or configured grant.  FFS for the mixed grant case.  Q2: Joint channel estimation can be applicable to repetition type B for use case 3. PUSCH repetition type A can be scheduled by dynamic grant or configured grant.  FFS for the mixed grant case.  Q3: Joint channel estimation shall NOT be applicable to different TBs for PUSCH transmissions for use case 1 since the frequency domain resource allocation, the modulation order, the code rate for different TBs may be different, which will result in different PUSCH transmission power and make it impossible for joint channel estimation.  Q4: Yes. |
| Sharp | Q1: Joint channel estimation can be applicable to repetition type A for use case 3. Dynamic and configured grant can be supported.  Q2: Joint channel estimation can be applicable to repetition type B for use case 3. Dynamic and configured grant can be supported.  Q3: Joint channel estimation can be applicable to different TBs for PUSCH transmissions for use case 3. Dynamic and configured grant can be supported. Network can schedule two PUSCHs with the same power and the same FDRA. If coding rate is different, then the network can disable the delta MCS.  Q4: Joint channel estimation can be applicable to one TB over multi-slots for use case 3. |
| Apple | Q1: joint channel estimation could apply to PUSCH repetition type A with dynamic grant or configured grant.  Q2: joint channel estimation could apply to PUSCH repetition type B with dynamic grant or configured grant.  Q3: No, joint channel estimation should only apply to same TB.  Q4: Yes, joint channel estimation can be applicable to one TB over multi-slots . |
| ZTE | As commented above, we are fine with all above cases as long as it can satisfy RAN4 conditions and has limited additional spec impacts compared use case 1. |
| CATT | Q1: Joint channel estimation can be applied to PUSCH repetition type A, no matter with dynamic grant or configured grant.  Q2: Joint channel estimation can be applied to PUSCH repetition type B, no matter with dynamic grant or configured grant.  Q3: Theoretically, joint channel estimation can be applied to different TBs for PUSCH transmissions. Whether the power/phase/spatial/FDRA/gap satisfies the requirement(s) is another story, though it may be hard in practice.  Q4: Joint channel estimation can be applied to TB over multi-slot PUSCH. |
| Samsung | Joint channel estimation can be applicable to repetition type A/B and one TB over multi-slots but not to different TBs for PUSCH transmissions. |
| Panasonic | Q1: Joint channel estimation can be applicable to PUSCH repetition Type A for use case 3. Both DG PUSCH and CG PUSCH can be considered.  Q2: Joint channel estimation can be applicable to PUSCH repetition Type B for use case 3. Both DG PUSCH and CG PUSCH can be considered.  Q3: We think it is not required to consider joint channel estimation to different TBs for PUSCH transmissions because it would cause the limitation/scheduling restriction in order to keep phase continuity, such as same frequency resource allocation.  Q4: Joint channel estimation can be applicable to one TB over multi-slots for use case 3. |
| InterDigital | Q1 : Yes, joint channel estimation can be applicable to repetition type A for use case 3. PUSCH repetition type A can be scheduled by dynamic or configured grant.  Q2 : Yes, joint channel estimation can be applicable to repetition type A for use case 3. PUSCH repetition type A can be scheduled by dynamic or configured grant.  Q3 : Yes, different TB scheduled by configured or dynamic grant should be supported as long as conditions (e.g., same modulation order, same frequency domain resource allocation) for enabling joint channel estimation (e.g., phase/power continuity) are met.  Q4 : Yes. TB over multi-slots already has inherent transmission side benefits (time diversity) and it can benefit from receiver side enhancements such as joint channel estimation. |
| Intel | Q1: Joint channel estimation could apply to PUSCH repetition type A with dynamic grant or configured grant.  Q2: Joint channel estimation could apply to PUSCH repetition type B with dynamic grant or configured grant.  Q3: No, joint channel estimation only applies to same TB.  Q4: Yes, joint channel estimation can be applicable to one TB processing over multi-slots. |
| WILUS | Q1: It can be supported for PUSCH repetition Type A scheduled by either dynamic grant or configured grant.  Q2: It can be supported for PUSCH repetition Type B scheduled by either dynamic grant or configured grant.  Q4: It can be supported for one TB over multi-slots. |
| vivo | Q1: Yes. If PUSCH repetition type A is scheduled by dynamic grant or configured grant separately, joint channel estimation can be applied.  Q2: Yes. If PUSCH repetition type B is scheduled by dynamic grant or configured grant separately, joint channel estimation can be applied.  Q3: No, refer to our comments for different TBs for case 1.  Q4: Yes. |
| Nokia/NSB | Q1: Joint channel estimation can be applied for repetition type A for use case 3 for both DG and CG.  Q2: Joint channel estimation can be applied for repetition type B for use case 3 for both DG and CG.  Q3: Joint channel estimation can be applied for PUSCH transmission with different TBs for use case 3 for both DG and CG.  Q4: Joint channel estimation can be applied for one TB over multi-slots for use case 3. |
| CMCC | Q1: joint channel estimation could be used for repetition type A for use case 3. Dynamic grant transmission is preferred, since the CG transmission is not a typical use case for the coverage enhancements.  Q2: yes. Dynamic grant transmission should be prioritized.  Q3: yes, if the constraints or conditions of joint channel estimation are fulfilled. Dynamic grant transmission should be prioritized.  Q4: yes. |
| Lenovo, Motorola Mobility | As long as the PUSCH transmission are back-to-back, joint channel estimation can be applied to all scenarios under Q1, Q2, Q3 and Q4 (for both CG and DG PUSCH) |
| Qualcomm | * Q1: Whether joint channel estimation can be applicable to repetition type A for use case 3? If joint channel estimation is applied, whether PUSCH repetition type A can be scheduled by dynamic grant or configured grant? * A1: Yes, joint channel estimation can be applied to repetition A for use case 3. DG and CG can both be considered. * Q2: Whether joint channel estimation can be applicable to repetition type B for use case 3? If joint channel estimation is applied, whether PUSCH repetition type B can be scheduled by dynamic grant or configured grant? * A2: No. No need to extend support to rep. type B as it is unlikely to benefit a coverage-limited UE. * Q3: Whether joint channel estimation can be applicable to different TBs for PUSCH transmissions for use case 1? If joint channel estimation is applied, whether different TBs for PUSCH transmissions can be scheduled by dynamic grant or configured grant? * A3: Yes, we can consider this further. * Q4: Whether joint channel estimation can be applicable to one TB over multi-slots for use case 3? * A4: Yes, this can be considered. |
| Sierra Wireless | Q1: Yes, joint channel estimation for Type A repetition is applicable for both dynamic and configured grant PUSCH transmissions.  Q2: Yes, joint channel estimation for Type B repetition is applicable for both dynamic and configured grant PUSCH transmissions although the degree of coverage improvement for JCE for type B is unclear.  Q3: Apply JCE across separately schedule TB is an unnecessary enhancement. This could only be done if the same frequency resources are used for both TB which is a corner case or puts a lot of scheduling constraints on gNB.  Q4: Yes. JCE must be able to be applied across multi-slots. |
| Ericsson | Different TBs may be more difficult to meet phase continuity requirements for, and it is not so clear that these configurations are found in coverage scenarios, as commented above. The one TB schemes seem more amenable to phase continuity. However, all this needs to be confirmed based on RAN4’s feedback. |
| Huawei, HiSilicon | Q1: Joint channel estimation can be applied for repetition type A for use case 3 for both DG and CG.  Q2: Joint channel estimation can be applied for repetition type B for use case 3 for both DG and CG.  Q3: Joint channel estimation can be applied for PUSCH transmission with different TBs for use case 3 for both DG and CG.  Q4: Joint channel estimation can be applied for one TB over multi-slots for use case 3. |
| Xiaomi | Q1: Joint channel estimation can be applicable to repetition type A for use case 3. Dynamic and configured grant can be supported.  Q2: Joint channel estimation can be applicable to repetition type B for use case 3. Dynamic and configured grant can be supported.  Q3: No  Q4: Yes |
| LG | Q1. Joint channel estimation can be applicable to repetition type A for use case 3, where PUSCH repetitions A is scheduled by dynamic grant or configured grant.  Q2. In technical perspective, channel estimation can be applied to repetition type B. However, we don’t think coverage enhancement of repetition type B is in the work scope.  Q3. Since the same uplink Tx power, uplink transmission timing, PRB allocation, uplink Tx precoder, and UL spatial filter, etc are not guaranteed for different TBs for PUCH transmissions, joint channel estimation is not applicable in this case.  Q4. Yes |

**FL’s comments:**

**It seems the majority support joint channel estimation over back-to-back PUSCH transmissions for repetition type A/B scheduled by dynamic grant or configured grant, and TB processing over multiple slots. While for different TBs, there are different understandings, further discussion is needed. Thus, FL would like to propose the following proposal.**

**Proposal:**

* For back-to-back PUSCH transmissions across consecutive slots, if power consistency and phase continuity can be maintained.
  + Joint channel estimation over back-to-back PUSCH transmissions for repetition type A scheduled by dynamic grant or configured grant is supported.
  + Joint channel estimation over back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant is supported.
  + Joint channel estimation over back-to-back PUSCH transmissions for TB processing over multiple slots is supported.
  + FFS: whether joint channel estimation over back-to-back PUSCH transmissions with different TBs can be supported.

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| LG Electronics | We are fine with FL’s proposal except PUSCH transmissions for repetition type B. |
| Nokia/NSB | We are fine with the FL’s proposal. |
| InterDigital | We support the FL’s proposal. In WID, it is stated as follows “Mechanism(s) to enable joint channel estimation over multiple PUSCH transmissions…”. Thus joint channel estimation should be applicable to type B repetitions if phase/power continuity conditions are met. We are ok to discuss the different TB scenario. |
| Lenovo, Motorola Mobility | Fine with the FL’s proposal |

## 3.2 Time-domain window for joint channel estimation

**Proposal:**

* Define a time domain window during which UE is required to maintain power consistency and phase continuity among PUSCH transmissions.
  + Option 1: a set of repetition
  + Option 2: a set of slots
  + Option 3: a set of symbols

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | Not sure whether such a time domain window is needed to enable joint channel estimation.  At the gNB, the gNB can use a sliding window (e.g., slots 1/2/3/4 or slots 2/3/4/5, or slots 3/4/5/6 etc.) to perform joint channel estimation, therefore it only require the UE to maintain power consistency and phase continuity among PUSCH transmissions in the sliding window, which is easy for the UE implementation. With such sliding window, the gNB can average the channel among all the PUSCHs.  Otherwise, if a time domain window is defined, the gNB can only average the channel among the PUSCHs within every time domain windows and the performance will be inferior to using the sliding window. |
| Sharp | In our understanding, the time domain window is not intended for specifying any gNB behaviour but specifying the UE behaviour for phase continuity management. Option 1 is not applicable to different TBs for PUSCH transmissions. Therefore, Option 2 or 3 is preferred. |
| NTT DOCOMO | We are fine with the proposal. Setting the time window can make sure that the condition for joint channel estimation is met. |
| Apple | Option 2 is preferred. |
| ZTE | We are not sure whether there is a need to define a time window. A UE may be able to keep phase continuity as long as the PUSCH transmissions are consecutive or the gap among PUSCH transmissions is small. Whether/how gNB would perform the joint channel estimation is up to implementation. |
| CATT | Option 2 seems better, since TB processing over multi-slot PUSCH shall also be considered. |
| Samsung | Joint channel estimation procedure can be defined in the unit of the time domain window. We are open to all above options. |
| Panasonic | We support the proposal. If joint channel estimation to different TB for PUSCH transmission is not considered, Option 1 is reasonable. |
| InterDigital | We support the proposal. If the UE needs to maintain power/phase continuity, a window during which the UE is expected to maintain power/phase continuity needs to be defined. Granularity of the window length (repetition/symbol/slot) may depend on the feedback from RAN4 regarding feasibility of phase/power maintenance. We are open to all options. |
| Intel | At least option 1 and 2 can be supported. If joint channel estimation is supported for PUSCH repetition type B, a set of repetition can be used as the window; while for PUSCH repetition type A, a set of slots/repetitions can be applied. It is not clear whether Option 3 can work. |
| WILUS | It can be determined based on supporting use cases in section 3.1. For now, we have preference on Option 1 and 2. |
| vivo | If a time domain window is a common understanding, the window should be necessary. Both option 1 & 2 can be considered for DMRS bundle size determination. For option 3, a finer granularity seems not necessary. |
| Nokia/NSB | We are fine with the proposal. |
| CMCC | If a time window is needed for joint channel estimation, at least option 1 and 2 could be supported. If the intention of option 3 is to cover the case of special slot, we could be open. And we could also discuss how to include the special slot case in both option 2 and 3. |
| Lenovo, Motorola Mobility | Option 1 is preferred, but okay to support option 2 as well. |
| Qualcomm | Request the following change:  “Define a time domain window during which UE may ~~is required to~~ maintain power consistency and phase continuity among PUSCH transmissions subject to phase continuity requirements.”  Prefer to indicate set of slots (Option 2). Span of repetitions is difficult to predict/control and is therefore not preferred.  We would like to add the following FFS:  FFS: single or multiple time domain windows |
| Sierra Wireless | We do not think there is a need to define a time window.  The amount of time JCE can be performed over depends on many factors:   * Doppler (band and mobility) * Residual CFO * UE’s ability to maintain phase cont (depends on system tolerance to timing/power error)   If the transmissions are short (e.g. <32 slots) then UEs should maintain phase across the entire transmission of the TB.  When JCE was specified for eMTC/NB-IOT, a time window was not defined as this was left up to gNB implementation. The UE was expected to maintain phase across the entire transmission of the TB (except when gaps are added). |
| Ericsson | While we can understand that UEs may need to adjust transmissions at the slot boundary, we’d like to better understand the how DMRS bundling durations work in general. For example, TDD may have less of a need for an explicit bundling window if back-to-back transmission is required to maintain phase coherence. On the other hand, FDD will be more likely to use back-to-back scheduling. Do companies think that the window always needs to be configured when bundling is configured? Also, can UE vendors comment on how frequently adjustments large enough to degrade phase coherence are made? |
| Huawei, HiSilicon | Not sure if a time window is necessary now which may need more input from RAN4 reply LS. If a time window is needed for joint channel estimation, the difference between three options seem about how to signaling, which can be discussed after concrete design and consensus on the necessity of time window. |
| Xiaomi | Defining a time domain window is good to constrain the UE behaviour, such as phase and power continuity. Considering joint channel estimation for type A is based continuous slots, so at least option 2 should be supported. As for option 1: maybe it is necessary for DMRS bundling for PUSCH type B across repetitions, so we are fine with it. For option 3, our concern is that it can not guarantee the scheme effectiveness. |
| LG | To make a UE does not adjust its transmit power and/or transmission timing, time domain window should be defined. We support Option 2 considering the same channel environment cannot be assumed when neighbouring two UL slots are located far away. |

