**3GPP TSG RAN WG1 #106-e**  **R1- 210xxxx**

e-Meeting, August 16th – 27th, 2021

**Agenda item:** 7.2.2

**Source:** Moderator (vivo)

**Title:** Summary of [106-e-NR-NRU-02] Issue#T6: Frequency hopping for multi-PUSCH scheduling with single DCI

**Document for:** Discussion and Decision

# 1 Introduction

This document is to kick-off the following email discussion:

* [106-e-NR-NRU-02] Email discussion/approval on frequency hopping for multi-PUSCH scheduling with single DCI (Issue T6) until August 20 – Gen Li (vivo)

**Please provide your feedback by UTC 11:59 AM, August 18.**

# 2 Background

In RAN1#105-e meeting, issue on frequency hopping for multi-PUSCH scheduling is discussed under agenda 8.2.5 in NR Rel-17 52.6-71GHz WI [1]. Among the discussions, it seems not clear on how to perform frequency hopping in NRU for multi-PUSCH scheduling in case of resource allocation type 1. In this meeting, two papers are discussing this issue for NRU maintenance.

In **[2]**, the following CR is proposed to clarify that only intra-slot frequency hopping applies to PUSCH transmissions scheduled with a single DCI:

\*\*\* Unchanged text omitted \*\*\*

6.3 UE PUSCH frequency hopping procedure

6.3.1 Frequency hopping for PUSCH repetition Type A

For PUSCH repetition Type A (as determined according to procedures defined in Clause 6.1.2.1 for scheduled PUSCH, or Clause 6.1.2.3 for configured PUSCH), a UE is configured for frequency hopping by the higher layer parameter *frequencyHoppingDCI-0-2* in *pusch-Config* for PUSCH transmission scheduled by DCI format 0\_2, and by *frequencyHopping* provided in *pusch-Config* for PUSCH transmission scheduled by a DCI format other than 0\_2*,* and by *frequencyHopping* provided in *configuredGrantConfig* for configured PUSCH transmission. One of two frequency hopping modes can be configured:

- Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission and multiple PUSCH transmissions scheduled by a DCI.

- Inter-slot frequency hopping, applicable to multi-slot PUSCH transmission.

In case of resource allocation type 2, the UE transmits PUSCH without frequency hopping.

In case of resource allocation type 1, whether or not transform precoding is enabled for PUSCH transmission, the UE may perform PUSCH frequency hopping, if the frequency hopping field in a corresponding detected DCI format or in a random access response UL grant is set to 1, or if for a Type 1 PUSCH transmission with a configured grant the higher layer parameter *frequencyHoppingOffset* is provided, otherwise no PUSCH frequency hopping is performed. When frequency hopping is enabled for PUSCH, the RE mapping is defined in clause 6.3.1.6 of [4, TS 38.211].

For a PUSCH scheduled by RAR UL grant, fallbackRAR UL grant, or by DCI format 0\_0 with CRC scrambled by TC-RNTI, frequency offsets are obtained as described in clause 8.3 of [6, TS 38.213]. Otherwise, for a PUSCH scheduled by DCI format 0\_0/0\_1 or a PUSCH based on a Type2 configured UL grant activated by DCI format 0\_0/0\_1 and for resource allocation type 1, frequency offsets are configured by higher layer parameter *frequencyHoppingOffsetLists* in *pusch-Config*. For a PUSCH scheduled by DCI format 0\_2 or a PUSCH based on a Type2 configured UL grant activated by DCI format 0\_2 and for resource allocation type 1, frequency offsets are configured by higher layer parameter *frequencyHoppingOffsetListsDCI-0-2* in *pusch-Config*.

- When the size of the active BWP is less than 50 PRBs, one of two higher layer configured offsets is indicated in the UL grant.

- When the size of the active BWP is equal to or greater than 50 PRBs, one of four higher layer configured offsets is indicated in the UL grant.

For PUSCH based on a Type1 configured UL grant the frequency offset is provided by the higher layer parameter *frequencyHoppingOffset* in *rrc-ConfiguredUplinkGrant*.

For a MsgA PUSCH the frequency offset is provided by the higher layer parameter as described in [6, TS 38.213].

