
Agenda Item: 5.1.3.2.2.3
Source: Huawei, HiSilicon
Title: Support of long-PUCCH over multiple slots
Document for: Discussion and decision

1 Introduction

In RAN1#87 and RAN1#88 meeting, the following agreements for long-PUCCH over multiple slots were made in [1][2][3].

- *A UCI carried by long duration UL control channel at least with low PAPR design can be transmitted in one slot or multiple slots*
 - *Transmission across multiple slots should allow a total duration of [1] ms at least for some cases*
 - *FFS: more than [1] ms at least for some cases*
 - *FFS the numbers of the slots*
- *For PUCCH in long duration,*
 - *At least for 1 or 2 UCI bits, the UCI can be repeated within N slots ($N > 1$)*
 - *The N slots may or may not be adjacent in slots where PUCCH in long duration is allowed*
 - *Details are FFS, including repetition scheme including same or different formats, the possible value(s) N, the mechanism to determine the value of N, etc.*
 - *FFS for > 2 UCI bits*
 - *FFS the case of within a slot*

In this contribution, we will discuss how to support long-PUCCH over multiple slots, including the structure and frequency hopping of long-PUCCH over multiple slots.

2 Structure of long-PUCCH over multiple slots

In RAN1 #87 meeting, it was agreed that *long duration PUCCH channel at least with low PAPR design can be transmitted in multiple slots*. Furthermore, if NR is targeting a same coverage as LTE, transmission across multiple slots should allow a total duration of 1ms. For example, an uplink-only slot of 14 symbols with reference numerology supports a total duration of 1ms and has the similar coverage as LTE. However, for other type of slots, e.g., uplink-dominant slot, the number of available UL symbols would be smaller than 14. In such case, multiple slots can be aggregated together to support a total duration of 1ms or more than 1ms.

There are two options to achieve a total duration of 1ms or more than 1ms over multiple slots, as shown in Figure 1. Please note the Figure 1 does not consider frequency hopping issue. The frequency hopping of long-PUCCH over multiple slots will be discussed in the next section.

- **Option 1: long-PUCCH over multiple slots is transmitted always spanning all available long-PUCCH symbols of each slot.**

As shown in Figure 1(a), UE1 transmits the UCI in one long-PUCCH with 9 symbols in slot1 and the other long-PUCCH with 9 symbols in slot2. For 15KHz numerology, the total duration of long-PUCCH for UE1 is more than 1ms. The structure of each long-PUCCH, i.e., long-PUCCH with 9 symbols in slot1 and slot2, is achieved from the structure of the long PUCCH with corresponding number of symbols within a slot.

- **Option 2: long-PUCCH over multiple slots is transmitted based on the number of PUCCH symbols needed for coverage.**

As shown in Figure 1(b), UE1 transmits the UCI in one long-PUCCH with 9 symbols in slot1 and the other long-PUCCH with 5 symbols in slot2 to achieve 1ms with 15KHz numerology. The left part of UL resource with 4 symbols can be scheduled to transmit other UCI from other UEs. The structure of each long-PUCCH, i.e., long-PUCCH with 9 symbols in slot1, long-PUCCH with 5 symbols in slot2 and long-PUCCH with 4 symbols in slot 2, is achieved from the structure of the long PUCCH with corresponding number of symbols within a slot.

Option 2 can improve the resource utilization compared with Option 1. For example, as shown in Figure 1(b), the long-PUCCH for UE1 has already achieved 1ms with 15KHz numerology. So, in slot2, the left part of UL resource with 4 symbols can be scheduled to transmit other UCI from other UEs to improve the resource utilization. But the complexity of scheduling for Option 2 will increase, as gNB need to schedule a UE occupy a part of UL resource to transmit long-PUCCH within one slot. The mechanism to reduce the complexity of scheduling for Option 2 needs to be considered.