**FL’s comments:**

**It seems the majority support defining a time domain window. Regarding the duration of the window, e.g., a set of repetitions/slots/symbols, it may depend on the use cases. FL would like to propose the following proposal.**

**Proposal:**

* Define a time domain window during which UE may ~~is required to~~ maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.
  + FFS: a set of repetitions/slots/symbols
  + FFS: sliding window
  + FFS: single or multiple time domain windows

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| LG Electronics | We are fine with FL’s proposal. |
| Nokia/NSB | We are not sure about the meaning of changing the wording from “is required to” to “may”. The intention of introducing the window is for the network to assume that power consistency and phase continuity requirements are satisfied in this window for applying joint channel estimation. If the UE does not have such capability, the UE can simply report no capability. Now, the wording “may” introduces some levels of uncertainty and the network doesn’t know whether it can apply joint channel estimation on the PUSCHs (which satisfy the requirements) within this window or not. |
| InterDigital | Thank you very much for the proposal. We have some suggestions for rewording the proposal. The changes are underlined in red.  **Proposal:**   * Define a time domain window during which UE may ~~is required to~~ maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.   + FFS: the length of the time domain window is defined by a set of repetitions/slots/symbols   + FFS: sliding or fixed window   + FFS: single or multiple time domain windows |
| Lenovo, Motorola Mobility | We are fine with the proposal and are also okay to InterDigital’s suggestions |

* Size of time domain window
  + Repetition type A
    - Equal to the number of repetitions
    - Smaller than the number of repetitions
  + Repetition type B
    - Equal to the number of nominal/actual repetitions
    - Smaller than the number of nominal/actual repetitions
  + Different TBs for PUSCH transmissions
  + One TB over multi-slots
    - Equal to the number of slots
    - Smaller than the number of slots

Companies are encouraged to provide views on the size of time domain window.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | We need to firstly discuss whether we need the time domain window. |
| Sharp | We have no clear view on this aspect so far. Defining a time domain window during which UE is required to maintain power consistency and phase continuity among PUSCH transmissions should be discussed first. |
| Apple | Considering the gNB capacity and delay requirements, the time domain window should be equal or smaller than the repetition number for repetition type A, this is also related to the configured maximum repetition number. |
| ZTE | As we commented above, we don’t see a need to explicitly define a time window. |
| CATT | We think both ‘equal’ and ‘smaller’ are reasonable, depending on the estimation implementation and the actual repetition times. |
| Samsung | We think that the size of time domain window can be considered both equal to the number of slots and smaller than the number of slots. The size of time domain window can be determined, e.g., by the gNB frequency clock error for phase continuity. |
| Panasonic | Not only the number of repetitions or number of slots for TB processing, the period of inter-slot frequency hopping should also be taken into account. |
| InterDigital | The choice and definition of window may depend on the feedback from RAN4. |
| Intel | Depending on whether inter-slot frequency hopping with inter-slot bundling is applied, window for joint channel estimation should be smaller than the number of repetitions.  For one TB over multi-slots, window is also smaller than the number of slots, which also depends on the inter-slot frequency hopping pattern.  As commented above, we do not support joint channel estimation for multi-TB PUSCH transmission, which is out of scope for coverage enhancement. |
| vivo | The window size within which UE can maintain phase continuity may depends on UE capability, which can be smaller than the time duration for PUSCH repetitions. And from NW perspective, a long DMRS bundle size may not lead to better performance especially in channel with high doppler shift/spread, hence NW may configure a windows size equal to or smaller than UE capability and the duration for PUSCH repetition. |
| Nokia/NSB | The window can be separately configured/indicated by the gNB since precoder and transmit power can be different across the windows. At this stage, we don’t see the need to tie the window size with other parameters such as repetition number or number of slots for multi-slot PUSCH. |
| CMCC | At least, all the options with “equal” could considered. Do not see any motivation for the “smaller than” case. |
| Lenovo, Motorola Mobility | First, we need to agree on how the time domain window is determined, then we can further discuss this proposal |
| Qualcomm | Support bundling only for type A repetitions and not for type B repetitions.  Discussion on size of time domain window can be scoped out after durther design details on the definition of the time domain window are agreed. Size of time domain window may depend on UE capability and the span of repetitions.  Bundling framework that is developed for type A repetition can be reused for multi-slot TB transmission. |
| Sierra Wireless | We don’t think this is needed but if needed it should simply be the equal to the number of repetitions. |
| Ericsson | This is FFS for us, as it depends on the more basic questions above. |
| Huawei, HiSilicon | Prefer to conclude the necessity of time window first. |
| Xiaomi | Window size for joint channel estimation should be smaller or equal than the number of repetitions which depends on the number of repetition.  In our simulation, when the transmission number is 16, it is about 1.2 dB gain can be obtained when increasing the granularity from 2 to 4; while joint channel estimation among 8 repetitions only provides extra 0.2 dB gain compared with 4 repetitions. We can observe that the size of joint channel estimation is not as larger as better. |
| LG | The time window can be equal to or smaller than the number of repetitions. |

* Signaling for time domain window
  + Implicit signaling
    - E.g., derived from number of repetition
  + Explicit signaling
    - Cell specific or UE specific?
    - Option 1: Configurable by gNB
    - Option 2: Reported by UE
    - Option 3: Configurable by gNB based on UE capability reporting

Companies are encouraged to provide views on the signalling for time domain window.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | We need to firstly discuss whether we need the time domain window. |
| Sharp | We support it controlled by gNB. |
| NTT DOCOMO | In explicit signalling for time domain, window UE specific is preferred, because some UEs are not required to apply PUSCH coverage enhancement (for example UEs close to the gNB). |
| Apple | The window can be configured by gNB, not sure why this related to the UE capability. |
| ZTE | As we commented above, we don’t see a need to explicitly define a time window. |
| CATT | If the time domain window is introduced, it should be signalled by gNB. Also, the gNB shall consider the window size based on the UE capability report, e.g. the window size should not be larger than the longest time a UE can maintain phase/power consistence. |
| Samsung | Both explicit signalling and implicit signalling are fine. However, we are not sure whether explicit signalling’s Option 2 and Option 3 are needed or not. We don’t think UE capability report is needed because the joint channel estimation will be conducted on the gNB side and phase continuity also can be determined by the gNB. Need for UE capability report should be further discussed. |
| Panasonic | At least UE specific signalling is required. |
| InterDigital | We support explicit signalling, slightly prefer Option 1. We are open to implicit signalling as well. Details of implicit signalling need to be discussed. |
| Intel | It can be both implicit signalling, e.g., for Msg3 PUSCH repetition, or explicit signalling with option 1, i.e., which is configured by gNB. |
| vivo | As our previous comments, Option 3 is preferred. |
| Nokia/NSB | As discussed above, the window can be separately configured/indicated by the gNB as precoder and transmit power can be different across the windows. Then letting the gNB control the window size would provide better scheduling flexibility for the gNB to exploit the joint channel estimation. |
| CMCC | Both implicit and explicit signaling could be considered. Option 3 is preferred for the explicit signaling. |
| Lenovo, Motorola Mobility | We prefer UE-specific explicit signalling |
| Qualcomm | Signaling aspects can be discussed after other design details are scoped out further. For now prefer to keep both implicit and explicit signaling options. |
| Sierra Wireless | Signalling for time domain window is not needed.  However, a new UE capability indicating whether the UE can support phase cont across all repeats should be considered. |
| Ericsson | We are open to either explicit signalling or implicit determination. If signalling is needed, it should be per UE. We don’t expect rapid on/off signalling or window size adjustment is needed as a design target. |
| Huawei, HiSilicon | As commented before, too early to discuss the detailed signaling. |
| Xiaomi | We prefer it is configured by gNB based on UE capability reporting |
| LG | We support explicit signaling of time window with Option 1 or Option 3. It can be configured UE specifically, since each UE has a different capability and channel conditions. |

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

If a time domain window is defined, there can be three options for the size of time domain hopping interval:

* Option 1: Smaller than the size of time domain window
* Option 2: Equal to the size of time domain window

Companies are encouraged to provide views on the size of time domain hopping interval.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | We need to firstly discuss whether we need the time domain window. |
| Sharp | Option 2 for simplicity. |
| Apple | Option2 is preferred. |
| ZTE | For now, we think it’s better to discuss time domain hopping interval for inter-slot FH separately with the time window which may or may not introduced. |
| CATT | There may be a typo since it is said that ‘there can be three options’, or one option is missed.  In our view, for hopping interval, both larger than or equal to the time domain window are reasonable case. |
| Samsung | Option 2 is fine if option 2 means that UE perform inter-slot frequency hopping based on the configured size of time domain window. |
| Panasonic | We prefer Option 2. |
| Intel | Option 2. The size of time domain hopping interval can be equal to the size of time domain window. |
| WILUS | We have preference on Option 2. |
| vivo | Support Option 2. |
| Nokia/NSB | We prefer Option 2 since the goal here is to enable joint channel estimation. |
| CMCC | Option 2 is preferred. But whether the condition of joint channel estimation could be fulfilled in frequency hopping need more discussion and should refer to RAN4’s feedback. |
| Lenovo, Motorola Mobility | Option 2 should be supported |
| Qualcomm | Let us first finalize design for the case without inter-slot freq hopping before discussing this. There doesn’t seem to be a common understanding on what this time domain window means. |
| Sierra Wireless | We need to firstly discuss whether we need the time domain window. We do not feel a time domain window is needed.  As we showed in our paper, JCE can be done across frequency hops when UE can maintain across frequency hops.  The size of the FH bundle can be RRC configured. |
| Ericsson | Our expectation is the UE will maintain phase continuity only within a hop, so if the gNB relies on phase continuity, Option 2 is needed if window size is specified. |
| Huawei, HiSilicon | Option 2 is preferred if time window is necessary. |
| Xiaomi | We prefer Option 2 . |
| LG | We are open to both options. However, considering the gain from frequency hopping is more important than joint channel estimation gain in small number of repetitions, independent configuration of hopping interval (Option 1) seems necessary. |

* Signaling for time domain hopping interval
  + Cell specific or UE specific?
  + Implicit signaling
    - E.g., derived from number of repetition, time domain window, available resources
  + Explicit signaling
    - Semi-static or dynamic

Companies are encouraged to provide views on the signalling for time domain hopping interval.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | Since different UE may have different channel condition with different correlation time, it would be better to have a UE specific time domain hopping interval.  For FDD, it shall be decoupled with the number of repetition, time domain window.  For TDD, may it can be derived from the slot structure, e.g., the contiguous uplink/available slots.  Or, it can be explicitly signaled with semi-static RRC signaling. |
| Sharp | Implicit way based on the time domain window is simple. |
| Apple | We prefer hopping interval is implicitly derived from time domain window. |
| ZTE | We prefer UE specific signaling similar as intra-slot or inter-slot FH which is enabled/disabled UE specifically. We have no strong view on whether to use implicit or explicit signaling for now.  We agree with OPPO that the time domain hopping interval for TDD also depends on the slot structure. |
| CATT | We slightly prefer implicit signalling. We are open to the question whether it should be cell-specific or UE specific. |
| Samsung | We can discuss signalling details in later stage once RAN1 introduce ‘time domain hopping interval’. |
| Panasonic | At least UE specific signalling is required. |
| Intel | It can be equal to the time domain window for joint channel estimation or based on explicit signalling |
| vivo | If joint channel estimation is enabled, time domain window for joint channel estimation can be same as time domain hopping interval. |
| Nokia/NSB | If the time domain hopping interval equals to the window (i.e. Option 2 in the previous proposal), then we can discuss the signalling of the window size only. |
| CMCC | First the pattern for joint channel estimation combined with frequency hopping should be designed. Then we could discuss the signalling of time domain. |
| Lenovo, Motorola Mobility | We prefer UE-specific explicit signalling for either hop duration or joint channel estimation/DM-RS bundling duration. If one is signalled, other could be implied. |
| Qualcomm | Same comment as Samsung. Too early to discuss. For now, UE-specific signaling will be required. |
| Sierra Wireless | The size of the FH bundle can be UE specifically RRC configured. |
| Ericsson | We expect the control is at least UE specific, but would study the details further. |
| Huawei, HiSilicon | UE-specific signalling if time window is necessary |
| Xiaomi | Agree with OPPO. |
| LG | Similar to joint channel estimation time window configuration, we think UE specific and semi-static signalling is necessary for frequency hopping interval signalling. We think frequency hopping interval can be configured explicitly and independently from time window for joint channel estimation. |

## 3.4 Optimization of DMRS location/granularity in time domain

Companies are encouraged to answer the following question.

