**3GPP TSG RAN WG1 #108-e R1-22XXXXX**

**e-Meeting, February 21st – March 3rd, 2022**

**Source: Moderator (vivo)**

**Title: Summary of [108-e-R16-NR-U-03] Issue#T2: Frequency hopping for NR-U CG-PUSCH**

**Agenda Item: 7.2.2**

**Document for: Discussion and Decision**

1. **Introduction**

The document is to collect companies’ inputs and provide a summary for the email discussion thread

[108-e-R16-NR-U-03] Email discussion/approval on frequency hopping for NR-U CG-PUSCH (Issue T2 in R1-2202492) by February 25 – Gen Li (vivo)

Companies are highly appreciated providing your Round 1 inputs before the 1st checkpoint:

* **1st checkpoint: 22nd Feb. 23:59 UTC**

1. **Discussions**

## Background

In RAN1#107-e, it was agreed that only intra slot frequency hopping is supported for each of multiple PUSCHs scheduled by a single DCI for both licensed and unlicensed band. Besides, the frequency hopping is applied only when the two hops are in the same RB set for PUCCH/SRS/PUSCH, where corresponding CRs were endorsed in R1-2112822 (CR0265) on TS38.213 and R1-2112823 (CR0220) on TS38.214 [1].

In NR-U Rel-16, a new type of configured grant PUSCH transmission is specified by providing *cg-nrofSlots* and *cg-nrofPUSCH-InSlot* in a configuration. The resource allocation refers to the following text in TS 38.214 [1]:

6.1.2.3 Resource allocation for uplink transmission with configured grant

A set of allowed periodicities *P* are defined in [12, TS 38.331]. The higher layer parameter *cg-nrofSlots*, provides the number of consecutive slots allocated within a configured grant period. The higher layer parameter *cg-nrofPUSCH-InSlot* provides the number of consecutive PUSCH allocations within a slot, where the first PUSCH allocation follows the higher layer parameter *timeDomainAllocation* for Type 1 PUSCH transmission or the higher layer configuration according to [10, TS 38.321], and UL grant received on the DCI for Type 2 PUSCH transmissions, and the remaining PUSCH allocations have the same length and PUSCH mapping type, and are appended following the previous allocations without any gaps. The same combination of start symbol and length and PUSCH mapping type repeats over the consecutively allocated slots.

Besides, repetition scheme for NR-U CG-PUSCH refers to the following text in TS 38.214 [1]:

6.1.2.3.1 Transport Block repetition for uplink transmissions of PUSCH repetition Type A with a configured grant

For both Type 1 and Type 2 PUSCH transmissions with a configured grant, when *K >* 1*,* the UE shall repeat the TB across the *K* consecutive slots applying the same symbol allocation in each slot, except if the UE is provided with higher layer parameters *cg-nrofSlots* and *cg-nrofPUSCH-InSlot*, in which case the UE repeats the TB in the *repK* earliest consecutive transmission occasion candidates within the same configuration. A Type 1 or Type 2 PUSCH transmission with a configured grant in a slot is omitted according to the conditions in Clause 9, Clause 11.1 and Clause 11.2A of [6, TS38.213].

Obviously, NR-U CG-PUSCH belongs to PUSCH repetition Type A, where applicable frequency hopping modes are specified below:

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.

However, it is not clear which frequency hopping mode is applicable to the new NR-U CG-PUSCH when *cg-nrofSlots* and *cg-nrofPUSCH-InSlot* are provided. Therefore, this issue is discussed in [2], [5] and [6] while related Rel-16 CRs are provided in [3], [4]and [7].

In [2], the following three candiates for frequency hopping are analyzed: intra-slot, inter-slot and inter-repetition frequency hopping. Geenrally, it is proposed in [2] to support intra-slot FH only for NR-U CG-PUSCH to achive a good tradeoff of gain and impact by considering comparison in the following aspects.

|  |  |  |  |
| --- | --- | --- | --- |
|  | More Spec impact | Diversity gain | LBT impact |
| Intra-slot FH | No | Yes | No |
| Inter-slot FH | No | No | Yes |
| Inter-repetition FH | Yes | Yes | Yes |

In [5], it is also proposed to support intra-slot FH only for NR-U CG-PUSCH due to the fact that inter-slot FH is not suitable for NR-U CG-PUSCH repetition. This is because the same TB may be included in the same hop but different TB included in the different hop.

In [6], it is proposed that the applicable frequency hopping mode depends on the value of *repK*. Namely, intra-slot FH is supported for NR-U CG-PUSCH with *repK*=1 and inter-repetition frequency hopping is supported with *repK*>1.

In general, the following alternatives are proposed for applicable FH mode to NR-U CG-PUSCH:

* Alt. 1 ([2] and [5]): Only intra-slot frequency hopping is applicable to NR-U CG-PUSCH
* Alt. 2 ([6]): Intra-slot frequency hopping is applicable to NR-U CG-PUSCH with *repK*=1 and inter-repetition frequency hopping is applicable to NR-U CG-PUSCH with *repK*>1

## Company views (Round 1)

Please kindly provide your views in the tables below.

