

Agenda item: 7.2.4

Source: LG Electronics Inc.

Title: Proposed Scheduling Request (SR) structure and multiplexing with PUCCH

Document for: discussion and decision

1. Overall description

In last RAN1 meeting, there was a partial agreement on the transmission of Scheduling Request (SR) that SR and CQI should be separated, i.e. embedded SR transmission on CQI channel should be averted so that SR and CQI are not associated with each other. Even though there has not been further agreement, the implication of this agreement is that separate dedicated channel for SR transmission should be designed and provided.

In designing SR channel structure, one should consider various aspects and restrictions that are imposed by the current agreements on PUCCH structure and possible multiplexing mechanisms in order not to violate so-called single carrier property.

In this document, two possible alternative SR structures are proposed that are quite in line with the currently agreed-upon PUCCH structure and do not breach single carrier property when multiplexing with other PUCCH data is required.

2. Proposed Scheduling Request (SR) structure and operational method

In general, SR is predisposed to be transmitted solely without the other control information in many request opportunities. But, one cannot completely rule out the situations where simultaneous transmission with ACK/NAK or CQI is required when SR is to be transmitted. In this section, two types of SR structures (so called 'Alternative 1' and 'Alternative 2') are proposed, and the operational methods of each proposed SR structure are specified.

'Alternative 1' has been designed with the premise that simultaneous transmission of SR and ACK/NACK can be shunned arbitrarily by means of either delaying SR transmission or discarding ACK/NACK transmission, while 'Alternative 2' has been devised, taking into account the simultaneous transmission of SR and ACK/NACK. Each alternative scheme has its own merit and demerit. 'Alternative 1' has the advantage of larger multiplexing capability over 'Alternative 2' at the cost of slight degradation in downlink system throughput. On the contrary, 'Alternative 2' makes it possible for UEs to transmit SR and ACK/NACK simultaneously in one subframe at the cost of reduced multiplexing capability.

In the following sections, the explanation of each scheme will be elaborated in detail together with its own pros and cons.

2.1 Alternative 1 for Scheduling Request

2.1.1 Basic SR structure

Figure 1 shows the proposed SR transmission mechanism where SR from one UE can be multiplexed together with ACK/NACK signal from the other UEs on the same RB reserved for ACK/NACK channel. This can be done by reserving some resources for SR transmission in a dedicated manner. Currently, there is on-going discussion how to simultaneously multiplex ACK/NAK signal and CQI signal from a certain UE with the current PUCCH structure. Several proposals have been introduced, such as joint coding of ACK/NACK and CQI, or symbol by symbol TDM transmission between ACK/NACK signal and CQI signal, but none of which seems to satisfactorily meet the target BER requirement

agreed upon by the group from our perspective. Therefore, our preference is not to allow simultaneous transmission of ACK/NACK signal and CQI signal from one UE during the same subframe. Quite similarly, simultaneous transmission of SR and ACK/NACK transmission from one UE may be prevented by means of priority setting, which makes a lot of aspects simpler and easier when designing SR structure. However, regardless whether simultaneous SR transmission with the other PUCCH signal is supported from one UE or not, it would be quite preferable in terms of flexible RB management for PUCCH that SR from one UE can be multiplexed together with other UEs' ACK/NACK signal on the same RB

Figure 1 and 2 depict a proposed SR structure, which enables SR transmission from one UE to be multiplexed together with ACK/NAK signal from the other UEs on the same RB. It should be also noted that multiplexing with CQI can be possible, but is omitted just for simplicity in these figures. In the figure 1 and 2, ZC_shift_K ($K=1\sim6$) is K-th CAZAC sequence shifted from one root sequence in frequency domain, $OC(i)$, $i=1\sim3$ or 4, denotes i-th orthogonal covering sequence in time domain. Here in these figures, the number in the axis of orthogonal index represents the index of dedicated or shared orthogonal resource that is assigned to each ACK/NACK, SR or CQI.

Proposed SR structure can have 3 different symbols lengths.

- (1) SR with length of 4 symbols is spread over 4 SC-FDMA symbols in the same position where ACK/NAK information part is located, i.e. 1st, 2nd, 6th, 7th symbol in case of 1st slot (Block A and B in figure 1 and 2).
- (2) SR with length of 3 symbols is spread over 3 SC-FDMA symbols in the same position where ACK/NAK reference signal part is located, i.e. 3rd, 4th, 5th symbol in case of 1st slot (Block C in figure 1 and 2).
- (3) SR with length of 7 symbols is spread over 7 SC-FDMA symbols. However, spreading sequences of two different lengths are applied to 7 symbols, one is SF4 for 1st, 2nd, 6th, 7th symbol in case of 1st slot, the other is SF3 for 3rd, 4th, 5th symbol in case of 1st slot (Block D in figure 1 and 2).

