

Source: Intel Corporation
Title: Resource allocation for NR uplink control channel
Agenda item: 5.1.3.2
Document for: Discussion and Decision

1 Introduction

At the RAN1 #87 meeting, the following agreements were made regarding NR UL control channel [1]:

- Physical uplink control signaling should be able to carry at least hybrid-ARQ acknowledgements, CSI reports (possibly including beamforming information), and scheduling requests
- Support 'UCI on PUSCH', i.e. using some of the scheduled resources for UCI in case of simultaneous UCI and data
- Support 'simultaneous PUSCH and PUCCH at least for the long PUCCH format', i.e. transmit uplink control on PUCCH resources even in presence of data
- At least a low PAPR/CM design should be supported for the 'long PUCCH'
- A combination of semi-static configuration and (at least for some types of UCI information) dynamic signaling is used to determine the PUCCH resource both for the 'long and short PUCCH formats'
- It should be possible to dynamically indicate (at least in combination with RRC) the timing between data reception and hybrid-ARQ acknowledgement transmission as part of the DCI.

In addition, the following agreements were made with respect to NR UL control channel with short duration [1]

- Support FDM of 'short UCI' and data, both within a UE and between UEs at least for the case where the PRBs for short UCI and data are non-overlapping
- FFS: PUSCH in the short UL duration can be scheduled independently
- In order to support TDM of short PUCCH from different UEs in the same slot, a mechanism to tell the UE in which symbol(s) in a slot to transmit the short PUCCH on is supported at least above 6 GHz (exact mechanism FFS)

Furthermore, the following agreements were made on NR UL control channel with long duration [1]: **Error! Reference source not found.**

- 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
 - o FFS: more than [1] ms at least for some cases
 - FFS the numbers of the slots
- For UL control channel with long duration, TDM between RS and UCI is supported at least for DFT-S-OFDM
 - FFS on location of RS symbol(s) (e.g., front-loaded RS, fixed-location RS)

In this contribution, we present our view on UL control channel formats and resource allocation for NR uplink control channel for HARQ ACK/NACK feedback.

2 Discussion on UL control channel formats

In LTE, multiple PUCCH formats are specified to support various UCI payload sizes as follows:

- PUCCH format 1/1a/1b for positive SR, 1 or 2 bit HARQ-ACK or 4 bit HARQ-ACK with channel selection
- PUCCH format 2/2a/2b for CSI report with and without 1 or 2 bit HARQ-ACK.
- PUCCH format 3 for CSI report, 1 bit positive/negative SR and HARQ-ACK.
- PUCCH format 4 for more than 22 bits of UCI including HARQ-ACK, SR and CSI report

- PUCCH format 5 for more than 22 bits of UCI including HARQ-ACK, SR and CSI report

For NR, similar design principle can be considered, i.e., multiple NR PUCCH formats can be supported in order to accommodate various UCI types and payload sizes. Note that channel coding scheme for each NR PUCCH format should be carefully designed towards optimization of decoding performance on the supported payload size. Further, as UL control channel can be transmitted in short and long duration, a relatively large number of formats would be expected. To reduce specification and implementation effort, a limited number of NR PUCCH formats should be defined.

Proposal 1

- *Multiple NR PUCCH formats can be supported to accommodate various UCI types and payload sizes.*
- *A limited number of NR PUCCH formats should be defined to reduce specification and implementation effort.*

Note that simultaneous transmission of multiple UCI feedbacks in a single NR PUCCH in the same slot should be supported. In case when one symbol is used for NR PUCCH transmission, when multiple UCI feedbacks are scheduled in the same slot, it may be more desirable to combine the multiple UCI feedbacks and carry these information in a single NR PUCCH. This is primarily due to the fact that high PAPR/CM and potential inter-modulation distortion (IMD) would be expected when multiple UCI feedbacks are transmitted in independent and non-contiguous NR PUCCH resource in one symbol.