In case of intra-slot frequency hopping, the starting RB in each hop is given by:

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where *i*=0 and *i*=1 are the first hop and the second hop respectively, and  is the starting RB within the UL BWP, as calculated from the resource block assignment information of resource allocation type 1 (described in Clause 6.1.2.2.2) or as calculated from the resource assignment for MsgA PUSCH (described in [6, TS 38.213]) and is the frequency offset in RBs between the two frequency hops. The number of symbols in the first hop is given by , the number of symbols in the second hop is given by , where is the length of the PUSCH transmission in OFDM symbols in one slot.

In case of inter-slot frequency hopping, the starting RB during slot  is given by:

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where  is the current slot number within a radio frame, where a multi-slot PUSCH transmission can take place,  is the starting RB within the UL BWP, as calculated from the resource block assignment information of resource allocation type 1 (described in Clause 6.1.2.2.2) and is the frequency offset in RBs between the two frequency hops.

\*\*\* Unchanged text omitted \*\*\*

In **[3]**, frequency hopping for multi-PUSCH scheduling has been discussed with the following observations and proposals:

*Observation 1: Multi-PUSCH scheduling by DCI format 0\_1 follows PUSCH repetition Type A procedure when determining the time domain resource allocation for PUSCH scheduled by PDCCH.*

*Observation 2: No multi-slot PUSCH transmission will be expected if multi-PUSCH scheduling is configured or enabled.*

***Proposal 1: Clarify that intra-slot frequency hopping is applicable to multi-PUSCH scheduling, while inter-slot frequency hopping is not applicable to multi-PUSCH scheduling.***

# 3 Discussions

The main issue is clarification of frequency hopping type applicable to multi-PUSCH scheduling scheduled by a single DCI in case of resource allocation type 1. Please provide your views on the following two questions:

### Question 1:

Do you agree that “only intra-slot frequency hopping applies to PUSCH transmissions scheduled with a single DCI in case of resource allocation type 1”? If answer to the above is no, please provide your alternative views.

|  |  |
| --- | --- |
| Company | View |
| Nokia, NSB | Yes, we agree |
| Intel | Yes, we agree |
| Huawei, HiSilicon | Yes, we agree that “only intra-slot frequency hopping applies to PUSCH transmissions scheduled with a single DCI in case of resource allocation type 1”, and that inter-slot frequency hopping doesn’t apply to PUSCH transmissions scheduled with a single DCI. |
| LG | Yes, we also agree. |
| Lenovo, Motorola Mobility | Yes, we agree |
| Sharp | Yes, we agree. |
| Ericsson | Yes, we agree. |
| Samsung | Yes, we agree. |
| Spreadtrum | Yes, we agree. |
| WILUS | Yes, we agree. |
| ZTE, Sanechips | Yes, we agree. |
| Qualcomm | We feel we should disallow inter-slot and intra-slot hopping for PUSCH transmission with type 1 resource allocation. There is a channel access issue involved in NR-U. Say if the first hop is within one RB set but the 2nd hop is in another RB set, we don’t have a mechanism to perform another LBT before the 2nd hop, which has large gap from the gNB DL transmission. Instead of a complicated solution, it is easier to disallow hopping for type 1 RA when shared spectrum access is used. |
| vivo | Yes, we agree |

### Question 2:

Regarding how to clarify the above understanding, please provide your views on the following alternatives:

* Alt. 1: Conclusion is enough and no spec change is needed.
  + Note: Multi-PUSCH scheduled by a single DCI belongs to single slot PUSCH transmission.
* Alt. 2: Spec change is needed as proposed in [2].

