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Source: Cohere Technologies

Title: Forward Compatibility Aspects of NR Control Channel

Agenda item: 7.1.4.1

Document for: Discussion/Decision

1. Introduction

The continuing evolution of wireless technology, as well as the appearance of new services, makes forward compatibility (FC) a crucial design aspect of NR. Among other things, new components of NR beyond the Phase 1 specification may be needed to support the following:

- MTC and/or URLLC support
- New services with new traffic requirements
- New verticals with distinguished air interface
- Introduction of new modulation schemes and reference signals
- Changes in system architecture

Discussions in past 3GPP meetings have led to a number of agreements on FC. Among other aspects, it was agreed in RAN1#85 that [1]

"Forward compatibility of NR shall ensure smooth introduction of future services and features with no impact on the access of earlier services and UEs."

In this contribution we discuss possible interactions between Phase 1 NR and possible new future designs (FD) of the air interface.

2. Forward Compatibility Modes

We consider two possible scenarios. In a first scenario, an FD is defined for data transmission, using time-frequency resources assigned for FC. In this scenario, Phase 1 control channels are used for control signaling. Moreover, other Phase 1 functionalities, such as cell discovery, synchronization signals, and initial access, are also used. In a second scenario, an FD is defined for both data and control information transmission. In this scenario, an FD design covers at least data and control channels, and possibly the physical channels for other network functions such as cell discovery, synchronization signals, and initial access. In the following sections we describe these two options in more detail. Other options, such as employing an FD for other specific components, such as e.g. a new reference signal, should not be precluded but are not discussed in this contribution.

3. Forward Compatibility with Phase 1 Control Signaling Reuse

Performance of wireless networks is heavily dependent on the efficiency of data transmission. Newly defined waveforms or other components may be developed in the future, which improve performance or are more suitable for different performance targets, such as e.g. low packet error rate, high mobility, etc. Reusing control signaling defined in Phase 1 may significantly shorten the introduction of an FD, since there is a need to design a much smaller number of components of the air interface. However, Phase 1 design of control signaling and protocols should ensure that an FD targeting data transmission only can be supported.

In an example scenario, an FD is used for data transmission in a dynamically defined time-frequency region, as shown in Figure 1. In the figure, a downlink-centric subframe and an uplink-centric subframe are shown. Note that no FD is provided for the control region, implying that Phase 1 control signaling, located in the Phase 1 downlink and uplink control regions, is used.

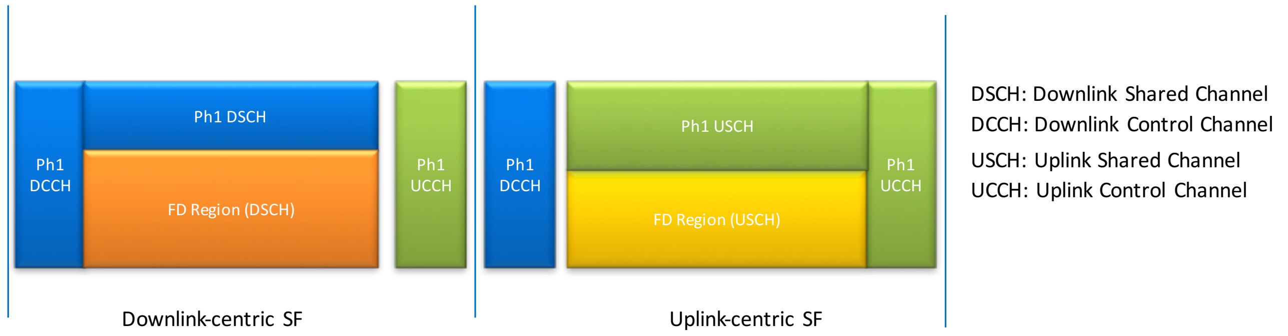

Figure 1. Example configuration of FD design with Phase 1 control channel reuse.

In addition to the advantages in terms of design, reusing Phase 1 control channels and protocols also has operational advantages. First, it simplifies the inclusion of FC regions, since only space for data transmission must be reserved. Smaller allocations for control signals, including scheduling or HARQ feedback, are not needed since Phase 1 control regions can be used. As a result, a reduction in signaling overhead to indicate FC resources can be expected.