Considering that SR channel for a specific UE is a dedicated channel for which dedicated resource has to be assigned in terms of sequence or resource block (e.g. sequence, resource block), the dedicated resource management for SR should be made as simple as possible. Therefore, three types of operational methods can be considered for SR transmission as given below.

- (1) Block A, B and C can be used for SR transmission. The eNB can choose where to assign certain UE among block A, B and C depending on UE status and system condition.
- (2) Only Block D is used for SR transmission irrespective of those conditions.
- (3) Block A, B, C, and D can be used for SR transmission. In terms of flexibility in the view point of system operation and management, this option seems to be most promising. However, there may be some increase in operational complexity.

Regardless of the selected operational mode among the above, maximum of 42 UEs' SR can be accommodated together in one RB if this RB is solely utilized for SR transmission.

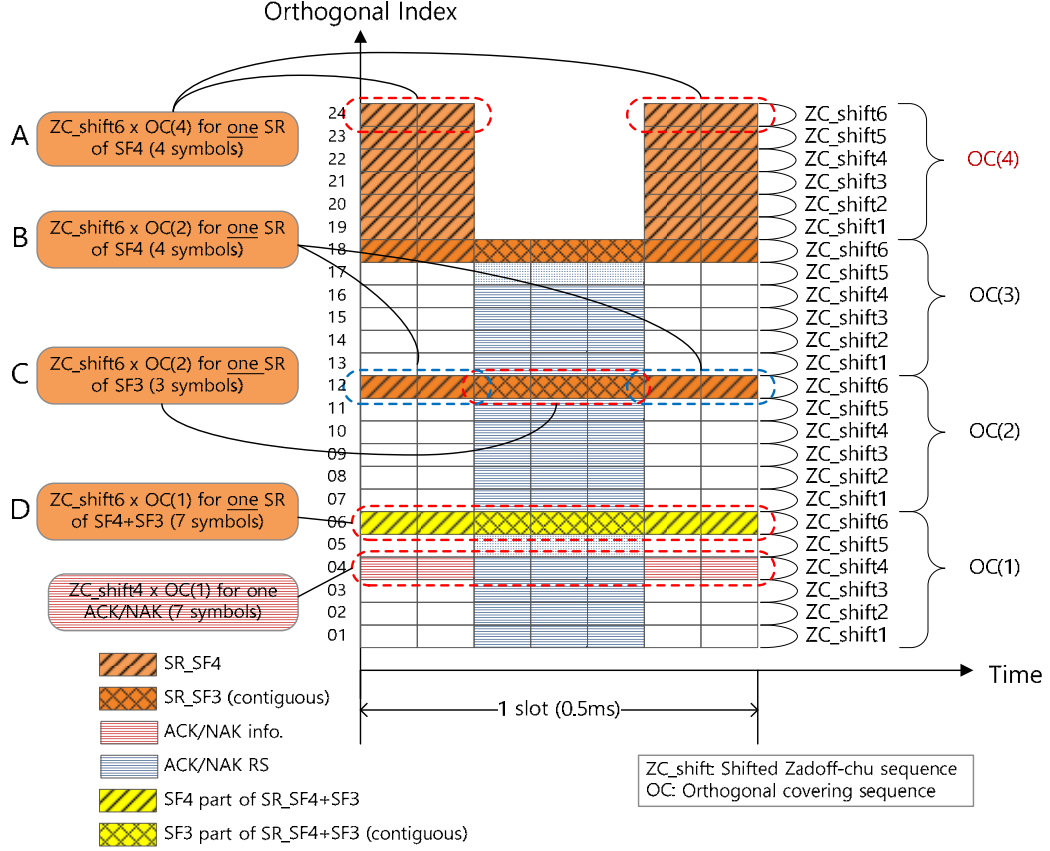


Figure 1: SR structure multiplexed with ACK/NAK

Figure 2 shows similar structure from figure 1 with additional consideration on co-existence with sounding RS. As investigated in the companion contribution [1], sounding RS multiplexing with PUCCH is very important issue to be considered. If it is agreed that sounding RS should be transmitted over one SC-FDMA symbol that is exclusive only for sounding RS, certain PUCCH slot formats for ACK/NAK and CQI should be defined for simultaneous transmission of sounding RS and PUCCH during the same subframe. Similar PUCCH slot format should also be utilized for SR transmission as shown in figure 2.