##### Question 1: Which one of the following alternatives is preferred for applicable frequency hopping mode of NR-U CG-PUSCH?

* Alt. 1: Only intra-slot frequency hopping is applicable to NR-U CG-PUSCH
* Alt. 2: Intra-slot frequency hopping is applicable to NR-U CG-PUSCH with *repK*=1 and inter-repetition frequency hopping is applicable to NR-U CG-PUSCH with *repK*>1
* **If there is no preferred one from the above two alternatives, please provide other alternatives below**

|  |  |  |
| --- | --- | --- |
| Company | Preferred Alternative | Comment |
| Huawei, HiSilicon | Alt. 2 | We understand that the benefit of frequency diversity should be attained per TB. As such, intra-slot FH is the only way to achieve the frequency diversity when Krep=1.  However, due to the similarity between NR-U CG PUSCH resource allocation and PUSCH repetition type B from one TB perspective, we think applying inter-repetion FH as specified for PUSCH repetition type B is more natural approach as shown in the figure below.  Comparing the 1st and 3rd rows of the table above, we do not understand what additional LBT impact is implied if inter repetition FH is adopted for repK>1 given that the 1st and 2nd hps are in the same RB set. We do understand though that there would be some more spec impact, but we believe it is minor as shown in TP3 below.    **Figure 1 Intra slot, inter repetition and inter slot frequency hopping for configured grant PUSCH transmission when with *cg-nrofSlots, cg-nrofPUSCH-InSlot* are configured.** |
| Intel | Neither alternative is preferred. | In unlicensed operation, frequency hopping is highly detrimental since a device is mandated to perform LBT at each hop, and in case the LBT may fail any benefits deriving from frequency diversity will be lost. For this reason, we are not OK with neither alternatives, and we would prefer to leave the spec as is. |
| Samsung | Alt 1 |  |
| ZTE, Sanechips | Alt1 |  |
| LG Electronics | Alt 1 |  |
| Lenovo, Motorola Mobility | Alt 1 |  |
| Nokia, NSB | Neither option is prefered | Agree with Intel: the use case for frequency hopping at unlicensed bands is questionable, considering the need to perform LBT and implications on other users LBT procedures. We prefer not to change the specs. |
| vivo | Alt 1 | Response to intel and Nokia:  The endorsed CRR1-2112823 was agreed in RAN1 107-e: **For operation with shared spectrum channel access, the UE does not expect that two hops of a PUSCH transmission are in different RB sets.**  In our understanding, it means that once the LBT success, the frequency diversity would be achived with the two hops are within one RB set.  Response to Huawei:  Thanks for question. In our contribution R1-2201070, we have explained the LBT impact, we copy here for your convenience. Hope it can help your understanding  In figure 1 and figure 2, for the inter-repetition frequency hopping for CG-PUSCH repetition, the position of first hop is dependent on the LBT result. From gNB’ perspective, the decoding complexity is increased.    Figure 3-1 Inter-repetition frequency hopping for CG-PUSCH repetition    Figure 3-2 Inter-repetition frequency hopping for CG-PUSCH repetition |
| Huawei, HiSilicon 2 | OK with either Alt2 or Alt1 | @Intel and Nokia, we agree with Vivo’s comment; we have already agreed and captured in the endorsed CR in R1-2112823 in RAN1 107-e: that “*For operation with shared spectrum channel access, the UE does not expect that two hops of a PUSCH transmission are in different RB sets.*”  @Vivo, thanks for clarifying what is meant by the ‘LBT impact’ of inter-repetition FH. We do not see an increase to the decoding complexity at gNB though since the gNB knows exactly on which RBs to attempt decoding the repetition PUSCH if the previous one was not detected due to LBT failure.  Having said so, we are OK with either Alt2 or Alt1 |
| Ericsson | Alt-1 | For simplicity and uniformity with single PUSCH and multi-PUSCH |

##### Question 2: If Alt. 1 is adopted, which one of the following TPs is preferred for Rel-16 CR?

* **TP1** in [2]

-----------------------------------------------------------**TP1 for 38.214 6.3.1**-------------------------------------------------------------

<unchanged part omitted>

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 and each of multiple configured grant PUSCH transmissions in a configuration where the higher layer parameter *cg-nrofSlots* and *cg-nrofPUSCH-InSlot* are provided.

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

<unchanged part omitted>

-----------------------------------------------------------**TP1 for 38.214 6.3.1-**------------------------------------------------------------

* **TP2** in [5] (Note: It seems original TP in [5] is based Rel-17 spec and thus changed based on Rel-16 spec)

-----------------------------------------------------------**TP2 for 38.214 6.3.1**-------------------------------------------------------------

<unchanged part omitted>

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 and configured PUSCH transmission when *cg-RetransmissionTimer* is configured.