|  |  |
| --- | --- |
| Company | View |
| Nokia, NSB | Alt 2: we prefer a spec change as proposed. |
| Intel | Alt 2 |
| Huawei, HiSilicon | We think a spec change is preferable than a conclusion. The note under conclusion in Alt1 may be confusing in itself if it is taken outside its context.  The spec change proposed in [2] could be improved in our view. “multiple PUSCH transmissions scheduled by a DCI” could still be confusing since even Rel-15 uses one DCI for providing multiple timing offsets for semi persistent reporting using PUSCH.  Additional clarity could be provided by referring to the higher-layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH*:  - Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission, and to multiple PUSCH transmissions scheduled by a DCI if the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH* is configured. |
| LG | We also prefer Alt 2 with slight modification for the clarity as below.  - Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission and each of multiple PUSCH transmissions scheduled by a DCI. |
| Lenovo, Motorola Mobility | We prefer a spec change. LG’s modification seems better. |
| Sharp | Alt 2. |
| Ericsson | As proponent, we prefer a spec change for clarity. We are okay with LGE and Huawei’s proposed changes, and they can be merged. |
| Samsung | We support a spec change.  We also think adding ‘each of’ suggested by LGE together with ‘*pusch-TimeDomainAllocationListForMultiPUSCH*’ is more clear. |
| Spreadtrum | We prefer Alt 2 with the proposed changes of Huawei and LGE. |
| WILUS | We prefer a spec change with suggestion by both LG and HW as following:  - Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission, and each of multiple PUSCH transmissions scheduled by a DCI if the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH* is configured. |
| ZTE, Sanechips | We prefer Alt 2 with the proposed changes of Huawei and LGE. |
| Qualcomm | - Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission.  - Inter-slot frequency hopping, applicable to multi-slot PUSCH transmission.  For operation with shared spectrum channel access, intra-slot frequency hopping and inter-slot frequency hopping are not applicable. |
| vivo | Support Alt 2 with the proposed changes of Huawei and LGE |

# 4 Summary and Proposal

### Summary on Question 1:

* Only intra-slot frequency hopping applies to multiple PUSCH transmissions scheduled with a single DCI in case of resource allocation type 1.
  + Support: Nokia, NSB, Intel, Huawei, HiSilicon, Lenovo, Motorola Mobility, Sharp, Ericsson, Samsung, Spreadtrum, WILUS, ZTE, Sanechips, vivo
  + Not support: Qualcomm (disallow hopping for type 1 RA when shared spectrum access is used)

### Summary on Question 2:

All companies prefer to have spec updates to clarify frequency hopping issue and the following two TPs are proposed:

* **TP1 for TS 38.213**: Supported by Nokia, NSB, Intel, Huawei, HiSilicon, Lenovo, Motorola Mobility, Sharp, Ericsson, Samsung, Spreadtrum, WILUS, ZTE, Sanechips, vivo

\*\*\* Unchanged text omitted \*\*\*

6.3 UE PUSCH frequency hopping procedure

6.3.1 Frequency hopping for PUSCH repetition Type A

For PUSCH repetition Type A (as determined according to procedures defined in Clause 6.1.2.1 for scheduled PUSCH, or Clause 6.1.2.3 for configured PUSCH), a UE is configured for frequency hopping by the higher layer parameter *frequencyHoppingDCI-0-2* in *pusch-Config* for PUSCH transmission scheduled by DCI format 0\_2, and by *frequencyHopping* provided in *pusch-Config* for PUSCH transmission scheduled by a DCI format other than 0\_2*,* and by *frequencyHopping* provided in *configuredGrantConfig* for configured PUSCH transmission. One of two frequency hopping modes can be configured:

- Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission and each of multiple PUSCH transmissions scheduled by a DCI if the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH* is configured.

- Inter-slot frequency hopping, applicable to multi-slot PUSCH transmission.

\*\*\* Unchanged text omitted \*\*\*

* **TP2 for TS 38.213**: Proposed by Qualcomm

\*\*\* Unchanged text omitted \*\*\*

6.3 UE PUSCH frequency hopping procedure

6.3.1 Frequency hopping for PUSCH repetition Type A

For PUSCH repetition Type A (as determined according to procedures defined in Clause 6.1.2.1 for scheduled PUSCH, or Clause 6.1.2.3 for configured PUSCH), a UE is configured for frequency hopping by the higher layer parameter *frequencyHoppingDCI-0-2* in *pusch-Config* for PUSCH transmission scheduled by DCI format 0\_2, and by *frequencyHopping* provided in *pusch-Config* for PUSCH transmission scheduled by a DCI format other than 0\_2*,* and by *frequencyHopping* provided in *configuredGrantConfig* for configured PUSCH transmission. One of two frequency hopping modes can be configured:

- Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission.

- Inter-slot frequency hopping, applicable to multi-slot PUSCH transmission.

For operation with shared spectrum channel access, intra-slot frequency hopping and inter-slot frequency hopping are not applicable.

\*\*\* Unchanged text omitted \*\*\*

In the above discussion, Qualcomm mentioned that LBT for hopping PUSCH transmission may become complicated when one hop is on one RB set and the other hop is on another RB set when operation with shared spectrum access.