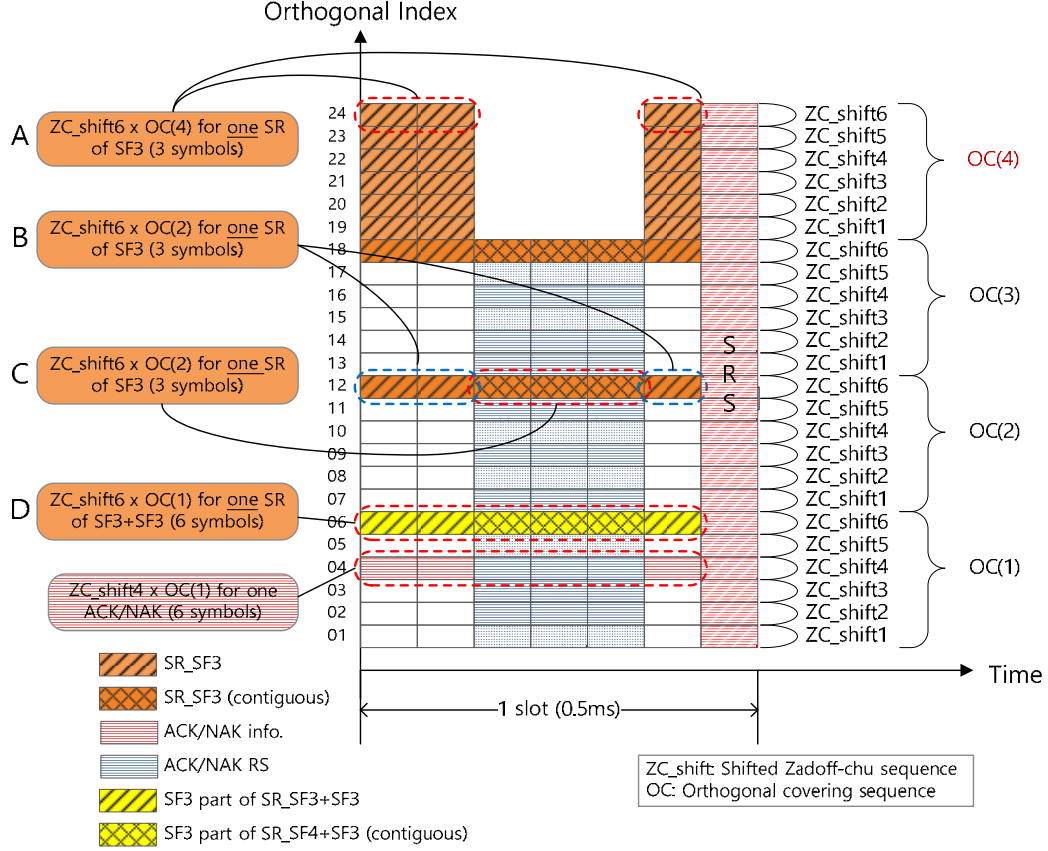


Figure 2: SR structure multiplexed with ACK/NAK and S-RS (Sounding RS)

2.1.2 Scheduling Request transmission in the presence of ACK/NAK transmission

From time to time, UEs would encounter the cases where they want to transmit their SR at the same time when ACK/NACK should be transmitted. In this case, one of two signals should be delayed or discarded in order not to violate single carrier property if SR structure given in figure 1 or figure 2 is used.

It seems to be common understanding and assumption of many companies that there is certain fixed time relationship between ACK/NACK signal and downlink packet transmission. Therefore, it would be quite intuitive and reasonable to delay SR transmission instead of ACK/NACK signal when a certain UE has both signals to transmit. In other words, ACK/NACK signal is presumed to have higher priority in general.

However, there might be a case once in a while where one should consider the other way around. For example, if large amounts of on-going downlink HARQ processes are in places at time and hence UE should transmit its ACK/NACK signal continuously, UE would have a hard time to find an opportunity to transmit its SR for a while even though UE buffer occupancy rises to a certain level of emergency. Therefore, proper management on the priority would be necessary in order to circumvent this kind of situation.