A second operational advantage is related to the HARQ protocol. By reusing the Phase 1 control regions, more flexibility can be expected to schedule HARQ feedback, since there is no need to wait for a specific ACK/NACK transmission opportunity in a specific region defined for FC. This concept is illustrated in Figure 2 for a downlink-centric subframe.

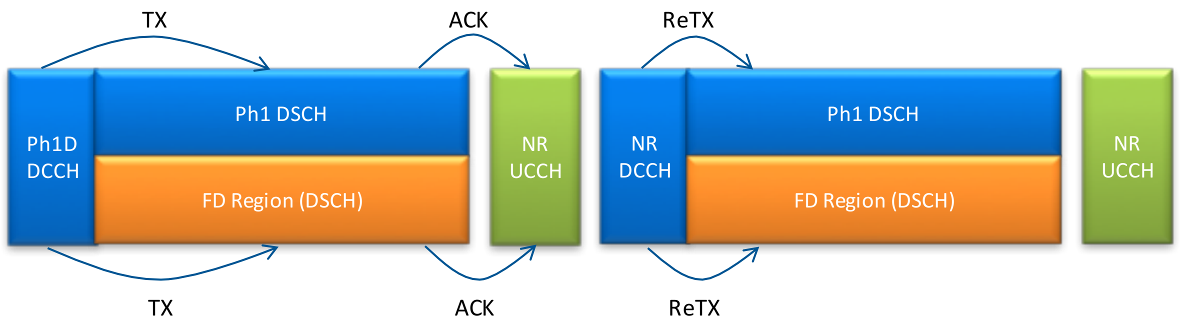

Figure 2. Illustration of HARQ flow reusing Phase 1 control channel.

In order to ensure Phase 1 control channel and protocol reuse, the following aspects should be observed:

- Initial configuration: a UE could be configured to transmit/receive FD transmissions with upper layer signaling. It should be considered for further study whether a UE can receive both Phase 1 and FD transmissions, either simultaneously or in alternate subframes.
- Allocation of FC region: A time-frequency region should be allocated for FC, containing FD transmissions. The allocation can be semi-static or dynamic. Implicit or explicit signaling of the FC region may be used.
- Scheduling of FD transmissions: Phase 1 control channel should have the ability to schedule FD transmissions. It should not be precluded that FD transmissions have different granularity or resource partitioning schemes. For that reason, it should be possible to define, at a later stage, new DCI message formats not envisioned for Phase 1. Moreover, the Phase 1 uplink control channel should have the ability to carry scheduling requests for FD transmissions, according to the format defined in Phase 1.
- HARQ feedback: Phase 1 control channels should have the ability to carry HARQ feedback from FD transmissions.
- Phase 1 control region should also take into consideration control information of other network functions related to initial access, sync, beam tracking, etc. intended for FD users.
- Cross-carrier scheduling functions defined for Phase 1 should be extensible to UE configured for FD transmissions.

Our discussion can be summarized with the following observations:

Observation 1: Reusing Phase 1 control channels and protocols may significantly speed up the introduction of a Future Design that targets improvements on physical data transmission and data channels, since there are much less components to design.

Observation 2: Reusing Phase 1 control channels may have operational advantages, since only forward compatibility regions for data transmission must be reserved.

The following is proposed for Forward Compatibility:

Proposal 1: Phase 1 control channel design should be designed to support, in a forward compatible way, data transmission using a future design.

4. Forward Compatibility Without Phase 1 Control Signaling Reuse

Forward compatibility should also account for the introduction of new systems for which the Phase 1 control signaling scheme may not be reused. In this scenario, FC regions for future control channel designs should be reserved. To ensure that FD users can attain the same performance as Phase 1 users, in terms of throughput and latency, it should be possible to adapt the size of Phase 1 control regions to make space for FD control regions. This is particularly critical for self-contained subframes, where it is possible that, in either uplink or downlink direction, all resources are allocated to the control region. An example is provided in Figure 3. Note that, in this example, if only resources corresponding to the shared data channel are available for the FD, it would not be possible to schedule HARQ feedback in the same subframe where the original transmission takes place. This would make it impossible to have self-contained transmissions using a FD for control and data transmission, and UE in FD mode would incur a significant latency penalty. Moreover, this would result in additional scheduling constraints regarding the uplink/downlink nature of the data region.