* Whether optimization of DMRS location in time domain is supported?

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | Yes.  In Rel-15, DMRS pattern is designed for single slot PUSCH transmission.  For CE in Rel-17, the DMRS pattern can be redesigned taking into account into multiple slots PUSCH transmission and joint channel estimation. For example, it can be more uniform among multiple PUSCH slots to improve the performance of joint channel estimation. |
| Sharp | Given that the location optimization requires more studies, it may not be of high priority. |
| NTT DOCOMO | Optimization of DMRS location should be supported as long as the simulation results show the gain by the optimization. The number of DMRS symbols can be reduced by optimization, which leads to the low code rate due to more resource for data symbols |
| Apple | We don’t prefer the DMRS location optimization, the gain is marginal and is depending on the ideal joint channel estimation. If the optimization is supported, the standard and implementation impacts should be minimized. |
| ZTE | We are fine to support DMRS optimization in time domain since we observe some performance gain. However, the legacy DMRS location/granularity within each PUSCH repetition is flexible enough and should not be changed. We prefer only to potentially change the DMRS granularity among different repetitions, e.g., some of the repetition may not have DMRS. |
| CATT | Yes. We do not want to preclude any possibility to improve the performance at this very early stage. |
| Samsung | Support |
| Panasonic | It could be lower priority. Optimization of DMRS location should be specified only if the significant gain is identified. |
| InterDigital | We support DMRS location optimization. |
| Intel | At least higher density DMRS is not supported based on our simulation results. |
| vivo | Support |
| Nokia/NSB | Yes. As pointed out in out Tdoc, the Rel-16 DMRS allocation is not optimal for joint channel estimation. The DMRS optimization may depend on the discussion on use cases of joint channel estimation as well. |
| CMCC | Support. |
| Lenovo, Motorola Mobility | In our view, we mainly see issue with DM-RS time-domain patterns when additional DM-RS symbols are configured within a slot. If additional DM-RS symbols within each of the PUSCH transmission are needed for relatively higher mobility and DM-RS bundling/joint channel estimation is applied, then the overall DM-RS time-domain pattern across multiple PUSCHs might not always be ideal in terms of spacing between the DM-RS symbols according to current additional DM-RS patterns supported in NR Rel-15/16 (example copied from our contribution). Basically, with existing configuration, the additional DM-RS symbols could be placed quite close to the front-loaded DM-RS of next slot.    **Figure 1: Example of additional DM-RS pattern for multiple PUSCH (currently supported by NR Rel-15/16)**  An ideal time-domain pattern would something like illustrated below (copied from out contribution)    **Figure 2: Example of enhanced additional DM-RS pattern for multiple PUSCH**  Therefore, for the slots in between, the additional DM-RS pattern should be enhanced to allow equal spacing between DM-RS symbols. For the last slot, the same configuration as in Rel-15/16 could be used to avoid extrapolation over large number of DM-RS symbols |
| Qualcomm | Do not support DMRS location optimization. Adds additional complexity without clear gains. |
| Sierra Wireless | This is an enhancement where the amount of coverage gain is unclear and when that gain could be realized is unclear and thus we do NOT see this as a priority and should be discuss after priority items are agreed. Same view as Sharp, Apple, ZTE, Panasonic, Qualcomm |
| Ericsson | Optimization of DMRS location should be justified by performance gains. |
| Huawei, HiSilicon | We support the optimization of DMRS location in time domain in joint channel estimation. To list a few examples, current determination of DMRS position is within only one slot, where each slot/PUSCH has to configure at least one DMRS for independent channel estimation. According to previous discussion in SI, DMRS-less transmission with shared DMRS among multiple PUSCH transmissions can obtain gains and non DMRS PSUCH can be enabled. Furthermore, the DMRS determining mechanism in PUSCH repetition type B can also be optimized in joint channel estimation where a nominal repetition will be divided by slot boundary and DMRS is determined independently for each actual repetition, resulting a larger overhead of DMRS. |
| Xiaomi | Support. For CE in Rel-17, more DMRS patterns can be designed and supported for joint channel estimation adapting to different channel conditions. |
| LG | Before we discuss on potential optimization of DMRS location/granularity in time domain, a benefit and necessity of optimization of DMRS location/granularity should be justified. Then, we may discuss the details for DMRS optimization. So, it should be lower priority before the work is justified. |

Companies are encouraged to answer the following question.

* Whether optimization of DMRS granularity in time domain is supported?

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | Yes.  For low mobility case, the channel correlation among multiple PUSCH slots/PUSCH repetitions (including type B repetition) would be very good. Therefore, it isn’t necessary to have DMRS within each PUSCH slot/repetition.  DMRS-less PUSCH can be supported to reduce the DMRS overhead and improve the performance. |
| Sharp | We are OK to discuss at least for bundled transmission in S+U slots. In that case, DMRS-less transmission in S slot can be considered. |
| ZTE | As commented above, the legacy DMRS location/granularity within each PUSCH repetition is flexible enough and should not be changed. We prefer only to potentially change the DMRS granularity among different repetitions, e.g., some of the repetition may not have DMRS. |
| CATT | Yes. We do not want to preclude any possibility to improve the performance at this very early stage. |
| Samsung | Support |
| Panasonic | It could be lower priority. Optimization of DMRS granularity should be specified only if the significant gain is identified. |
| InterDigital | Yes. As long as DMRS in adjacent/closest slots/repetitions are included in the DMRS bundle, the number of DMRS symbols in the slot/repetition can be reduced. |
| Intel | At least higher density of DMRS symbols is not supported based on our simulation results. |
| vivo | Support |
| Nokia/NSB | Yes. However, we would like to ask for clarification on what is the difference between “optimization of DMRS location” in the previous question and “optimization of DMRS granularity” in this question? As checking 2.5 we see that they are almost the same except the case of non-DMRS PUSCH in “optimization of DMRS granularity”, which could also be considered as a subset of “optimization of DMRS location”. |
| CMCC | Support. |
| Lenovo, Motorola Mobility | Yes, same reply as for previous question |
| Qualcomm | Same question as Nokia. What is the distinction here? Needs more clarity. In general, not in favor of pursing DMRS optimization. |
| Ericsson | Optimization of DMRS granularity should be justified by performance gains. |
| Huawei, HiSilicon | Yes, the optimization of DMRS granularity in time domain can be supported, e.g. probably S+U slots or multiple PUSCH within a slot may share DMRS to reduce the DMRS overhead. |
| Xiaomi | Support. Low density of DMRS can reduce the DMRS overhead and save power and resource for PUSCH data transmission. High density of DMRS can improve the accuracy of channel estimation. So we need more diverse DMRS patterns with different density for flexible configuration according to different channel conditions. So we think it is necessary to support this optimization. We suggest supporting maintain a DMRS configuration table containing more diverse DMRS patterns for dynamically indication. |
| LG | In our view, current specification provides sufficient flexibility on DMRS overhead, i.e., 1~4 DMRS symbols per slot, and enhancement on DMRS granularity in time domain does not necessary. |

* Use cases for optimization of DMRS location in time domain
  + Repetition type A
  + Repetition type B
  + Different TBs for PUSCH transmission
  + One TB over multi-slots

Companies are encouraged to provide views on use cases for optimization of DMRS location.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | * + Repetition type A   + Repetition type B   + One TB over multi-slots   These 3 use cases can all be optimized. |
| ZTE | We prefer to first focus on PUSCH repetition type A which is more useful for coverage enhancement and may require relatively less spec impacts. |
| CATT | At least repetition type A, repetition type B and one TB over multi-slots can be considered. |
| Samsung | Higher priority for repetition type B. |
| InterDigital | The first 3 use cases can be supported. Optimization of DMRS location for one TB over multi-slot may need further study. |
| Intel | Lower DMRS density, e.g., no DMRS symbols in some repetitions may be applicable for repetition type B where a small number of symbols is allocated for one repetition. When relatively large number of symbols is used, e.g., for repetition type A, we did not observe performance gain if we reduce the number of DMRS symbols.  We do not see the need to optimize multi-TB PUSCH scheduling and one TB spanning multiple slots. |
| vivo | Except for different TBs, other sse cases for joint channel estimation could be considered for further optimization of DMRS location in time domain. |
| Nokia/NSB | As discussed above, the DM-RS optimization may be the same or different for different use cases. Therefore, we should discuss the use cases of DM-RS optimization after agreeing on the use cases for joint channel estimation. |
| Lenovo, Motorola Mobility | Yes, and same principle could be applied for all cases i.e. DM-RS time-domain pattern for additional DM-RS symbols is enhanced for all transmission occasions except last. |
| Qualcomm | Do not see any strong motivation for DMRS optimization. |
| Ericsson | The use cases that seem more possible are repetition type B and different TBs. But whether these use cases are needed for coverage enhancement should be further discussed. |
| Huawei, HiSilicon | The main motivation of optimization of DMRS location in time domain is to ensure a good channel estimation with low DMRS overhead, thus all 4 use cases can be supported in joint channel estimation, regardless same TB or different TB. |
| Xiaomi | At least repetition type A and type B can be considered. |

Companies are encouraged to provide views the following location for DMRS.

* + DMRS equally spaced among PUSCH transmissions
  + Located in special slots
  + DMRS for orphan symbol

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | At least DMRS equally spaced among PUSCH transmissions shall be supported.  Whether DMRS shall be located in special slots would depend on the discussion on the available slots, i.e., whether special slots can be used as available slots. |
| NTT DOCOMO | Locating DMRS in special slots can make use of uplink symbols in S slots. These UL symbols are not so many that allocating one TB in special slots results in high code rate. Therefore, locating DMRS for joint channel estimation is an efficient use of UL symbols. |
| ZTE | As commented above, the legacy DMRS location within each PUSCH repetition is flexible enough and should not be changed. |
| CATT | We support to further consider the first 2 options in principle. |
| Samsung | These 3 cases can be considered for optimization of DMRS. |
| InterDigital | All use cases can be considered. At least DMRS in special slots should be supported. |
| Intel | Need simulation results to show the performance gain before we conclude on this. We do not see the need to consider these three cases. |
| vivo | We support DMRS located in special slots and DMRS for orphan symbol. |
| Nokia/NSB | At least DM-RS symbols that are equally spaced among PUSCH transmissions can be supported. The other two cases would need further clarifications/discussions e.g. whether “DM-RS located in special slots” means that DM-RS symbol is allocated even if there is no PUSCH? Therefore, the other two cases can be further discussed after we agree on the “equally spaced among PUSCH transmissions” case. |
| Lenovo, Motorola Mobility | Yes, the location should be enhanced based on the principle to have equal separation between DM-RS symbols and avoid extrapolation on large number of symbols (in the last occasion). Also, copied our reply from previous question  In our view, we mainly see issue with DM-RS time-domain patterns when additional DM-RS symbols are configured within a slot. If additional DM-RS symbols within each of the PUSCH transmission are needed for relatively higher mobility and DM-RS bundling/joint channel estimation is applied, then the overall DM-RS time-domain pattern across multiple PUSCHs might not always be ideal in terms of spacing between the DM-RS symbols according to current additional DM-RS patterns supported in NR Rel-15/16 (example copied from our contribution). Basically, with existing configuration, the additional DM-RS symbols could be placed quite close to the front-loaded DM-RS of next slot.    **Figure 1: Example of additional DM-RS pattern for multiple PUSCH (currently supported by NR Rel-15/16)**  An ideal time-domain pattern would something like illustrated below (copied from out contribution)    **Figure 2: Example of enhanced additional DM-RS pattern for multiple PUSCH**  Therefore, for the slots in between, the additional DM-RS pattern should be enhanced to allow equal spacing between DM-RS symbols. For the last slot, the same configuration as in Rel-15/16 could be used to avoid extrapolation over large number of DM-RS symbols |
| Qualcomm | With use case 3 in mind, don’t think it is necessary to discuss this. No change in DMRS configuration. |
| Ericsson | We think Rel-16 configurations should be the baseline, and again are not clear on the need for DMRS optimization. We are open to further discuss. |
| Huawei, HiSilicon | All 3 cases can be considered in joint channel estimation |
| Xiaomi | We support DMRS located in special slots and DMRS for orphan symbol. |

* Use cases for optimization of DMRS granularity in time domain
  + Repetition type A
  + Repetition type B
  + Different TBs for PUSCH transmission
  + One TB over multi-slots

Companies are encouraged to provide views on use cases for optimization of DMRS granularity

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | * + Repetition type A   + Repetition type B   + One TB over multi-slots   These 3 use cases can all be optimized, among which Repetition type B is the most promising one since the time span of the adjacent PUSCH is small. |
| Sharp | Similar view as OPPO. For different TBs for PUSCH transmission, the specification impact may be high since the condition whether new DMRS mapping is used or not should be specified. For all other cases, the new mapping can be configured by RRC signalling. |
| ZTE | We prefer to first focus on PUSCH repetition type A which is more useful for coverage enhancement and may require relatively less spec impacts. |
| CATT | At least repetition type A, repetition type B and one TB over multi-slots can be considered. |
| Samsung | Higher priority for repetition type B. |
| Intel | As commented above, seems repetition type B needs further investigation based on our simulation results. |
| vivo | Except for different TBs, other sse cases for joint channel estimation could be considered for further optimization of DMRS granularityin time domain. |
| Nokia/NSB | The same use cases can be applied for both “optimization of DMRS location” and “optimization of DMRS granularity”. |
| Lenovo, Motorola Mobility | All cases can be supported based on similar principle |
| Qualcomm | Do not see any strong need for further DMRS optimization. |
| Ericsson | The use cases that seem more possible are repetition type B, and one TB over multiple slots. But whether these use cases are needed for coverage enhancement should be further discussed. |
| Huawei, HiSilicon | The main motivation is to ensure a good channel estimation with low DMRS overhead, thus all 4 use cases can be supported in joint channel estimation, regardless repetition type A or B， same TB or different TB. |

Companies are encouraged to provide views on the following granularity for DMRS.