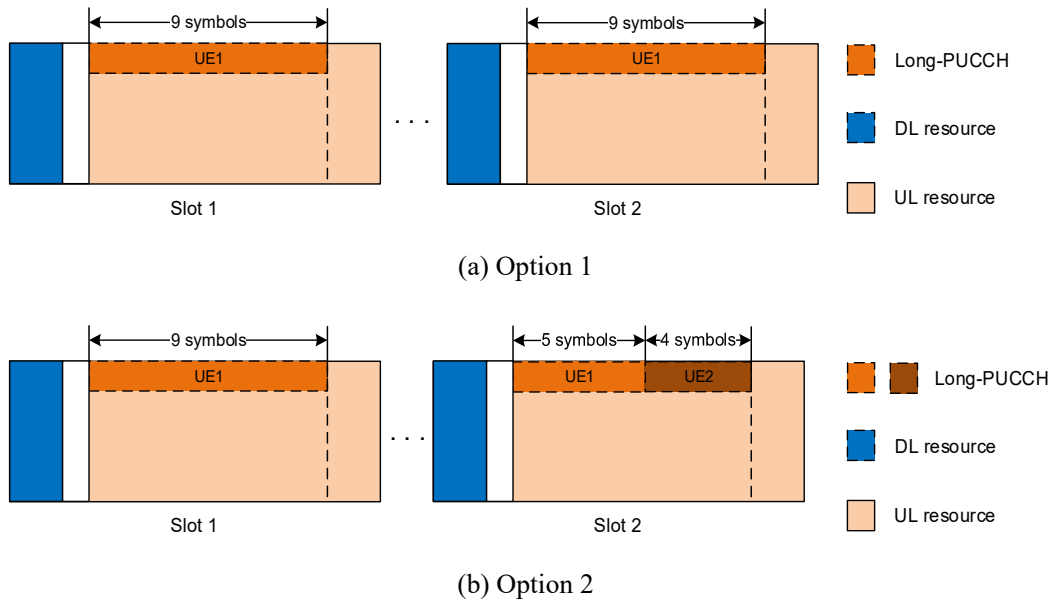


Figure 1. The structures of long-PUCCH over multiple slots

Proposal 1: For long-PUCCH over multiple slots, the structure of each long-PUCCH in each slot is achieved from the structure of a long PUCCH within a slot.

Proposal 2: For the structure of long-PUCCH over multiple slots, the following options can be considered:

- Option1: long-PUCCH over multiple slots is designed based on the integer number of slots
- Option2: long-PUCCH over multiple slots is designed based on the number of symbols

3 Frequency hopping of long-PUCCH over multiple slots

There are two alternatives of frequency hopping pattern among different slots, as shown in Figure 2.

Alternative 1: the hopping pattern of PUCCH channel in the second slot is the same as that of the first slot. An example is shown in Figure 2(a). In Figure 2(a), the hopping patterns in both slots are the same, both from the lower PRB(s) to the higher PRB(s).

Alternative 2: the hopping pattern of PUCCH channel in the second slot is a switched hopping of that in the first slot. Switched hopping means the hopping direction in the second slot is opposite to that in the first slots. An example is shown in Figure 2(b). In Figure 2(b), the hopping pattern in the first slot is from the lower PRB(s) to the upper PRB(s), while the hopping pattern in the second slot is from the upper PRB(s) to the lower PRB(s).

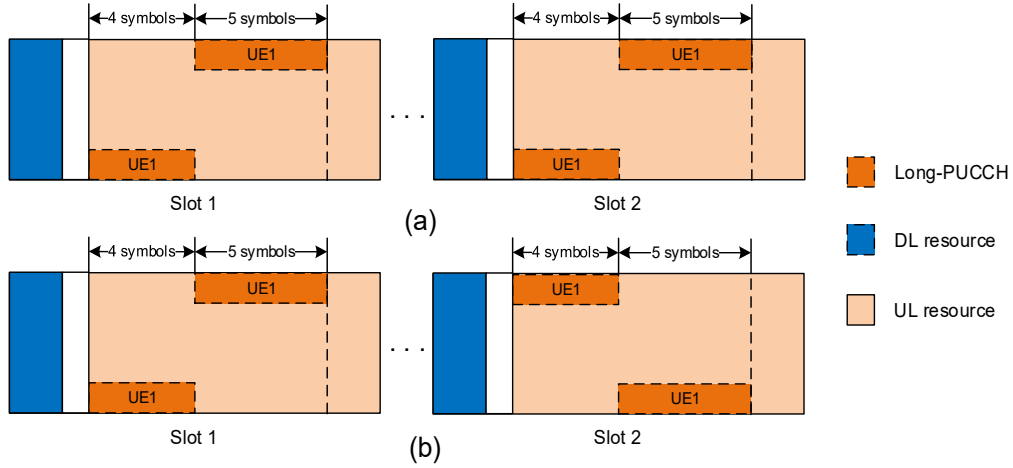


Figure 2. An example of 18 symbols in two slots for Option 1

In Alternative 1, the number of available uplink symbols is unequal for PRBs on each sides of the band. There are a total of 10 symbols operating on the upper PRB(s), but only 8 symbols operate on the lower PRB(s). The unequal number of symbols on each PRB(s) means that the diversity gain is not fully achieved.