From moderator’s understanding, multi-PUSCH scheduling applies to both licensed and unlicensed operation. At least there is no LBT issue for intra-slot frequency hopping applied to multi-PUSCH transmission in licensed operation. Then TP1 is still valid to clarify the frequency hopping mode for multi-PUSCH transmission scheduled by a DCI. Besides, even for unlicensed operation, intra-slot frequency hopping still works for the case when two hop transmissions are confined within the same RB set. Since LBT mechanism is not defined for the case that two hop transmissions are not confined within the same RB set, gNB implementation should avoid such case by proper configuration and scheduling.

Considering majority support of TP1 and the above explanation, the following proposal is made:

### Moderator Proposal:

Only intra-slot frequency hopping applies to multiple PUSCH transmissions scheduled with a single DCI in case of resource allocation type 1 with the following spec update in TS 38.213:

\*\*\* Unchanged text omitted \*\*\*

6.3 UE PUSCH frequency hopping procedure

6.3.1 Frequency hopping for PUSCH repetition Type A

For PUSCH repetition Type A (as determined according to procedures defined in Clause 6.1.2.1 for scheduled PUSCH, or Clause 6.1.2.3 for configured PUSCH), a UE is configured for frequency hopping by the higher layer parameter *frequencyHoppingDCI-0-2* in *pusch-Config* for PUSCH transmission scheduled by DCI format 0\_2, and by *frequencyHopping* provided in *pusch-Config* for PUSCH transmission scheduled by a DCI format other than 0\_2*,* and by *frequencyHopping* provided in *configuredGrantConfig* for configured PUSCH transmission. One of two frequency hopping modes can be configured:

- Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission and each of multiple PUSCH transmissions scheduled by a DCI if the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH* is configured.

- Inter-slot frequency hopping, applicable to multi-slot PUSCH transmission.

\*\*\* Unchanged text omitted \*\*\*

Please provide your view for the above proposal:

|  |  |
| --- | --- |
| Company | View |
| Qualcomm | Understand majority view is to support intra-slot hopping only. Our question is, is hopping across RB sets considered as a problem, and do we need to further address it in channel access.  If we want to keep the feature for licensed band operation, maybe we can disallow hopping only for shared spectrum channel access by merging the TPs  - Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission and each of multiple PUSCH transmissions scheduled by a DCI if the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH* is configured.  - Inter-slot frequency hopping, applicable to multi-slot PUSCH transmission.  For operation with shared spectrum channel access, intra-slot frequency hopping and inter-slot frequency hopping are not applicable. |
| Huawei, HiSilicon | The problem raised by Qualcomm seems valid. For example, when PUSCH hopping occurs across 2x20 MHz then in the first half of the slot UE1 is not occupying one of the 20 MHz channel. Even if UE1 performed LBT over 40 MHz, another UE2 may have performed 20 MHz LBT over the unoccupied 20 MHz channel and started its own transmission, which will then collide with PUSCH of UE1 in the second half of the slot.  If hopping is across 2x10 MHz then UE2 may still be able to detect UE1 by performing 20 MHz LBT, but the protection distance will be reduced (due to max PSD constraints, not sure also if there is any OCB issue there for UE1).  We should note that NRU supports interlaced PUSCH transmission with resource allocation type 2, which can achieve the same frequency diversity benefits as PUSCH with intra-slot hopping with resource allocation type 1. Therefore, precluding intra-slot PUSCH hopping with resource allocation type 1 for NRU may not be critical.  In summary, we think Qualcomm’s TP above is reasonable. |
| ZTE, Sanechips | On a second thought, we think Qualcomm’s question is valid and critical, we need to further discuss and consider the validity of the 2nd Hop due to LBT. From this, we tend to support TP2 proposed by Qualcomm. |
| Ericsson | We agree that Qualcomm raises a valid point. But maybe it is a bit heavy handed to disable intra-slot frequency hopping completely for shared spectrum channel access. For the case of a 20 MHz carrier (single RB set) or for the case of a wideband carrier when no guard bands are used (zero-size guard bands) frequency hopping is feasible, and useful if Type-1 resource allocation is configured. For the case of zero-size guard bands, it implies that the UE performs "all-or-nothing" transmission, i.e., in all RB sets of the carrier or none.  To solve this, the following modification could be made to Qualcomm's TP:  For operation with shared spectrum channel access, intra-slot frequency hopping and inter-slot frequency hopping are not applicable unless the number of RB sets for the carrier is 1 or the UE is provided with *nrofCRBs =* 0 for all intra-cell guard band(s) on a carrier according to Clause 7. |
| OPPO | We support TP2 proposed by Qualcomm. |
| Sharp | We are fine with TP from Qualcomm. |
| LG | We are fine with TP from Qualcomm. |
| Nokia, NSB | We agree with Qualcomm’s point on problems in the unlicensed case and support the TP by QCOM. |

Moderator’s note: According to the discussions so far, two TPs are proposed by companies to solve unlicensed operation problem as provided below.