* + Different DMRS density for different PUSCH transmissions
  + No DMRS for some PUSCH transmissions

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | Both of these two techniques can be supported, especially for low mobility cases. |
| Sharp | No DMRS (i.e., DMRS-less) can be supported. |
| ZTE | It seems the first bullet can cover the second bullet. Basically, we prefer to focus on the second bullet. |
| Samsung | No DMRS for some PUSCH transmissions can be considered for DMRS overhead reduction |
| InterDigital | We support both options. |
| Intel | As mentioned above, lower DMRS density, e.g., no DMRS symbols in some repetitions may be applicable for repetition type B where a small number of symbols is allocated for one repetition. When relatively large number of symbols is used, e.g., for repetition type A, we did not observe performance gain if we reduce the number of DMRS symbols. |
| vivo | No DMRS for these PUSCH transmissions could be considered to achieve better performance with shared DMRS by adjacent PUSCH transmission. |
| Nokia/NSB | Both cases can be supported. For the “different DM-RS density for different PUSCHs”, the overall goal should be to ensure DM-RS symbols are equally distributed across PUSCHs for joint channel estimation. |
| CMCC | Both options could be a starting point for the study or system design |
| Lenovo, Motorola Mobility | Depending upon spacing requirements, the last PUSCH transmission may have a different DMRS density in time to avoid extrapolation on many symbols. For all other PUSCH transmissions (except last), same density is sufficient. |
| Qualcomm | Maintain fixed DMRS density across all transmissions. |
| Ericsson | The no DMRS case seems relevant, with the same caveats as above that it should first be justified by performance gain. |
| Huawei, HiSilicon | Both options can be supported in joint channel estimation. |
| Xiaomi | Both options can be supported. |

**FL’s comments:**

**From FL’s understanding, optimization of DMRS location means the location of DMRS can be changed while the granularity is maintained compared to Rel-16. For instance, the location of the front loaded DMRS is kept unchanged while the location of the additional DMRS can be changed. On the other hand, optimization of DMRS granularity means the number of DMRS symbols for each PUSCH transmission can be different. For instance, some PUSCH transmissions have both 1-symbol front loaded DMRS and 1-symbol additional DMRS while some PUSCH transmissions may have only 1-symbol front loaded DMRS or even no DMRS. It seems the majority support optimization of DMRS location and optimization of DMRS granularity. In addition, ZTE (R1-2100097) and vivo (R1-2100459) provided simulation results for optimization of DMRS granularity. FL would like to propose the following proposal:**

**Proposal:**

* Optimization of DMRS granularity in time domain is supported.
  + FFS: Different DMRS density for different PUSCH transmissions
  + FFS: No DMRS for some PUSCH transmissions
* FFS: Optimization of DMRS granularity in time domain
  + The proponents are encouraged to provide simulations results.

Companies are encouraged to provide views on the above proposal.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| LG Electronics | We do not support FL’s proposal.  Before we discuss on potential optimization of DMRS location/granularity in time domain, a benefit and necessity of optimization of DMRS location/granularity should be justified. Then, we may discuss the details for DMRS optimization. So, it should be lower priority before the work is justified. |
| Nokia/NSB | We are fine with the FL’s proposal. |
| Lenovo, Motorola Mobility | We support the FL’s proposal |

## 3.5 Others

Companies are encouraged to answer the following question.

* Q: Whether PUSCH transmission can be supported in special slots for repetition type A?

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| OPPO | Yes.  It can increase the available slot for PUSCH transmission, especially when there are sufficient uplink symbols in the special slots. |
| Sharp | The same TDRA among repetitions should be kept. Repetition type B can be used if resources in S slots should be exploited. |
| Apple | No, this was discussed in SI, and not agreed. |
| ZTE | If the intention is to allow transmission in a special slot even if the starting symbol or number of available symbols in the slot cannot satisfy the symbol allocation indicated by network, we are open to discuss. |
| CATT | It seems related to the 8.8.1.1 discussion on definition of available UL slot for repetition type A enhancement. Generally, we are supportive if special slot can be applied for coverage improvement. |
| Panasonic | FFS  Whether special slots is supported or not should be discussed together with definition of available slots for PUSCH repetitions in agenda item 8.8.1.1. |
| InterDigital | Yes. As long as there are enough symbols in a special slot, DMRS bundling should include PUSCH transmissions in special slots. |
| Intel | This is related to enhancement on PUSCH repetition type A. If the number of available symbols is >= number of indicated/configured symbols, PUSCH can be located in special slots. Otherwise, it can not be transmitted in the special slots. |
| vivo | Yes.  If there are enough uplink symbols with same S and L in special slots, these special slots could be available slots for repetition type A. |
| Nokia/NSB | The Rel-16 behaviour should be kept. If the UL symbols in the special slots is fully aligned with time-domain resource required for one repetition, then it can be used. If the repetition is overlap with DL symbols in the special slot, then it is not transmitted. We think that this question can be resolved in 8.8.1.1 first, before we further discuss joint channel estimation for the outcome scenario. |
| Qualcomm | Same comment as Nokia. Follow R16 behavior. No need for any changes in R17. |
| Ericsson | Special slot operation should be justified by performance gains, since it will add complexity. |
| Huawei, HiSilicon | Yes, S slot can be utilized to improve the coverage of PUSCH. |
| LG Electronics | Yes,  In the current specification, special slots can be used to transmit PUSCH repetitions if all symbols indicated by SLIV can be used for uplink.  If the intention is to utilize a special slot even if it cannot utilize all symbols indicated by SLIV for uplink, we need further discussion. |

Companies are encouraged to answer the following question.

* Q: Whether PUSCH transmission can be supported in special slots for orphan symbol for repetition type B?

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| NTT DOCOMO | Considering the widely used TDD pattern, e.g. DDDDDDDSUU for FR1, DDDSU for FR2, joint channel estimation can be applied only for FR1 if we don’t consider special slots. Therefore PUSCH transmission can be supported in special slots for repetition type B, to take advantage of symbol-level repetition. |
| Samsung | Support  Current mechanism does not support to transmit orphan symbol in repetition type B. However, when joint channel estimation is applied, orphan symbol can be transmitted easily. |
| InterDigital | Support. Joint channel estimation for repetition type B can benefit from symbols in a special slot. |
| Intel | It is not clear why we need to consider this for PUSCH enhancement. 1 symbol PUSCH in one actual repetition was not agreed in Rel-16 due to high code rate. In addition, this does not provide meaningful benefit for coverage enhancement. We do not support this. |
| vivo | Yes. Orphan symbols in special slots should be used to place DMRS and repetition type B, w.r.t, the limited uplink resources. |
| Nokia/NSB | Since this aspect is not the main focus of joint channel estimation, we can further discuss it later, after a basic framework for joint channel estimation is agreed. |
| Qualcomm | No. Out of scope. |
| Huawei, HiSilicon | Not sure if this is in scope of joint channel estimation. |
| LG Electronics | In our understanding, current specification supports PUSCH transmission with PUSCH repetition type B using valid symbols in special slots. However, an actual repetition with a single symbol is omitted except for the case of L=1.  We don’t see the significant benefit from PUSCH repetition type B enhancement in special slot. |

Companies can provide other issues not listed above, if any.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Ericsson | We would like companies’ feedback on whether they think joint channel estimation can be available more often, or better supported by UEs, when gNB can do wideband estimation of the relative phase between slots, as discussed in R1-2101522. If the UE can only maintain phase continuity for back-to-back transmissions, the benefit of joint channel estimation for TDD seems rather limited for the heavy DL:UL ratios that are commonly used. |
|  |  |
|  |  |
|  |  |

1. Email discussion (2nd round)

**FL’s comments:**

**Based on the 1st round of discussion, the majority are fine with the categorization of the use cases. The categorization of the use cases is necessary, as the discussion of some other issues depends on the use cases. It does not actually mean whether or not joint channel estimation can be applicable to each use case, which depends on RAN4 decision. Please refrain from any further concerns on the use cases.**

**In addition, from FL perspective, RAN4 does not have all the potential use cases in mind. LS sent by last RAN1 meeting to RAN4 only mentioned back-to-back transmission and PUSCH repetition. FL thinks it’s necessary to send another LS on PUSCH to RAN4 as early as possible, as we are not sure when RAN4 shall reply LS. Otherwise the whole progress would be delayed.**

**Regarding the red parts in brackets, can we remove them and leave them to RAN4 to identify the details?**

**Proposal 1:**

* 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 [with the maximum gap of x-symbols between two adjacent 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 [with the maximum gap of y-symbols between two adjacent PUSCH transmissions].
  + Use case 5: PUSCH transmissions across non-consecutive slots [with the maximum gap of z-slots between two adjacent PUSCH transmissions].
* Send LS to RAN4, asking following questions:
  + Whether joint channel estimation can be applicable to the above uses cases?
  + Under what conditions UE can maintain power consistency and phase continuity for gNB to implement joint channel estimation for each use case?

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Nokia/NSB | Support the FL proposal. For the red parts, we can let RAN4 to identify details. At this stage, we can remove them from the proposal and ask RAN4 about these constraints in the LS, if any. |
| Intel | We are fine with the FL proposal in principle, but it may be good to wait for RAN4 reply LS first before we send another LS. It may be the case that RAN4 already answered some of the above questions.  We are also fine with Nokia’s suggestion to remove the red parts. |
| Lenovo, Motorola Mobility | We support use cases 1,3 and are fine to further consider use cases 2,4,5 |
| Ericsson | Agree that further discussion with RAN4 in an LS is useful, although it is probably better to wait to send it until we receive RAN4’s answer, as we already are duplicating our questions with the earlier LS somewhat. Also support removing the red text.  We fail to see the coverage benefit of a UE transmitting multiple PUSCHs in one slot, since this may degrade capacity with increased overhead (e.g. with multiple CRC checks in one slot), as well as add complexity. However, presuming that it will not take much extra effort to handle in RAN4, we can compromise and will not oppose use cases 1 and 2 being potential use cases discussed with RAN4.  Since relative phase is not likely to be perfect, it would be good to refine the question. In addition to when power consistency and phase continuity can be maintained, can we get a rough estimate from RAN4 on how well they can be maintained? For example, if the UE can maintain say +/-40 degrees across slots, the gain from cross-slot channel estimation may be significantly less than if it can maintain +/-4 degrees, especially for a large number of repetitions. Can we add something like the following?:   * Send LS to RAN4, asking following questions:   + Whether joint channel estimation can be applicable to the above use~~s~~ cases?   + Under what conditions UE can maintain power consistency and phase continuity for gNB to implement joint channel estimation for each use case?   + Approximately how well can the UE maintain power consistency and phase continuity under these conditions? |
| Samsung | According to current RAN4 discussion, back-to-back PUSCH transmission may include non-zero gap in-between PUSCH transmissions (RAN4 is still discussing).   * If RAN1 is clear enough that back-to-back PUSCH transmission means ‘zero gap’ in-between, let’s first agree to that term. If it include ‘non-zero gap’, we don’t need ‘non-back-to-back’ PUSCH transmissions. We think this is the pre-requisite for the remaining part of our discussion. * Rather than sending another LS, we suggest to wait for RAN4 response on previous RAN1 questions. |
| ZTE | We are general fine with the proposal. When we draft the LS for RAN4, we need to make is clear that RAN1 only agrees to consider and discuss these use cases, while does not agree that these use cases has to be supported in the end. |
| Qualcomm | Same comment as others. Wait for RAN4 to respond before we go back with more questions.  We are interpreting back-to-back as being equivalent to zero gap.  We are also assuming that non-back-to-back PUSCH transmissions with X symbol/slot gap means that in the intervening gap no other transmission occur, i.e., the gap symbols/slots are unused (from a UE perspective).  It will be good to get both these points included in the proposal. |
| NTT DOCOMO | We are fine with the proposal and Ericsson’s suggestion. The threshold of phase continuity and amplitude continuity is not clear at the moment. |
| FL | @Qualcomm,  As commented by other companies, the details requirements to keep maintain power consistency and phase continuity is up to RAN4.  Can you accept the following revised proposal 1 with one note proposed by Samsung:  **Proposal 1:**   * 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. |
| vivo | Considering we have not received the feedback from RAN4 for previous LS, and we may down-select the scenarios later, we suggest to revise the proposal as follows,   * Subject to the prerequisite of DMRS bundling per RAN4 feedback, following potential use cases are considered and may be down-select for joint channel estimation for PUSCH: |
| Apple | Ok with FL’s proposal. |
| CATT | OK with the revised proposal. Anyway, further revision is expected after RAN4’s feedback. |
| Huawei, HiSilicon | In current spec, SRS must be configured for a UE’s PUSCH so that it is very highly probable that SRS is transmitted between two successive PUSCH occasions.    Therefore, in our understanding, this use case should be supported, otherwise such large restriction of joint channel estimation will cost UL coverage.  A change is suggested below,  **Proposal 1:**   * 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. (There may be SRS transmission between the two successive PUSCH transmissions.)   + 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. |