One possible solution is to make specific rules for the case. For example, if SR transmission concurs with ACK/NACK for the first time, ACK/NACK is transmitted since it has a higher priority over SR. However, if it happens successively N times (e.g. N=3 in figure 3), SR is transmitted instead of ACK/NACK at the N-th time. Unlike the case of SR where SR transmission can be delayed, ACK/NACK signal should be discarded in order not to complicate the on-going HARQ procedure if it happens. In order to support this operation, eNB is required to monitor both SR and ACK/NACK signal from a certain UE all the time. If eNB detects that SR has been transmitted from the UE instead of ACK/NACK signal at certain predefined time instant when ACK/NACK signal transmission is expected, eNB should just perform retransmission for the corresponding HARQ process since it has no information whether UE has successfully decoded previous sub-packet or not. Therefore, one retransmission in downlink would be squandered if previous sub-packet has been correctly received by the UE, leading to a slight degradation in downlink performance.

Actually, the successive coincidences of ACK/NACK and SR transmission will seldom happen, and accordingly the impact would be negligible. Hence, discarding ACK/NACK signal instead of delaying SR could be considered as adequate solution when SR transmission becomes imminent, since it won't have any serious impacts on the downlink system throughput.

According to the rule, either one of ACK/NAK or SR is chosen to be transmitted depending on parameter 'N' that would determine the priority at the time of transmission for SR. Of course, other metrics could be considered when determining the priority for signal transmission.

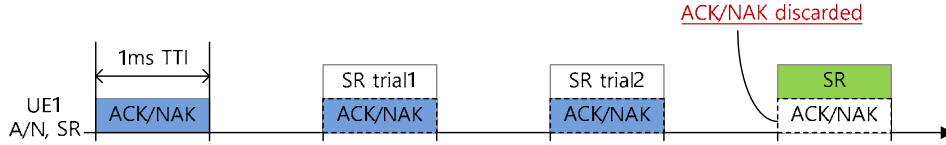


Figure 3: SR transmission when ACK/NAK is scheduled to be transmitted

2.1.3 Scheduling Request transmission in the presence of CQI transmission

From time to time, SR transmission may happen to coincide with CQI transmission. If it happens, it seems to be reasonable that SR (with higher priority in most cases) is mainly transmitted instead of CQI. We can also apply priority based selection method when they coincide at the same time. Figure 4 shows the exemplary case where CQI is skipped or delayed (depending on CQI schemes) when CQI transmission was scheduled at the same time when UE tries to transmit SR to eNB.

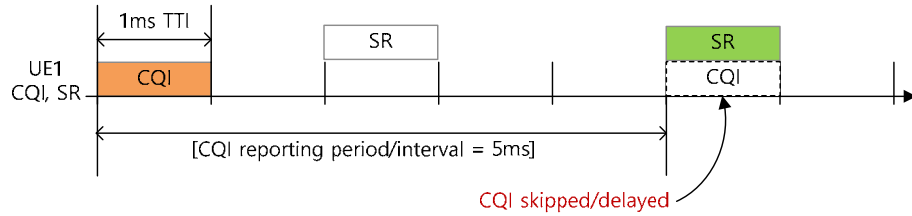


Figure 4: SR transmission when CQI is scheduled to be transmitted

2.2 Alternative 2 for Scheduling Request Structure

In order to transmit the SR and ACK/NACK simultaneously at the same subframe, the alternative SR channels, which reuse the CDM-based structure of ACK/NACK channel with different circular shift(s) of CAZAC code and block-spreading codes (resultantly, the same slot format as for ACK/NACK transmission is used also for SR transmission), can be considered. **This dedicated SR channel (i.e., 'Alternative 2') is fully compatible and co-existing with the PUCCH in the same time-frequency resource in a different way from the modified ACK/NACK channel structures for the SR transmission on the PUCCH [2], [3].**

Figure 5 shows the exemplary operation how to transmit SR and/or ACK/NACK signal with 'Alternative 2' proposal. As can be seen in the figure, two separate channels will be utilized by one UE in order to transmit either one of SR or ACK/NACK signal without multiplexing at a given time. In other words, if SR transmission from certain UE happens to coincide with its ACK/NACK signal transmission at the same subframe, ACK/NACK signal for this UE should be diverted to the dedicated resource which is assigned to the UE for SR transmission from common resource for ACK/NACK signal as shown in figure 5. However, when the UE should transmit its SR and ACK/NACK signal simultaneously, the ACK/NACK information is not transmitted on the ACK/NACK channel, but on the dedicated SR channel ((b) in Figure 5). In this case, the 1-bit SR using on-off keying is detected non-coherently by means of energy detection and then ACK/NACK information is obtained by coherent detection. In case of SR-only transmission ((c) in Figure 2), the SR can be allocated to the dedicated SR channel and detected in a non-coherent or coherent manner. In order to support this operation, eNB is required to monitor both SR channel and ACK/NACK channel at the same time. If eNB detects certain level of energy on SR channel at the time instant when ACK/NACK signal is expected from the UE,

eNB should perform coherent demodulation for ACK/NACK on the dedicated resource for SR, not on the common resource assigned for ACK/NACK transmission.

