**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. |
|  |  |

**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. |

* 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. |
|  |  |

## 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. |

* 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. |
|  |  |

* 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). |

## 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. |
|  |  |

* 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. |
|  |  |

## 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 |

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. |
|  |  |

* 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. |
|  |  |
|  |  |

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. |
|  |  |

* 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. |
|  |  |

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. |
|  |  |

## 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. |
|  |  |

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. |
|  |  |
|  |  |

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

|  |  |
| --- | --- |
| **Companies** | **Comments** |
|  |  |
|  |  |
|  |  |

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) |