**FL’s comments:**

**It seems the majority support joint channel estimation over back-to-back PUSCH transmissions within one slot for repetition type B scheduled by dynamic grant or configured grant. While for different TBs, there are different understandings, further discussion is needed. Thus, FL would like to propose the following proposal.**

**Proposal 2:**

* For back-to-back PUSCH transmissions within one slot, if power consistency and phase continuity can be maintained.
  + Joint channel estimation over back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant is supported.
  + FFS: whether joint channel estimation over back-to-back PUSCH transmissions with different TBs can be supported.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Nokia/NSB | Support the FL’s proposal. |
| Intel | We are fine with the proposal. |
| Lenovo, Motorola Mobility | We support the proposal |
| Ericsson | We would like some further technical discussion before agreeing to Type B repetition with back to back transmission in a slot.  If Type B repetition with more than one PUSCH in a slot is used to improve latency, the UE should be able to decode the first PUSCH in the slot the majority of the time if the latency is to be minimized. If the RS in a later PUSCH is bundled with the that of the first PUSCH, to get the channel estimation improvement, the gNB must wait for that later RS. So the gNB must either sacrifice the latency benefit for coverage or it can only get the RS combining gain for retransmissions, probably about 10% of the time. Therefore, the benefit for latency from RS bundling is not clear.  Since multiple Type B PUSCHs in one slot will increase overhead, it is also unclear why such a configuration would be used to improve coverage. |
| ZTE | Fine with the proposal. |
| Qualcomm | We don’t support this proposal.  We fail to see how this can increase coverage. Why is a gNB configuring a TB with two back-to-back transmissions as opposed to a single transmission that is twice as long?  In fact, if at all this can improve coverage, it can be through diversity (antenna virtualization, precoder cycling, beam switching, etc) across two back-to-back repetitions. But clearly, DMRS bundling precludes this.  Similar arguments can be made for the case with two different TBs. |
| Samsung | We are fine with FL’s proposal. |
| NTT DOCOMO | We support the proposal |
| vivo | Support this proposal. |
| Apple | The joint channel estimation can be applied to PUSCH repetition type B, but it seems not directly relevant to coverage enhancement. |
| CATT | We think this proposal is fine, at least from view of joint channel estimation feasibility. |
| InterDigital | We support the proposal. We also support to keep the FFS to study feasibility. |

**FL’s comments:**

**It seems the majority support joint channel estimation over back-to-back PUSCH transmissions across consecutive slots for repetition type A/B scheduled by dynamic grant or configured grant, and TB processing over multiple slots. While for different TBs, there are different understandings, further discussion is needed. Thus, FL would like to propose the following proposal.**

**Proposal 3:**

* For back-to-back PUSCH transmissions across consecutive slots, if power consistency and phase continuity can be maintained.
  + Joint channel estimation over back-to-back PUSCH transmissions for repetition type A scheduled by dynamic grant or configured grant is supported.
  + Joint channel estimation over back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant is supported.
  + Joint channel estimation over back-to-back PUSCH transmissions for TB processing over multiple slots is supported.
  + FFS: whether joint channel estimation over back-to-back PUSCH transmissions with different TBs can be supported.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Nokia/NSB | Support the FL’s proposal. |
| Intel | We are fine with the proposal. |
| Lenovo, Motorola Mobility | We support the proposal |
| Ericsson | While PUSCH repetition type B over back-to-back slots has more potential for coverage gain than type B within a slot, combining only a portion of a slot using Type B will have less gain than a full slot. The coverage benefits should be quantified before optimizing for Type B repetition.  On the other hand, if there is no real difference between bundling for type A or B, then there should be no problem to support both.  Then if the bundling mechanism is independent of Type A or Type B repetition, can we avoid the issue by saying something simpler, like:   * Joint channel estimation over back-to-back PUSCH transmissions of a TB across consecutive slots is supported, if power consistency and phase continuity can be maintained, at least for a subset of repetition Types and/or grant types. |
| ZTE | Fine with the proposal. |
| Qualcomm | Given the lack of design details on TBoMS, we prefer to leave it as an FFS at this point.  Better utilization of S+U slots is quoted as a justification of Type B repetitions. But Type B repetitions are restricted to consecutive slots. Its not clear how PUSCH configurations with Type B repetitions can match the performance offered by Type A repetitions. The TDD pattern DDSUU can used to illustrate this point --- in this case, Type B repetitions can utmost use two U slots and some symbols of S slot while Type A repetitions can use upto 16 U slots (once method of counting is updated). We therefore prefer to leave support of joint channel estimation for Type B repetitions as an FFS.  Here is the altered proposal:   * For back-to-back PUSCH transmissions across consecutive slots, if power consistency and phase continuity can be maintained.   + Joint channel estimation over back-to-back PUSCH transmissions for repetition type A scheduled by dynamic grant or configured grant is supported.   + FFS: Joint channel estimation over back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant is supported.   + FFS: Joint channel estimation over back-to-back PUSCH transmissions for TB processing over multiple slots is supported.   + FFS: whether joint channel estimation over back-to-back PUSCH transmissions with different TBs can be supported. |
| Samsung | We are fine with FL’s proposal |
| NTT DOCOMO | We support the proposal |
| vivo | Support this proposal |
| CATT | We are fine with this proposal. |
| InterDigital | We support the proposal. |

**FL’s comments:**

**It seems the majority support defining a time domain window. Regarding the duration of the window, e.g., a set of repetitions/slots/symbols, it may depend on the use cases. FL would like to propose the following proposal.**

**Proposal 4:**

* Define a time domain window during which UE may ~~is required to~~ maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.
  + FFS: the length of the time domain window is defined by a set of repetitions/slots/symbols
  + FFS: sliding or fixed window
  + FFS: single or multiple time domain windows

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Nokia/NSB | We would like to ask for further clarification that whether the wording “UE may maintain” means that there is no guarantee that PUSCHs can satisfy the requirements within this window and another signalling/confirmation from UE is needed, or it’s just a formal wording with the same meaning as “UE is required to”? This is just to avoid confusion for further discussion. Thank you! |
| Intel | It may be some confusions on the “sliding window” for UE to maintain power consistency and phase continuity. We did not propose to define the sliding window for this purpose. The sliding window in our tdoc is one type of the receiver algorithms in our simulations.  To avoid confusion, we suggest to remove “~~‐ FFS: sliding or fixed window~~” |
| Lenovo, Motorola Mobility | We are fine the proposal |
| Ericsson | Same question as Nokia: ‘may’ in this context does not say what the UE will do. Can we clarify the proposal? Is the wording ‘is able to … subject to power consistency and phase continuity requirements’ along the lines of what is intended? |
| ZTE | Same confusion as Nokia and Ericsson. |
| Qualcomm | @Nokia, Ericsson: So far, there has been no discussion on how this time domain window compares to a UE’s ability to maintain phase coherence across the desired duration. Without such a discussion, it is impossible to expect the UE to adher to phase coherence across this entire duration. A UE may prefer to split the signaled time window into multiple sub-windows over which phase coherence is maintained or alternately, this could be a best-effort bundling with certain events taking priority over bundling. |
| Samsung | We are fine the FL’s proposal.  We think that time domain window can be useful for compatibility with other schemes like frequency hopping and DMRS optimization. Regardless of explicit or implicit configuration, concept of time domain window based on phase continuity over multiple PUSCH transmission may be needed to perform joint channel estimation. |
| NTT DOCOMO | We have the same questions as Nokia and Ericsson. If all conditions are met and gNB lets UE maintain power and phase continuities, UE should be required to maintain power and phase continuity. Otherwise, gNB results in applying joint channel estimation without power and phase continuity. |
| FL | It seems many companies have concerns on the revision from “is required to” to “may”.  To address Qualcomm’s concern, can we add one sub-bullet “FFS: relation with UE capability”  **Proposal 4:**   * Define a time domain window during which UE is required to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.   + FFS: the length of the time domain window is defined by a set of repetitions/slots/symbols   + ~~FFS: sliding or fixed window~~   + FFS: single or multiple time domain windows   + FFS: relation with UE capability |
| vivo | In our opinion, even if the DMRS bundling size/duration is configured, UE may not be able to maintain phase continuity and power consistency due to some factors, e.g. impacted by other procedures, and such exceptions should be allowed. Hence, we prefer the wording to be revised to ‘is able to …’, as suggested by Ericsson. |
| Apple | We share the similar view as vivo, we can’t agree “UE is required to”, in some cases it could be beyond UE capability to maintain power and phase continuity. The wording “ UE is expected to …” could be better. |
| CATT | We think changing ‘is required to’ to ‘is expected to …’ is more realistic from UE’s view. |
| Nokia/NSB | Thank you, Qualcomm, vivo and Apple for further clarifications!  @Qualcomm: We see your concern now. We are open to discuss this aspect later, after we know more about the UE’s ability regarding the duration (e.g. after having feedback from RAN4). About your concern regarding the UE may want to split into multiple sub-windows, we think that UE capability on the window size can be discussed later (e.g. UE can support only a small maximum size) and this window can also be repeated in time-domain. Therefore, splitting into more sub-windows may not be needed.  @vivo and Apple: We think that adding an “FFS: Further constraints from UE to maintain the power consistency and phase continuity requirements” would help to clarify your concern and so that we can keep “UE is required to…” as in the FL’s proposal. But we are also fine with “UE is expected to…” without adding the FFS. |
| InterDigital | We support the FL’s proposal by changing to “UE is expected to maintain power consistency…”. |
| Huawei, HiSilicon | Thank you for the proposal.  The purpose of a time domain window is to align company understandings on the UE power consistency and phase continuity, it is too early to decide whether a time domain window is specified. Therefore, we suggest some change below,  **Proposal 4:**   * For joint channel estimation, define a time domain window during which UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.   + FFS: the length of the time domain window is defined by a set of repetitions/slots/symbols   + ~~FFS: sliding or fixed window~~   + FFS: single or multiple time domain windows * FFS: relation with UE capability * Note: the time domain window may not be specified |

**FL’s comments:**

**From FL’s understanding, optimization of DMRS location means the location of DMRS can be changed while the granularity is maintained compared to Rel-16. For instance, the location of the front loaded DMRS is kept unchanged while the location of the additional DMRS can be changed. On the other hand, optimization of DMRS granularity means the number of DMRS symbols for each PUSCH transmission can be different. For instance, some PUSCH transmissions have both 1-symbol front loaded DMRS and 1-symbol additional DMRS while some PUSCH transmissions may have only 1-symbol front loaded DMRS or even no DMRS. It seems the majority support optimization of DMRS location and optimization of DMRS granularity. In addition, ZTE (R1-2100097) and vivo (R1-2100459) provided simulation results for optimization of DMRS granularity. FL would like to propose the following proposal:**

**Proposal 5:**

* Optimization of DMRS granularity in time domain is supported.
  + FFS: Different DMRS density for different PUSCH transmissions
  + FFS: No DMRS for some PUSCH transmissions
* FFS: Optimization of DMRS location in time domain
  + The proponents are encouraged to provide simulations results.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Nokia/NSB | Support the FL’s proposal. |
| Intel | It is too early to decide whether optimization of DMRS granularity in time domain is supported without extensive study. We provided some simulation results and observed that for most of the cases, e.g., PUSCH repetition type A with large number of symbols for each repetition and higher DMRS density, there is no performance gain compared to existing DMRS pattern.  We suggest to first agree upon a set of simulation assumptions and further investigate whether there is indeed performance gain for the optimization of DMRS pattern. |
| Lenovo, Motorola Mobility | We support FL’s proposal and definitely see a need to enhance additional DM-RS position within a PUSCH to allow for equal spacing between DM-RS symbols across multiple PUSCHs. If we simply follow the current additional DM-RS pattern, then some DM-RS symbols will be quite closely placed to each other, while others will be quite far apart. |
| Ericsson | While we appreciate the results from ZTE and vivo, we would like further study before taking a decision to optimize a fundamental aspect like DMRS design. Further study could include TDD (in our understanding, ZTE and vivo’s results are for FDD), benefits in the presence of impairments like frequency offset error, different Rel-15/16 DMRS configurations, etc. We should also be more specific on the use case, e.g. do we assume full slots are used, is cross-slot channel estimation a prerequisite, etc. |
| ZTE | Support the proposal. As FL noted, we conducted some simulation and observed that there are performance gain for DMRS granularity optimization in time domain. We are also fine with adding some wording like ‘aiming for minimized specification impacts’ which may relieve a bit some of the concerns. |
| Qualcomm | We do not support this proposal.  We are afraid this will be a futile exercise. With the dynamics of ULCI, channel prioritizations, dynamic SFI, there is no guarantee that any given repetition is actually transmitted. When such is the case, DMRS optimization reduces to a theoretical exercise with little to no practical relevance. With robustness in mind, we prefer to not entertain any DMRS granularity/location optimizations. If DMRS overhead is a concern, the gNB can configure a UE with 1 DMRS per slot. Attempting to further reduce DMRS density is not a wise decision in our opinion. |
| Samsung | We support the FL’s proposal. |
| vivo | Support this proposal. |
| Apple | Maybe the meaning of optimization of DMRS granularity need to clarify, according to FL comments, DMRS density can decrease but not increase beyond configured number. |
| CATT | Considering this is the very early stage and DMRS design may be related to RAN4’s reply LS, maybe changing ‘is supported’ to ‘is encouraged to study’ will be better? |
| InterDigital | We support the FL’s proposal. |

1. Email discussion (3rd round)

**FL’s comments: Proposal 1 is stable.**

**Proposal 1:**

* 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.