This approach is appropriate for maintaining the single-carrier property for UL transmission while supporting the simultaneous transmission of SR and ACK/NACK.

The ‘Alternative 2’ has the smaller multiplexing capability than that of ‘Alternative 1’. ‘Alternative 1’ structure has some potential demerit in the view point of downlink system throughput while there is no such an impact in case of ‘Alternative 2’. Therefore, there is apparently a certain trade-off between ‘Alternative 1’ and ‘Alternative 2’, which needs to be carefully scrutinized before final selection.

In addition, the same operational method as described in section 2.1.3 can be exploited when considering the multiplexing with CQI signal also in case of ‘Alternative 2’ structure. Hence, CQI is skipped or delayed (depending on CQI schemes) when CQI and SR transmission timing is overlapped as shown in Figure 4.

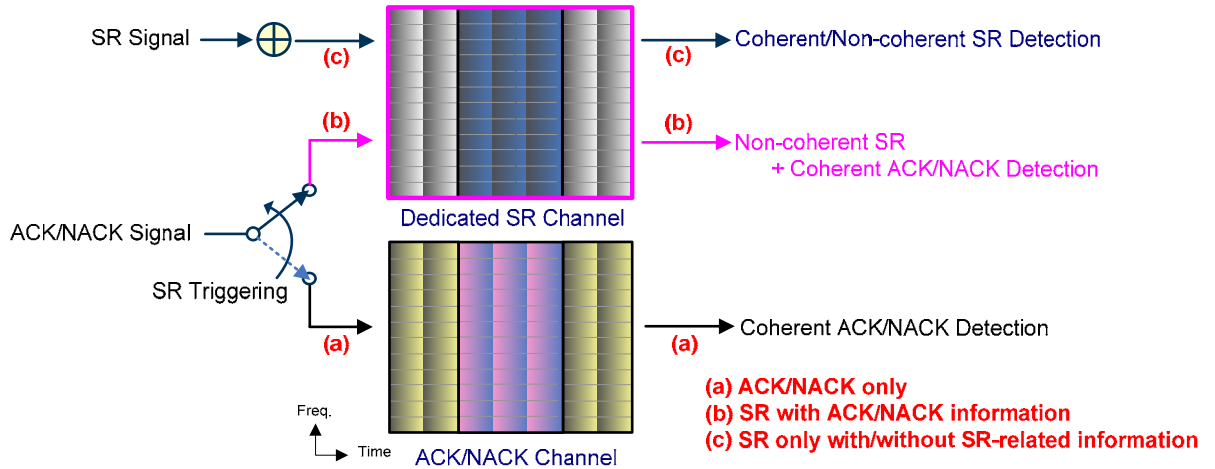


Figure 5: An illustration of multiplexing SR and/or ACK/NACK

3. Conclusion

In this contribution, two possible alternative SR structures (so called ‘Alternative 1’ and ‘Alternative 2’) are proposed that are quite in line with the currently agreed-upon PUCCH structure and do not breach single carrier property when multiplexing with other PUCCH data is required. Each alternative has its own merits and demerits compared with one another as described earlier. That is to say, there is apparently a certain trade-off between ‘Alternative 1’ and ‘Alternative 2’. Especially, ‘Alternative 1’ has an advantage in terms of multiplexing capability, while ‘Alternative 2’ has an advantage in simultaneous transmission of ACK/ANCK and SR aspect. Therefore, two alternative schemes need to be carefully scrutinized before final selection.

4. Reference

- [1] R1-072887 Investigation on problems in case of PUCCH and S-RS simultaneous transmission, LG Electronics, RAN1#49bis Orlando meeting.
- [2] R1-073011, “Multiplexing of scheduling request and ACK/NACK and/or CQI,” NSN, Nokia
- [3] R1-073066, “Multiplexing the scheduling request in the uplink,” Alcatel-Lucent

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