### TP 3:

\*\*\* Unchanged text omitted \*\*\*

6.3 UE PUSCH frequency hopping procedure

6.3.1 Frequency hopping for PUSCH repetition Type A

For PUSCH repetition Type A (as determined according to procedures defined in Clause 6.1.2.1 for scheduled PUSCH, or Clause 6.1.2.3 for configured PUSCH), a UE is configured for frequency hopping by the higher layer parameter *frequencyHoppingDCI-0-2* in *pusch-Config* for PUSCH transmission scheduled by DCI format 0\_2, and by *frequencyHopping* provided in *pusch-Config* for PUSCH transmission scheduled by a DCI format other than 0\_2*,* and by *frequencyHopping* provided in *configuredGrantConfig* for configured PUSCH transmission. One of two frequency hopping modes can be configured:

- Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission and each of multiple PUSCH transmissions scheduled by a DCI if the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH* is configured.

- Inter-slot frequency hopping, applicable to multi-slot PUSCH transmission.

For operation with shared spectrum channel access, intra-slot frequency hopping and inter-slot frequency hopping are not applicable.

\*\*\* Unchanged text omitted \*\*\*

### TP 4:

\*\*\* Unchanged text omitted \*\*\*

6.3 UE PUSCH frequency hopping procedure

6.3.1 Frequency hopping for PUSCH repetition Type A

For PUSCH repetition Type A (as determined according to procedures defined in Clause 6.1.2.1 for scheduled PUSCH, or Clause 6.1.2.3 for configured PUSCH), a UE is configured for frequency hopping by the higher layer parameter *frequencyHoppingDCI-0-2* in *pusch-Config* for PUSCH transmission scheduled by DCI format 0\_2, and by *frequencyHopping* provided in *pusch-Config* for PUSCH transmission scheduled by a DCI format other than 0\_2*,* and by *frequencyHopping* provided in *configuredGrantConfig* for configured PUSCH transmission. One of two frequency hopping modes can be configured:

- Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission and each of multiple PUSCH transmissions scheduled by a DCI if the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH* is configured.

- Inter-slot frequency hopping, applicable to multi-slot PUSCH transmission.

For operation with shared spectrum channel access, intra-slot frequency hopping and inter-slot frequency hopping are not applicable unless the number of RB sets for the carrier is 1 **[**or the UE is provided with *nrofCRBs =* 0 for all intra-cell guard band(s) on a carrier according to Clause 7**]**.

\*\*\* Unchanged text omitted \*\*\*

For TP3 proposed by Qualcomm, intra-slot frequency hopping applies to multiple PUSCH transmissions scheduled with a single DCI i in licensed operation and dis-allow frequency hopping in unlicensed operation in case of resource allocation type 1;

For TP4 proposed by Ericsson, frequency hopping is still allowed in certain cases of unlicensed operation, e.g. the number of RB sets for the carrier is 1. As mentioned by Huawei in email, moderator share the same view that no intra-guard band case may also have problem since it can’t occupy the RB set for 2nd hop. Then I put a bracket for that case in TP4.

Please continue to provide views on both TP3 and TP4 (acceptable or not) in the following table:

|  |  |  |  |
| --- | --- | --- | --- |
|  | **TP3** | **TP4 without bracket** | **TP4 with bracket** |
| vivo | Acceptable (2nd preference) | Acceptable (1st preference) | Not Acceptable |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

# References

1. [R1-2106105](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Docs/R1-2106105.zip), Summary #2 of PDSCH/PUSCH enhancements (Scheduling/HARQ), Modertaor (LG Electronics)

1. [R1-2107695](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_106-e/Docs/R1-2107695.zip), Correction on frequency hopping for multi-PUSCH scheduling with single DCI, Ericsson Inc.

1. [R1-2107976](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_106-e/Docs/R1-2107976.zip), Discussion on frequency hopping for multi-PUSCH scheduling, vivo.