**FL’s comments:**

**From FL understanding, PUSCH repetition type B can make full use of UL resources, e.g., UL symbols in special slots for TDD, and can achieve better performance than PUSCH repetition type A in some cases in terms of coverage. Joint channel estimation over back-to-back PUSCH transmissions for repetition type B is an enhancement. So PUSCH repetition type B is relevant to coverage enhancement.**

**Proposal 2:**

* For back-to-back PUSCH transmissions within one slot, if power consistency and phase continuity can be maintained.
  + Joint channel estimation over back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant is supported.
  + FFS: whether joint channel estimation over back-to-back PUSCH transmissions with different TBs can be supported.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Intel | We are fine with the proposal. |
| InterDigital | We support the FL’s proposal. |
| Panasonic | We are fine with the proposal. |
| Sharp | We are OK with FL proposal. |
| Qualcomm | We don’t support the proposal.  We don’t think Type B repetitions are relevant in the context of coverage enhancement. In a TDD setup, it is not possible to setup repetitions across non-contiguous slots using Type B repetitions. Therefore a gNB is likely to use Type A repetitions for a cell-edge UE.  We prefer to keep focus on Type A repetitions. |
| Samsung | We support the FL’s proposal. |
| CATT | We are OK with this proposal. |
| OPPO | We are fine with the proposal.  Joint channel estimation over back-to-back PUSCH transmissions with different TBs shall be further studied. E.g., the impact on power control, MCS, and potential specification impact. |
| Lenovo, Motorola Mobility | We are fine with the FL’s proposal |
| WILUS | We are fine with the proposal. |
| Xiaomi | Support the FL’s proposal. |
| Nokia/NSB | Support the FL’s proposal. |
| ZTE | Fine with the proposal. |
| LG | We don’t support the proposal and share the view with Qualcomm.  During the study item phase, enhancements on PUSCH repetition type B was discussed and ruled out from recommended solutions for coverage enhancement, since PUSCH repetition type B is targeting ULRRC traffic. We’d like to clarify that it is proposing that PUSCH repetition type B is applied for eMBB/VoIP traffic to enhance coverage. If so, since resources for the nominal repetitions includes not available resource for uplink in TDD, the coverage gain seems very limited.  If joint channel estimation for PUSCH repetition type B is supported, back-to-back PUCH within one slot in Proposal 2 seems not clear. In the current specification, Tx power control for PUSCH repetition type B is performed in units of the nominal repetition. Hence, the UE does not adjust its Tx power within a nominal repetition. Therefore, back-to-back PUSCH nominal repetition within one slot rather than back-to-back PUCH within one slot seems better. |
| Ericsson | We have similar concerns with Qualcomm and LG, as we commented in the second round. Again, we don’t think that repeating a PUSCH within a slot makes sense for eMBB and VoIP coverage that is in the scope of coverage enhancement. Won’t the overhead be higher for multiple PUSCHs than for one PUSCH in a slot? Also, if we want to improve latency, DMRS bundling within a slot leads to higher latency.  This proposal addresses back-to-back transmission within one slot, so we are not sure why the feature lead mentions special slot. Is the intention to support multiple PUSCHs within a special slot? |

**FL’s comments:**

**As for the comment, “*The TDD pattern DDSUU can used to illustrate this point --- in this case, Type B repetitions can utmost use two U slots and some symbols of S slot while Type A repetitions can use up to 16 U slots (once method of counting is updated)*”, does it imply that Rel-16 PUSCH repetition type B can achieve better performance than Rel-16 PUSCH repetition type A in some cases in terms of coverage? For Rel-17, if Rel-17 UE is not mandated to support enhanced PUSCH repetition type A with the number of repetitions counted on the basis of available UL slots, enhancement on repetition type B via joint channel estimation seems still meaningful. Regarding the comments on TBoMS from Qualcomm, this proposal is quite high level. It does not touch the detailed design of TBoMS. But I’m fine with adding “FFS” to TBoMS, if everyone is fine. As for Ericsson’s comments, it seems not clear what repetition type(s) or grant type(s) is/are supported.**

**Proposal 3:**

* For back-to-back PUSCH transmissions across consecutive slots, if power consistency and phase continuity can be maintained.
  + Joint channel estimation over back-to-back PUSCH transmissions for repetition type A scheduled by dynamic grant or configured grant is supported.
  + Joint channel estimation over back-to-back PUSCH transmissions for repetition type B scheduled by dynamic grant or configured grant is supported.
  + [FFS:] Joint channel estimation over back-to-back PUSCH transmissions for TB processing over multiple slots is supported.
  + FFS: whether joint channel estimation over back-to-back PUSCH transmissions with different TBs can be supported.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Intel | We support joint channel estimation for TB processing over multiple slots. We observed performance gain when employing joint channel estimation over TBoMS.  We are fine with other part of the proposals. |
| InterDigital | We support the FL’s proposal without the FFS for TBoMS. Joint channel estimation for TBoMS will provide additional receiver-side performance gain. |
| Panasonic | We are fine with the proposal. |
| Sharp | We think FFS should be fine for TBoMS since the design of TBoMS is not so clear at this state. If TBoMS is performed based on a PUSCH crossing multiple slots, joint channel estimation is not necessary. |
| Qualcomm | We in general support this proposal, but prefer to leave joint channel estimation over type B repetitions under FFS. As we have stated previously, there is no strong use case of type B repetitions for coverage enhancement. Prefer to focus on Type A repetitions to better use the limited available time for this sub-agenda. |
| Samsung | We are fine with FL’s proposal. We think joint channel estimation on TBoMS can be applied to get the additional coding gain and improve the performance of channel estimation. |
| CATT | We are fine with FL’s proposal.  We also support joint channel estimation for TB processing over multiple slots. Note that it has already been restricted that only ‘over back-to-back PUSCH transmissions’ is considered in this proposal. |
| OPPO | We are fine with the proposal.  Joint channel estimation over back-to-back PUSCH transmissions with different TBs shall be further studied. E.g., the impact on power control, MCS, and potential specification impact. |
| Lenovo, Motorola Mobility | We support FL’s proposal and also agree to support joint channel estimation for TB processing over multiple slots. |
| WILUS | We support the proposal. One minor comment is to change “consecutive slots” with “consecutive physical slots” to avoid any potential ambiguity. Note that there are some discussions on that consecutive slots are physical or logical under AI 8.8.1.2 (TBoMS). |
| Xiaomi | Fine with the proposal. We support that Joint channel estimation over back-to-back PUSCH transmissions for repetition type A/B scheduled by dynamic grant or configured grant and TB processing over multiple slots. But we are also confused that whether joint channel estimation over back-to-back PUSCH transmissions with different TBs can make any gain. |
| Nokia/NSB | We support the FL’s proposal. We prefer to remove the brackets on joint channel estimation over back-to-back PUSCH transmissions for TB processing. If we can support joint channel estimation for back-to-back PUSCH transmissions across consecutive slots for PUSCH repetitions, there is no reason why we cannot support it for TB processing, since the same TB is conveyed by the PUSCHs in both cases. |
| ZTE | Fine with the proposal. |
| LG | Similar view with Qualcomm.  We want to make joint channel estimation over type B repetitions as FFS. |
| CMCC | General fine with the proposal. We are open for the type B repetition.  We propose to remove the FFS in front of the 3rd bullet. Since if the condition of joint channel estimation is satisfied, we have no reason to not apply it to the TB over multiple slots. At least the MCS and precoding would be consistent between multiple slots.  For the 4th bullet, we need further guidance from RAN4 at least for MCS issue or others. If it could be clarified, we have no problem. |
| Apple | As several companies commented that joint channel estimation over PUSCH repetition type B, it’s fair to add FFS. Then the whole proposal can be agreeable for everybody. |
| Ericsson | Regarding the FL’s question on our proposed alternative:   * Joint channel estimation over back-to-back PUSCH transmissions of a TB across consecutive slots is supported, if power consistency and phase continuity can be maintained, at least for a subset of repetition Types and/or grant types.   As the FL points out, this does not say what repetition or grant types are supported. The intention is to make a first step, where we support at least consecutive slots for one TB and for at least one or more of the repetition or grant types we have. Supporting multiple repetition and grant types will have more spec impact and UE complexity, which should be study along with the gain of the various types for the use cases that are relevant to coverage enhancement.  If this proposal is not acceptable, we are also OK with having Type B as FFS. We don’t see the need to have the FFS for TBoMS, but can accept the majority view if this becomes a sticking point. |

**FL’s comments:**

**Regarding proposal 4, from FL perspective, I prefer to make a big step, i.e., “specify” or “define” if this is the majority view. I also understand that in some cases the time domain window may be implicitly derived, which means the time domain window may not be specified or configured. Then we have different alternatives to make progress.**

**Alt. 1: make a big step, agree to define or specify a time domain window.**

**Alt. 2: make a small step, agree to study a time domain window as suggested by Sierra Wireless.**

**Or can we make Alt 1 as a working assumption as a compromise? Then we can revisit it in next meeting if necessary.**

**Proposal 4:**

**Alt 1:**

* For joint channel estimation, define a time domain window during which UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.
  + 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 not be configured, e.g., depending on TDD frame structure.

**Alt 2:**

* For joint channel estimation, study a time domain window during which UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.
  + 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 not be configured or specified