According to this design principle, certain UCI feedbacks may be aggregated and transmitted simultaneously in a single NR PUCCH. For instance, in case when HARQ ACK/NACK feedback and periodic CSI report are scheduled in the same slot, UE may group HARQ ACK/NACK feedback and CSI report and transmit simultaneously on a single NR PUCCH. This mechanism can be beneficial, especially for retransmission when gNB may perform link adaptation and adjust MCS or resource according to latest channel statistics reported from UE.

Similarly, SR may be combined with HARQ ACK/NACK feedback and CSI report. In this case, 1 bit SR information (positive or negative) can be explicitly included in the NR PUCCH transmission.

In general, when total payload size for simultaneous transmission of multiple UCI feedbacks exceeds the payload size that NR PUCCH can support or if UE is configured not to simultaneously transmit multiple UCI feedbacks, certain dropping rule may need to be defined to allow proper detection or decoding process at gNB receiver. Given that HARQ ACK/NACK feedback contains the most critical information for downlink data transmission, it is more natural to define HARQ-ACK feedback as highest priority and drop other UCI feedbacks, e.g., CSI report accordingly.

Proposal 2

- *Combined feedback of multiple UCI types in a single NR PUCCH should be supported.*
- *HARQ ACK/NACK feedback can be combined with CSI report or SR in a single NR PUCCH.*

3 Resource allocation for HARQ ACK/NACK feedback

As agreed in the RAN1#87 meeting [1], a combination of semi-static configuration and (at least for some types of UCI information) dynamic signaling is used to determine the PUCCH resource both for the “long and short PUCCH formats”. With regard to PUCCH resource for HARQ ACK/NACK feedback, it can be explicitly signalled or implicitly derived.

- *Explicitly signalled:* gNB may configure the resource index for UL control channel transmission via RRC signaling or dynamically indicate it in the DCI as shown in Figure 1.
- *Implicitly derived:* UE may derive the resource index for HARQ ACK/NACK feedback on UL control channel based on parameters associated with scheduled downlink data transmission or control channel. Note that in LTE, resource index for PUCCH format 1a/1b is derived from the first CCE in the PDCCH which is used to schedule the downlink data transmission.

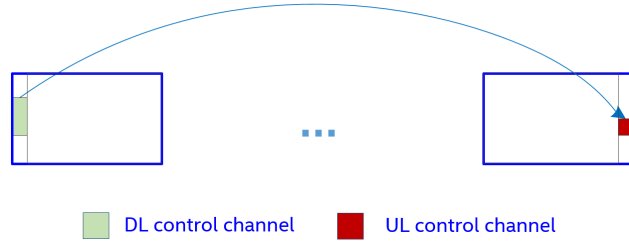


Figure 1. Explicitly signaling of resource index for HARQ ACK/NACK feedback in UL control channel

For the resource allocation option with explicit signalling, if uplink sub-band channel statistic is available at gNB side, system level performance gain can be achieved by employing frequency dependency based scheduling for UL control channel transmission. In this case, gNB may schedule the UL control channel transmission in the frequency resource with good channel quality. As presented in [2], substantial link budget and uplink coverage issue is observed when only 1 symbol is allocated for UL control channel transmission. This frequency dependency based scheduling mechanism for UL control channel would help to improve reliability of UL control channel transmission. In addition, the explicit signaling enables the UL control channel resource to be configured only when necessary and thus to minimize the dedicated resource for UL control channel.

Note that to fully exploit the scheduling flexibility, frequency resource index may be explicitly signalled among all available resources within system or UE specific transmission bandwidth. This mechanism, however, may not be desirable in term of substantial signalling overhead in the DCI. To strive for a balance between scheduling flexibility and signalling overhead, it is more desirable to configure a set of resource indexes from high layer signalling and explicitly signal one resource index from the set of resource indexes in the DCI for HARQ ACK/NACK feedback on UL control channel.