In Alternative 2, the number of available uplink symbols is unequal for PRBs on each sides of the band for total even number of uplink symbols. As shown in Figure 2(b), in the first slot, the first 4 uplink symbols are allocated on the lower PRB(s) and 5 uplink symbols are arranged on the upper PRB(s); in the second slot, the first 4 uplink symbols are allocated on the upper PRB(s) and 5 uplink symbols are arranged on the lower PRB(s). Hence, the number of symbols operating on the upper and the lower PRB(s) are the same, meaning that full diversity gain is achieved.

Alternative 2 is applicable to Option 1/Option 2 where slots may contain same or different number of uplink symbols. The PUCCH channel of the second slot similarly apply switched hopping to achieve maximum diversity gain. In each slot, the position of frequency hopping point is stated in the proposal of our companion contribution [4]:

Proposal 3: For structures of all NR long PUCCH formats, the frequency hopping point should locate at the middle of long PUCCH.

Assuming N_1 is the number of available uplink symbols in the first slot and N_2 is the number of available uplink symbols in the second slot, $\left\lfloor \frac{N_1}{2} \right\rfloor$ symbols are allocated on one side of PRB(s) and $\left\lceil \frac{N_1}{2} \right\rceil$ symbols are allocated on the other side of PRB(s) in the first slot, while $\left\lfloor \frac{N_2}{2} \right\rfloor$ symbols are allocated on the other side of PRB(s) and $\left\lceil \frac{N_2}{2} \right\rceil$ symbols are allocated on that one side of PRB(s). An example is given on

Option 2 with $N_1 = 9$ and $N_2 = 5$ as shown in Figure 3. In the first slot, 4 symbols are allocated on the lower PRB(s) and 5 symbols are allocated on the upper PRB(s) for UE1; in the second slot, 2 symbols are allocated on the upper PRB(s) and 3 symbols are allocated on the lower PRB(s). The number of symbols operating on the upper and the lower PRB(s) are both 7, indicating full diversity achievement.

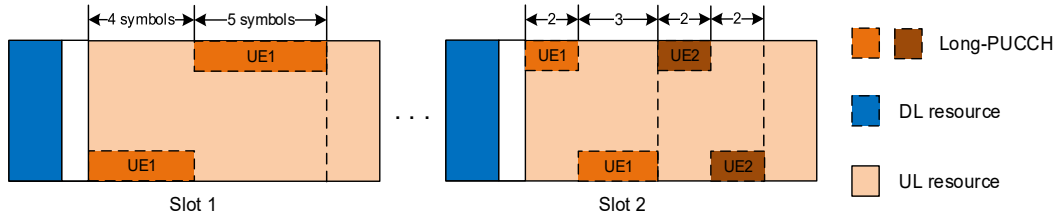


Figure 3. An example of different number of uplink symbols in two slots for Option 2

Proposal 4: For the structure of long PUCCH over multiple slots, switched hopping is preferred to maximize diversity gain.

- Switched hopping means the hopping direction in the second slot is opposite to that in the first slots.

4 Conclusions

In this contribution, we have the following proposals:

Proposal 1: For long-PUCCH over multiple slots, the structure of each long-PUCCH in each slot is achieved from the structure of a long PUCCH within a slot.

Proposal 2: For the structure of long-PUCCH over multiple slots, the following options can be considered:

- Option1: long-PUCCH over multiple slots is designed based on the integer number of slots
- Option2: long-PUCCH over multiple slots is designed based on the number of symbols

Proposal 3: For structures of all NR long PUCCH formats, the frequency hopping point should locate at the middle of long PUCCH.

Proposal 4: For the structure of long PUCCH over multiple slots, switched hopping is preferred to maximize diversity gain.

- Switched hopping means the hopping direction in the second slot is opposite to that in the first slots.

References

- [1] Chairman Notes, 3GPP TSG RAN WG1 Meeting #87.
- [2] Chairman Notes, 3GPP TSG RAN WG1 NR Ad-Hoc#1, January 2017.
- [3] Chairman Notes, 3GPP TSG RAN WG1 Meeting #88.
- [4] R1-1709960, “Overview of long PUCCH design”, Huawei, HiSilicon, Qingdao, China, 27-30 June, 2017.