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Intel | We support Alt. 1. In our view, a time domain window for joint channel estimation is needed. This is to ensure a common understanding between gNB and UE, i.e., from UE, when to transmit the PUSCH repetition with power consistency and phase continuity and from gNB, when to perform joint channel estimation. |
| InterDigital | We support Alt 1. At least, a framework for the time window can be defined and FFS points will assist the discussion. |
| Panasonic | We agree to SierraWireless comments that we are currently not so sure the need of time domain window itself as the terminology for the specification. On the other hand, to have such term would be useful at least for the discussion purpose. Therefore, we would like to suggest following update to Alt.1.  For joint channel estimation, for the discussion purpose at least, define a time domain window 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 term "time domain window" is used in the specification or not * 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 not be configured or specified |
| Sharp | We support Alt.1. As commented by Intel, the time domain window is necessary to ensure gNB/UE understanding. Discussion point should be whether the time domain window is explicitly configured or implicitly derived (e.g., by TDD configuration, the number of repetitions, etc.).  We are fine with putting an FFS proposed by Panasonic with minor change “FFS whether the term "time domain window" is used in the specification or **~~not~~replaced by other technical terms**”. In any case, we think “for the discussion purpose at least” can be removed. |
| Qualcomm | We support Alt 1. Specifying a window is necessary in some form or the other. The list of FFS bullets also offer a good picture on all the aspects in play while specifying such a window. |
| Samsung | We share similar view with Intel, we support Alt 1 to define the time domain window for power consistency and phase continuity. For compatibility with other schemes like inter-slot frequency hopping, same time domain windows should be applied to both gNB and UE. |
| CATT | We prefer Alt. 1. Also, we think we do not have to go with very detailed design here, so we suggest removing the example: ~~e.g., depending on TDD frame structure~~. It will be further studied anyway. |
| OPPO | Currently, we still cannot understand why a time domain window is needed for joint channel estimation based on current feedback from companies.  The proposal is that a time domain window during which UE is expected to maintain power consistency and phase continuity, is it a requirement for the UE’s hardware? How to understand maintain power consistency and phase continuity, zero error?  And what would have impact on the power consistency and phase continuity? It is not clear now.  Please note that during the study for MTC coverage enhancement, the residual frequency offset may have a dominant effect on feasibility of joint channel estimation and how many slots can be used for joint channel estimation.  As SierraWireless commented, there is no such time domain window specified for MTC for the purpose of joint channel estimation.So it shall be clearly justified why we need such a time domain window for NR.  We propose to firstly study which factors affect the power consistency and phase continuity. Then we decide how to enable this feature. |
| Lenovo, Motorola Mobility | We support Alt. 1 as we also agree that defining a time window is needed |
| WILUS | We support Alt 1. At least to ensure gNB/UE understanding, a concept of the time domain window can be defined in specification but how to define/implement the concept in specification should be further discussed. |
| Xiaomi | We think defining a time domain window is good for UE to maintain power consistency and phase continuity among PUSCH transmissions. But how to determine a suitable time domain window need to be further discussed. |
| Nokia/NSB | Although we supported the FL’s proposal in the previous round, we understand the concerns from Sierra Wireless and other companies. Therefore, in principle, we are fine with both alternatives. However, the wording “study” in Alt.2 may not be suitable for a WI and may cause some confusions in the next steps which require the time window. In this regard, we slightly prefer Alt. 1, in the worst case we can make it as a working assumption. |
| ZTE | We support Alt 2. We share with OPPO that we don’t see a need to explicitly specify a time window. For instance, a UE may be able to maintain power consistency and phase continuity for all consecutive PUSCH transmissions for a scheduled TB, then the time window would be the duration of these consecutive PUSCH transmissions, while there is no need to explicitly specify this time window. |
| LG | We support Alt. 1 in general.  During the time domain window, it should be guaranteed that UE is expected to maintain transmission timing consistency among PUSCH transmissions in addition to power consistency and power continuity.  Thus, we propose to modify the main bullet as follows.   * For joint channel estimation, define a time domain window during which UE is expected to maintain power consistency, ~~and~~ phase continuity, and transmission timing consistency among PUSCH transmissions subject to power consistency, ~~and~~ phase continuity, and transmission timing consistency requirements. |
| CMCC | We see not strong motivation to define a time domain window. If consecutive slots could satisfy the requirements of joint channel estimation, the slots could be as long as it required. In this case, there will be no even single or multiple windows, since all the window could be different according to the scheduling.  We share a similar view that, the “e.g., depending on TDD frame structure.” should be removed. A unified design is preferred for the system including both paired and unpaired system, and all the frame structure that supported. The condition of joint channel estimation should be on the basis of the slots or symbols. Then there is no need to emphasis frame structures. |
| Apple | We are a little conservative for this issue, as we don’t know yet whether joint channel estimation is feasible over non-consecutive slots. If not, then the time domain window is derived implicitly. Thus, the Alt.2 is slight preferred at this moment. |
| Ericsson | We prefer Alt. 2, or Panasonic’s version of Alt 1.  While there could be a need to specify a time window, how it would work and what the net benefit could be is not crystal clear yet. Given that this is a first meeting and that this is a fairly fundamental mechanism, we do not see the need to specify a time window in this meeting. Further discussion would give some time e.g. for UE vendors to elaborate further on how frequently adjustments large enough to degrade phase coherence are made, whether companies think the window always needs to be configured, etc. |

**FL’s comments:**

**It seems we need more study on optimization of DMRS location/granularity. Proposal 5 is revised as follows:**

**Proposal 5:**

* Companies are encouraged to study optimization of DMRS granularity in time domain, including:
  + Use cases
  + Simulations results
  + Enhanced schemes, e.g.,
    - Different DMRS density for different PUSCH transmissions
    - No DMRS for some PUSCH transmissions
* Companies are encouraged to study optimization of DMRS location in time domain, including:
  + Use cases
  + Simulations results
  + Enhanced schemes, e.g.,
    - DMRS equally spaced among PUSCH transmissions
    - DMRS located in special slots
    - Orphan symbol used for DMRS

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Intel | It would be good to first agree on simulation assumptions for DMRS optimization in order to check the performance of new proposed DMRS patterns vs. existing DMRS patterns. |
| InterDigital | We support the FL’s proposal. We support enhancement of DMRS for coverage enhancement and the outcome of additional study may clarify supporters’ views. In our view, baseline assumptions related to DMRS during the study item phase can be used in the evaluation. Thus, there is no need to have additional discussions for simulation assumptions for DMRS optimization. |
| Panasonic | We are fine with the proposal. |
| Sharp | We support FL proposal. |
| Qualcomm | We would be supportive of such a proposal. May we suggest adding one sub-bullet on “impact of dynamic changes, e.g., cancellation of a repetition” |
| Samsung | We are fine with FL’s proposal. |
| CATT | We are fine with the proposal. |
| OPPO | We are fine with the proposal.  To aligh companies’ simulation, it may be beneficial to agree the simulation assumptions. |
| Lenovo, Motorola Mobility | We support optimization of DMRS location in time-domain and are fine with FL’s proposal. Also agree to align on simulation assumptions. |
| WILUS | We are fine with the proposal. |
| Xiaomi | We are fine with the proposal. |
| Nokia/NSB | We are fine with the proposal. |
| ZTE | Fine with the proposal. We can first agree on this proposal, and if possible we can further set some baseline assumptions for more aligned comparison. For instance, focus on VoIP service in 700MHz FDD scenario using the assumptions studied in SI. |
| LG | First of all, the motivation of DMRS optimization should be verified taking into account specification work and performance benefit. So far, the priority on DMRS optimization should be lower than other fundamental topics. |
| CMCC | Fine with the proposal. And support the optimization of DMRS under the condition of joint channel estimation. |
| Apple | We are fine with the proposal. |
| Ericsson | We are OK to study DMRS enhancement, but agree with Intel, Lenovo, and OPPO on the importance of well aligned simulation assumptions. Also, impairments such as frequency offset should be taken into account to accurately gauge the potential of enhanced DMRS patterns.   * + Simulations results including where impairments are used   Also, according to the WID, DMRS enhancements are to support joint channel estimation:   * + 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   So ‘with joint channel estimation’ should be added to the main bullets for clarity, i.e.:   * Companies are encouraged to study optimization of DMRS granularity in time domain with joint channel estimation, including:   Companies are encouraged to study optimization of DMRS location in time domain with joint channel estimation, including: |

1. Email discussion (4th round)

**Proposal 4:**

Working assumption:

* For joint channel estimation, define a time domain window during which UE is expected to maintain power consistency and phase continuity among PUSCH transmissions subject to power consistency and phase continuity requirements.
  + 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 not be configured or specified.
* FFS: whether the term "time domain window" is used in the specification or replaced by other technical terms

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Sharp | We are OK with FL proposal. |
|  |  |
|  |  |

**Proposal 5:**

* 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
  + [impact of dynamic changes, e.g., cancellation of a repetition]
* 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 used for DMRS
  + [impact of dynamic changes, e.g., cancellation of a repetition]
* 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]

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Sharp | We are OK with FL proposal. |
|  |  |
|  |  |

**FL’s comments:**

**Based on the discussion during the GTW session, it seems difficult to achieve consensus on joint channel estimation for PUSCH repetition type B. Let’s continue the discussion on joint channel estimation for PUSCH repetition type B in next meeting. Regarding joint channel estimation for TBoMS, I would like to have another try whether we can make some progress.**

**Proposal 6:**

* 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 over multiple slots.

|  |  |
| --- | --- |
| **Companies** | **Comments** |
| Sharp | As commented in the GTW session, we can discuss joint channel estimation support for TB processing over multiple slots once we agree on the basic structure.   * If repetition type A is reused for TBoMS, joint channel estimation is already supported with the previous agreement. * If repetition type B is reused for TBoMS, according to FL observation, it should be discussed in the next meeting. * If new structure such as PUSCH crossing the slot boundary is adopted for TBoMS, we don’t see the need for joint channel estimation for single PUSCH transmission crossing the slot boundary.   In that sense, we propose to defer it to the next meeting. |
|  |  |
|  |  |

1. Agreements

**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)

1. Reference
2. 3GPP RP-202928, “New WID on NR coverage enhancements”, China Telecom, RAN#90e, December 7th – 11th, 2020.
3. R1-2100097 Discussion on joint channel estimation for PUSCH ZTE
4. R1-2100174 Joint channel estimation for PUSCH OPPO
5. R1-2100233 Discussion on Joint channel estimation for PUSCH Huawei, HiSilicon
6. R1-2100399 Discussion on joint channel estimation for PUSCH CATT
7. R1-2100459 Discussion on Joint channel estimation for PUSCH vivo
8. R1-2100558 Potential techniques for PUSCH coverage enhancement Potevio Company Limited
9. R1-2100667 Discussion on joint channel estimation for PUSCH Intel Corporation
10. R1-2100714 Discussions on joint channel estimation for PUSCH LG Electronics
11. R1-2100733 Discussions on joint channel estimation for PUSCH InterDigital, Inc.
12. R1-2100797 Considerations on joint channel estimation over multi-PUSCH Spreadtrum Communications
13. R1-2100917 Discussion on joint channel estimation for PUSCH China Telecom
14. R1-2101003 Enhancements for DM-RS bundling for multiple PUSCH Lenovo, Motorola Mobility
15. R1-2101020 Discussion on joint channel estimation for PUSCH Panasonic Corporation
16. R1-2101057 Discussion on joint channel estimation for PUSCH CMCC
17. R1-2101223 Joint channel estimation for PUSCH Samsung
18. R1-2101329 Design Considerations for Joint channel estimation for PUSCH Sierra Wireless, S.A.
19. R1-2101397 Discussion on joint channel estimation for PUSCH Apple
20. R1-2101479 Joint channel estimation for PUSCH Qualcomm Incorporated
21. R1-2101522 Joint Channel Estimation for PUSCH Ericsson
22. R1-2101547 Joint channel estimation for PUSCH Sharp
23. R1-2101643 Joint channel estimation for PUSCH NTT DOCOMO, INC.
24. R1-2101681 Discussion on joint channel estimation for PUSCH WILUS Inc.
25. R1-2101712 Joint channel estimation for PUSCH coverage enhancements Nokia, Nokia Shanghai Bell
26. Appendix