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

<unchanged part omitted>

-----------------------------------------------------------**TP2 for 38.214 6.3.1**-------------------------------------------------------------

* **Please indicate your preference and comments to the above TPs if Alt. 1 is adopted.**

|  |  |  |
| --- | --- | --- |
| Company | Preferred TP | Comment |
| Huawei, HiSilicon |  | We prefer Alt 2. |
| Intel |  | See comments above. |
| Samsung | TP2 | Either TP is ok to us, and TP2 is slightly preferred. |
| ZTE, Sanechips | TP2 | Compared with TP1, we prefer the wording of TP2. |
| LG Electronics | TP2 | Either TP is ok to us but TP2 is slightly preferred. |
| Lenovo, Motorola Mobility | TP2 | TP2 seems more concise and is slightly preferred to us. |
| vivo | TP1 | We prefer TP1. The difference of TP1 and TP2 is the RRC parameter. *cg-RetransmissionTimer* is always configured for operation with shared spectrum channel access. *cg-nrofSlots* and *cg-nrofPUSCH-InSlot* are used for time domain allocation for CG-PUSCH. As we discuss the resource allocation here, the latter is more direct. While, if the majority support TP2, we can also accept it. |
| Huawei, HiSilicon 2 | TP1 | If Alt 1 is adpted, we share the same views as Vivo that TP1 should be used for the same reasons. |
| Ericsson | TP1 | @Moderator  Before agreeing to TP1, can you clarify if the TP only affects CG for operation with shared spectrum channel access (unlicensed), or does it affect CG in general? |

##### Question 3: If Alt. 2 is adopted, do you agree the following TP for Rel-16 CR?

* **TP3** in [6]

-----------------------------------------------------------**TP3 for 38.214 6.3.1**-------------------------------------------------------------

<unchanged part omitted>

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 the following frequency hopping modes can be configured:

- Intra-slot frequency hopping, applicable to single slot and multi-slot PUSCH transmission, each of multiple PUSCH transmissions scheduled by a DCI if the higher layer parameter *pusch-TimeDomainAllocationListForMultiPUSCH* is configured, and PUSCH transmission when the higher layer parameters *cg-nrofSlots* and *cg-nrofPUSCH-InSlot* are provided with *repK=1*.

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

- Inter-repetition frequency hopping, applicable to PUSCH transmission when the higher layer parameters cg-nrofSlots and cg-nrofPUSCH-InSlot are provided with repK > 1.

<unchanged part omitted>

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

,

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.

In case of inter-repetition frequency hopping, the starting RB for the *n*-th repetition follows that of an actual repetition within the *n*-th nominal repetition of PUSCH Repetition Type B with inter-repetition frequency hopping in Clause 6.3.2.

<unchanged part omitted>

-----------------------------------------------------------**TP3 for 38.214 6.3.1-**------------------------------------------------------------

* **Please indicate your comments to the above TP if Alt. 2 is adopted.**

|  |  |
| --- | --- |
| Company | Comment |
| Huawei, HiSilicon | We support avove TP as the proponent if Alt. 2 is adopted |
| Intel | See comments above |
| vivo | We do not support alt.2 as comment above. While, if Alt. 2 is adopted, we do not agree the TP3 for Rel-16 CR. As we responsed to Huawei in Q2, for the inter-repetition and inter-slot frequency hopping for CG-PUSCH repetition, the position of first hop is dependent on the LBT result. So the position of hopping should depend on the configured SLIV, that the TP3 should consider the modification. |
| Huawei, HiSilicon 2 | @Vivo based on your clarification of what is meant by the ‘LBT impact’ of inter-repetition FH, we do not see an increase to the decoding complexity at gNB since the gNB knows exactly on which RBs to attempt decoding the repetition PUSCH if the previous one was not detected due to LBT failure.  So, we support avove TP as the proponent if Alt. 2 is adopted |

##### Question 4: If any alternative other than Alt. 1 and Alt. 2 is preferred, please provide corresponding TP in the following table:

|  |  |
| --- | --- |
| Company | Comment |
|  |  |
|  |  |
|  |  |
|  |  |

## Summary of Round1

[TBD]

**Conclusion**

[TBD]

**Reference**

1. TS 38.214, Physical layer procedures for data, V16.8.0.
2. R1-2201070, Discussion on frequency hopping for PUSCH with a configured grant, vivo
3. R1-2201071, Draft CR on frequency hopping for PUSCH with a configured grant, vivo
4. R1-2201072, Draft CR on frequency hopping for PUSCH with a configured grant, vivo
5. R1-2201398, Clarification on frequency hopping for CG-PUSCH, ZTE, Sanechips
6. R1-2201622, Discussion on the frequency hopping for CG-PUSCH in unlicensed band, Huawei, HiSilicon
7. R1-2201623, Corrections on frequency hoppping for CG-PUSCH in TS38.214, Huawei, HiSilicon