Proposal 3

- *A hybrid high layer signalling and dynamic indication of resource for HARQ ACK/NACK feedback on UL control channel should be supported in NR.*
 - *A set of resource indexes for HARQ ACK/NACK feedback on UL control channel are configured via high layer signalling and one resource index among the set of resource indexes is explicitly signaled in the DCI.*

4 Switching between short and long UL control channel

For NR, UL control channel can be transmitted with short and long duration. Figure 2 illustrates candidate TDD subframe structures for UL control channel with short and long duration in UL data slot. In particular, for UL control channel with short duration, UL control channel and data channel may be multiplexed in a TDM manner while for UL control channel with long duration, FDM based multiplexing between UL control channel and data channel can be considered for NR.

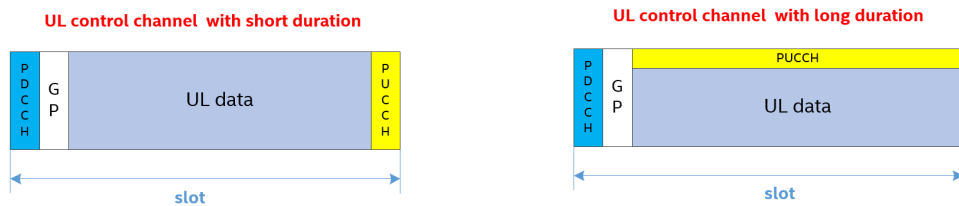


Figure 2. Candidate TDD subframe structure for UL control channel with short and long duration

As analyzed in [2], UL control channel with short duration is mainly targeted for cell center UEs with relatively good link budget. UL control channel with long duration, however, can be used to carry UCI payload for cell edge UEs where coverage enhancement is needed.

To allow gNB to allocate appropriate amount of resource for UL control channel, e.g., with short or long duration, in as an early stage as possible, resource partitioning can be considered for NR PRACH transmission to inform gNB on coverage

status for one particular UE. For initial access, UE may first measure pathloss between gNB and UEs, and subsequently randomly selects one preamble signature in a subset according to the measured pathloss and transmits PRACH signal in the associated PRACH resources. Upon successful PRACH detection on dedicated resources, gNB can determine coverage status for this UE and allocate proper amount of resource for UL control channel.

By doing so, resource waste for UL control channel may be reduced, thereby improving system level spectrum efficiency. For instance, for UEs in a good coverage, gNB may assign resource for UL control channel with short duration, which may result in better scheduling flexibility and increased DL data throughput for dynamic TDD system due to reduced UL control channel overhead, given the fact that center part of resource within one slot can be allocated for either DL or UL data transmission.

Further, for UEs in a mobility condition, coverage status may change somewhat dynamically, e.g., from good coverage to bad coverage. In this case, it may need to be supported for UL control channel to switch from short duration to long duration, or vice versa. Towards this end, RRC configuration/reconfiguration can be used to update the resource allocation between short and long duration for UL control channel.

Proposal 4

- *Switching between UL control channels with short and long duration can be supported via high layer signaling.*

5 Conclusions

In this contribution, we shared our view on UL control channel formats and resource allocation for NR uplink control channel for HARQ ACK/NACK feedback. Based on the discussion, our views are provided through the following proposals:

Proposal 1

- *Multiple NR PUCCH formats can be supported to accommodate various UCI types and payload sizes.*
- *A limited number of NR PUCCH formats should be defined to reduce specification and implementation effort.*

Proposal 2

- *Combined feedback of multiple UCI types in a single NR PUCCH should be supported.*
- *HARQ ACK/NACK feedback can be combined with CSI report or SR in a single NR PUCCH.*

Proposal 3

- *A hybrid high layer signalling and dynamic indication of resource for HARQ ACK/NACK feedback on UL control channel should be supported in NR.*
 - *A set of resource indexes for HARQ ACK/NACK feedback on UL control channel are configured via high layer signalling and one resource index among the set of resource indexes is explicitly signaled in the DCI.*

Proposal 4

- *Switching between UL control channels with short and long duration can be supported via high layer signaling.*

References

- [1] Chairman's notes, RAN1 #87, Reno, USA, November, 2016.
- [2] R1-1611996, "Payload size considerations for UL control channel in short duration", Intel Corporation, RAN1 #87, Reno, USA, November, 2016