|  |  |
| --- | --- |
| **Company/Tdoc** | **Views** |
| ZTE/ R1-2100097 | ***Proposal 1:*** *For the determination of inter-slot bundling size, RAN1 down-selects from the two options below.*   * *Option 1: Inter-slot bundling size is implicitly determined by the number of repetitions K, e.g., floor (K/2) or cell(K/2).* * *Option 2: Inter-slot bundling size is RRC configured or dynamically indicated to a UE.*   ***Proposal 2:*** *FFS the inter-slot FH bundling pattern for TDD operation.*  ***Proposal 3:*** *If optimization of DMRS location/granularity in the time domain is supported, the following conditions should be considered to minimize specification impacts.*   * *DMRS optimization is only applied for PUSCH repetition type A.* * *DMRS pattern in each repetition is not changed.* * *Consider to reuse the repetition bundle defined for inter-slot FH for DMRS optimization.*   ***Proposal 4:*** *Postpone RAN1 discussion related to the conditions to keep power consistency and phase continuity among repetitions till receiving input from RAN4.* |
| OPPO/R1-2100174 | ***Observation: joint channel estimation may be impacted due to power reduction during PUSCH repetition.***  ***Proposal 1: Same DMRS antenna ports, same transmission power, same codebook, same Tx spatial parameters and same frequency domain resource allocation shall be applied among multiple PUSCH slots to enable joint channel estimation.***  ***Proposal 2: Study potential interoperation of joint channel estimation and pre-coder cycling.***  ***Proposal 3: PUSCH is hopped across different slot bundles to enable joint channel estimation.***  ***Proposal 4: DMRS-less, optimized DMRS pattern and non-uniform distributing DMRS can be considered for PUSCH repetition.*** |
| Huawei/ R1-2100233 | ***Proposal 1***: *From functionality perspective, the following use cases are beneficial and are expected to be supported.*   * *Continuous PUSCH transmissions with the same transmission power.* * *Muting symbols with zero transmission power (not downlink symbols) or SRS transmitted between successive PUSCH transmissions with the same transmission power.*   ***Proposal 2:*** *In joint channel estimation, DMRS patterns with different DMRS density for different PUSCH transmissions can be supported to better match fading channels*  ***Proposal 3:*** *In joint channel estimation, unavailable slots in PUSCH transmission but consist of UL symbols can be allocated as DMRS to improve the channel estimation performance once phase continuity between these slots and PUSCH transmissions can be ensured, e.g. S slot in TDD mode*  ***Proposal 4:*** *In joint channel estimation by DMRS sharing of multiple PUSCHs, non-DMRS PUSCH can be supported for a PUSCH transmission with very few number of symbols to reduce the DMRS overhead of this PUSCH.*  ***Proposal 5:*** *For inter-slot frequency hopping with inter-slot DMRS bundling, frequency hopping is performed every K slots where K is configurable.* |
| CATT/ R1-2100399 | ***Observation 1: Cross-slot channel estimation can be applied to PUSCHs in consecutive slots satisfying the requirement of power consistence and phase continuity.***  ***Observation 2: Joint channel estimation can be applied to multiple PUSCH transmissions including PUSCH with repetition, PUSCH with different TBs and TB processing over multi-slot PUSCH .***  ***Proposal 1: New DMRS patterns on continuous slots with lower DMRS density should be futher studied .***  ***Proposal 2: Frequency hopping pattern with inter-slot bundling can be determined according to the bundling window size.*** |
| vivo/ R1-2100459 | *Proposal 1: The mechanism to determine the DMRS bundling size should be considered.*  *Proposal 2: The time granularity for DMRS bundling is configurable, and NW provide the granularity based on UE capability.*  ***Proposal 3: UE can report capability on whether UE can ensure phase continuity for UL transmission across multiple occasions, and how long UE can maintain the phase continuity.***  ***Proposal 4: PUSCH transmissions with DMRS bundling may be interrupted by other transmissions/procedures, and whether and how to ensure phase continuity in these cases should be further studied. The interruptions can be caused in the following cases***   * ***PUSCH transmissions is cancelled by SFI, CI or higher priority transmissions,*** * ***UL transmission in another serving cell, when intra band CA is configured.***   ***Proposal 5: Support frequency hopping with inter-slot bundling to enable joint channel estimation.***  ***Proposal 6: The time domain granularity of frequency hopping/DMRS bundling size can be determined in consideration of available resources.***  ***Proposal 7: If DMRS bundling is supported, optimization on DMRS overhead in time domain can be considered.*** |
| Potevio/R1-2100558 | ***Proposal 1:*** Enhancement of inter-slot frequency hopping should be supported for NR coverage enhancement, and the number of inter-slot frequency hop positions should be increased to improve PUSCH coverage.  ***Proposal 2:*** Inter-repetition frequency hopping bundling should be supported to enable DMRS sharing.  ***Proposal 3:*** Actual repetitions segmented from the same nominal repetition in the same or continuous slots should share DMRS.  ***Proposal 4:*** Dynamic indication window size and inter-slot bundling size may be more suitable for cross-slot channel estimation.  ***Proposal 5:*** For joint channel estimation, whether the power and phase continuity can be kept across slot boundary should be further studied. |
| Intel/ R1-2100667 | **Proposal 1**   * *UE needs to keep same Tx power, precoder and frequency resource within a window for joint channel estimation over multiple PUSCHs.*   **Proposal 2**   * *Higher DMRS density in time domain is not supported for PUSCH coverage enhancement.*   **Proposal 3**   * *FFS lower DMRS density in time domain for PUSCH coverage enhancement.*   **Proposal 4**   * *For inter-slot frequency hopping with inter-slot bundling, the bundle size may be configured by higher layers, or implicitly determined based on the number of repetitions for PUSCH.* |
| LG/R1-2100714 | ***Proposal 1:*** A UE should not adjust uplink Tx power and uplink transmission timing within a duration of multiple slots for joint channel estimation.  ***Proposal 2:*** Clarify whether CA and/or DC operation scenario are/is included in work scope for coverage enhancement.  ***Proposal 3:*** Slot boundary for joint channel estimation is based on consecutive slots in both paired and unpaired spectrum.  ***Proposal 4:*** For frequency hopping with inter-slot bundling, frequency hopping boundary is defined by using consecutive *Y* slots on the cell-specific common time grid (i.e., slot index).  ***Proposal 5:*** The frequency hopping interval can be the equal to or smaller than slot bundle size for joint channel estimation. |
| R1-2100733/InterDigital | **Proposal 1: Support DMRS bundling across a set of Type A PUSCH repetitions scheduled by DCI**  **Proposal 2: Support DMRS bundling across a set of Type A PUSCH repetitions in configured grants**  **Proposal 3: Support DMRS bundling for Type B repetitions for both dynamic and configured grant**  **Proposal 4: Support DMRS bundling between PUSCH transmissions scheduled by different DCIs.**  **Proposal 5: Support DMRS bundling between a PUSCH transmission scheduled by DCI and a PUSCH transmission in a configured grant.**  **Proposal 6: Support DMRS bundling which includes PUSCH transmission in a special slot**  **Proposal 7: Support a semi-static mechanism to indicate to the UE that DMRS from the indicated group of PUSCHs can be used by gNB for joint channel estimation**  **Proposal 8: Support a grant-type dependent index which indicates PUSCH(s) to bundle** |
| Spreadtrum/R1-2100797 | ***Proposal 1. Most of the work can be left to gNB implementation for joint channel estimation over multiple PUSCH transmissions***  ***Proposal 2. Some studies needs to be done to avoid the unbalanced DMRS issue, at least the following two solutions can be considered:***   * ***Opt-1: Replace the unbalanced DMRS pattern by balanced pattern*** * ***Opt-2:Up to gNB to guarantee no appearance of unbalanced DMRS pattern under coverage enhancement mode***   ***Proposal 3. For both inter/intra-slot hopping, the supported PUSCH hoping positions/number should be increased, e.g., 4, 8, etc.*** |
| China Telecom/R1-2100917 | **Proposal 1: RAN1 needs to wait for the reply from RAN4 to determine whether there is any specification impact on UE behaviours in power control.**  **Proposal 2: With joint channel estimation over multiple PUSCH transmission, DMRS location/granularity in time domain can be optimized.**  **Proposal 3: For inter-slot frequency hopping with inter-slot bundling, the time domain hopping interval should be determined separately for FDD and TDD. The candidate values of the time domain hopping interval for FDD can be {1, 2, 4, 8} slots; the candidate values of the time domain hopping interval for TDD can be {1, 5, 10, 20} slots.** |
| Lenovo, Motorola Mobility/ R1-2101003 | ***Proposal 1: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, additional DM-RS time-domain pattern should be enhanced and consider:***   * ***to support equally spaced DM-RS symbols across multiple PUSCH*** * ***to avoid extrapolation for large number of symbols for the last PUSCH (similar design aspect as supported in NR)***   ***Proposal 2: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, UE should be configured with an additional new configuration for additional DM-RS patterns (for up to 14 symbols) to apply to all but the last PUSCH transmission***   * ***For the last PUSCH transmission, the current additional DM-RS configuration should be applied***   ***Proposal 3: For supporting joint channel estimation with DM-RS bundling across multiple PUSCHs for coverage enhancements in NR Rel-17, support multi-slot frequency hopping and multi-slot DM-RS bundling for joint channel estimation for entire hop***   * ***Association between frequency hop duration and DM-RS bundle duration should be considered*** |
| Panasonic/R1-2101020 | **Proposal 1: For joint channel estimation, whether back-to-back transmission is mandated or not is decided based on RAN4 guidance.**  **Proposal 2: Optimization of DMRS location/granularity should be specified only if the significant gain is identified.**  **Proposal 3: The length of DMRS bundling and the period of inter-slot frequency hopping can be the same.**  **Proposal 4: The indication to enable DMRS bundling and the length of DMRS bundling is UE-specific configuration.** |
| CMCC/R1-2101057 | **Proposal 1:**  **Study the constraint of joint channel estimation and identify the conditions and using scenarios of joint channel estimation.**  **Proposal 2:**  **The special slot should be considered for the joint channel estimation, considering additional DMRS resources to improve the accuracy of channel estimation and additional transmission resources to improve the data rates.**  **Proposal 3:**  **The optimization of DMRS location or granularity, such as reduced density in time domain should be considered during the study of joint channel estimation.**  **Proposal 4:**  **Design new frequency hopping pattern for PUSCH to facilitate joint channel estimation.** |
| Samsung/R1-2101223 | ***Proposal 1: UE controls PUSCH transmission power for power consistency in case of joint channel estimation.***  ***Option 1: UE can apply same PUSCH transmission power over a set of multiple PUSCH repetitions of a PUSCH transmission.***  ***Option 2: UE does not expect to change the PUSCH transmission power over all repetitions of a PUSCH transmission.***  ***Proposal 2: UE performs PUSCH frequency hopping based on the set of multiple PUSCH transmissions for joint channel estimation. The set is either configured by the gNB (option 1) or is equal to N/2 (option 2) for a PUSCH transmission with N repetitions.***  ***Proposal 3: In case of joint channel estimation, UE performs DMRS mapping based on the total number of symbols of multiple PUSCH repetitions.***  ***Proposal 4: Available UL symbols (e.g. actual repetitions with single symbol) can be used as PUSCH transmission and/or DMRS in case of joint channel estimation.***  ***Proposal 5: A UE determines the set of repetitions for joint channel estimation, inter-slot frequency hopping, UL power control, and DMRS mapping based on***  ***Option 1: The number of PUSCH repetitions***  ***Option 2: Network configurations by RRC*** |
| Sierra Wireless/ R1-2101329 | 1. LLS simulation assumptions for joint channel estimation should focus on indoor low doppler scenarios (e.g. 2 Hz) since it is most likely to experience coverage issues due to inbuilding penetration loss. 2. LLS simulation assumptions for joint channel estimation should assume some residual CFO  * **FFS: CFO values (e.g. uniformly distributed -30 to 30Hz)**  1. Wait for RAN4’s response on phase continuity before agreeing to specify inter-slot bundling for frequency hopping as it may not be needed. 2. Study resource allocation and procedural changes which could increase the likelihood that a UE could maintain phase continuity across TDD frames.   Proposal 5: Specify that UEs shall signal their phase continuity capabilities to the gNB. |
| Apple/R1-2101397 | **Proposal 1: Joint channel estimation on the non-continuous UL slots is not supported. For continuous UL slots, wait for RAN4 feedback on the conditions to perform joint channel estimation.**  **Proposal 2: Specify the inter-slot frequency hopping pattern to enable the conjunction operation of repetition, frequency hopping and cross-slot channel estimation.** |
| Qualcomm/R1-2101479 | **Proposal 1**: Joint channel estimation is supported for PUSCHs scheduled by dynamic grant subject to phase continuity requirements.  **Proposal 2**: Joint channel estimation is supported for PUSCHs scheduled by configured grant subject to phase continuity requirements.  **Proposal 3**: Joint channel estimation is not supported for PUSCHs of different scheduling types.  **Proposal 4**: Joint channel estimation is only supported for Type A PUSCH repetitions.  **Proposal 5**: Discuss whether joint channel estimation should be considered for PUSCHs scheduled to carry different transport blocks in Rel-17.  **Proposal 6:** Define a bundling window over which the UE may bundle DMRSs of PUSCH transmissions according to phase continuity requirements.   * The UE is not required to bundle DMRS of the PUSCH transmissions scheduled outside of the bundling window. * FFS: how to indicate the bundling window configuration.   **Proposal 7**: For each PUSCH transmission, the UE signals a bundling indication in a UCI multiplexed with the PUSCH transmission.  **Proposal 8:** The PUSCH transmissions in the same hop may be bundled. Furthermore, only support non-interleaving case where the bundled PUSCHs are consecutively transmitted. |
| Ericsson/R1-2101522 | **Proposals:**   * Further study the benefit of gNB estimated inter-slot relative phase correction for PUSCH, addressing how frequency selective such phase corrections would need to be for UEs and/or conditions that do not sufficiently support maintaining inter-slot relative phase. * Consider operation with and without frequency hopping or multiantenna transmission such as UL MIMO or transparent transmit diversity. * Identify which mechanisms should be specified and which can be gNB implementation to support phase coherence across slots with multiple repetitions. |
| Sharp/R1-2101547 | **Proposal 1: Phase continuity requirement should be specified only when there are no DL portions in two PUSCH transmissions. A duration where the phase continuity shall be maintained should not overlap with DL portions.**  **Proposal 2: Within a duration where the phase continuity shall be maintained, the gNB ensures the same UE transmission power for the PUSCH transmission occasions within the duration.**  **Proposal 3: The duration where the phase continuity shall be maintained can be considered as a frequency hopping interval.**  **Proposal 4: Joint channel estimation for multiple PUSCHs with separate DCI formats is supported.** |
| DOCOMO/R1-2101643 | **Proposal 1: S+U slots in TDD configuration should be considered for joint channel estimation.**  **Proposal 2: New DM-RS symbol position (location/granularity in time domain) should be considered when cross-slot channel estimation is adapted.**  **Observation 1: It is valuable to insert DM-RS symbols in S slot for the joint channel estimation with next uplink slot.** |
| WILUS/R1-2101681 | ***Proposal 1: For inter-slot frequency hopping with inter-slot bundling, it should be further discussed to determine frequency hopping index by taking into account UE multiplexing, frequency hop balancing and availability of joint channel estimation.*** |
| Nokia, NSB/R1-2101712 | [**Proposal 1.** **RAN1 to specify an indication method letting the gNB enable/disable the power consistency and phase continuity requirements for the UE.**](#_Toc61887413)   * ***FFS: Details of the indication methodology, e.g., dynamic/semi-static etc.*** * ***FFS: Whether any restriction should be applied, e.g., joint channel estimation is only applied across PUSCH with the same PHY priority, or joint channel estimation is only applied across repetitions of the same PUSCH transmission.***   [**Proposal 2.** **A time-domain window, within which power consistency and phase continuity are guaranteed across PUSCHs for joint channel estimation, should be configured by gNB.**](#_Toc61887414)   * ***FFS: Definition of the details of time-domain window configuration and indication.***   [**Proposal 3.** **For the Rel-17 joint channel estimation feature, RAN1 to specify a procedure for equally distributing DM-RS symbols on the concatenated resource of the PUSCHs in time-domain that satisfy the power and phase conditions.**](#_Toc61887415)   * ***FFS: Details of the procedure for equally distributing DM-RS symbols, including introducing a spacing parameter such DM-RS symbols between the first and the last one in the considered resource at a constant spacing one from another.*** * ***FFS: Method for indicating the spacing parameter***   [**Proposal 4.** **For inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation, a concept of inter-window frequency hopping should be specified, where each window is a time-domain window, within which power consistency and phase continuity are both guaranteed across PUSCHs for joint channel estimation.**](#_Toc61887416) |