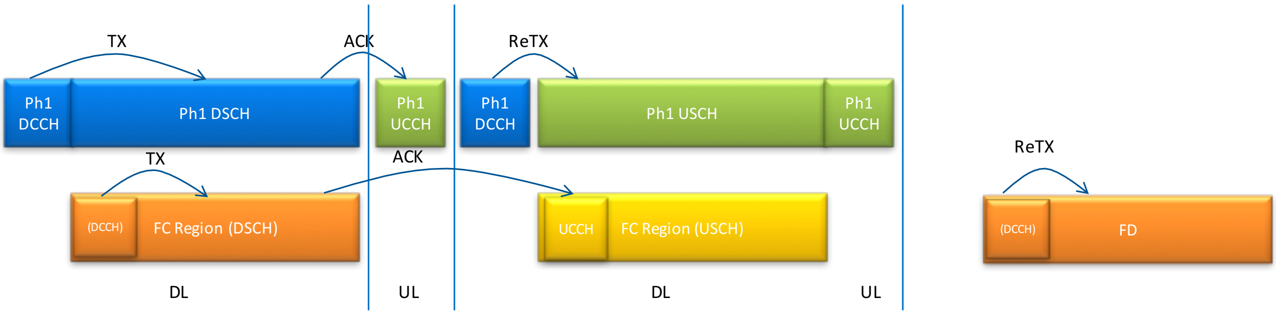

Figure 3. Illustration of HARQ cycle. All control region resources are reserved for Phase 1 control channel, which results in a much longer HARQ cycle for FD UE.

Enabling allocation of control resources for Future Designs is much more effective. As it can be seen in Figure 4, FD users can complete a HARQ cycle within a subframe, preserving the advantage of the self-contained design.

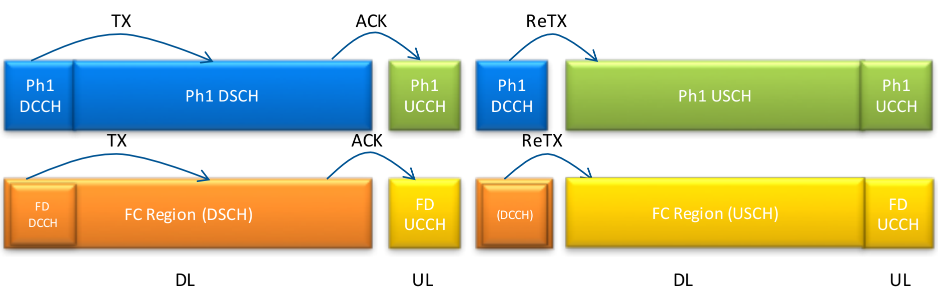

Figure 4. Allocation of FC resources in both data and control regions.

In order to ensure effective operation of users in FD mode, the following aspects related to the allocation of FC resources should be observed:

- Initial configuration: a UE could be configured to transmit/receive FD transmissions with upper layer signaling. It should be considered for further study whether a UE can receive both Phase 1 and FD transmissions in a given session, either simultaneously or in alternate subframes.
- Allocation of FC region: A time-frequency region should be allocated for FD transmissions. The allocation can be semi-static or dynamic. Implicit or explicit signaling of the FC region may be used. It should be possible to reserve resources for FC in both control and data regions. This is particularly important for self-contained subframes. It should be considered for further study whether cross-carrier allocation of FC regions should be used.
- Size of control region: Variable size of the Phase 1 control region should be supported, to minimize overhead when a large part of data transmission resources is allocated for FC.

We summarize our views in the following observations:

Observation 3: In order to achieve good performance of future designs utilizing resources reserved for forward compatibility, it should be possible to reserve resources in the control region as well as the data region. This is particularly important to minimize latency in self-contained subframes.

Observation 4: A variable/configurable size of the Phase 1 control region is necessary to allow allocation of resources for forward compatibility in the subframe control regions.

Accordingly, the following is proposed for Forward Compatibility:

Proposal 2: It should be possible to allocate resources for forward compatibility in the control regions, including for self-contained subframes. To that effect, the size of the control region for Phase 1 should be configurable.

5. Conclusions

In this contribution we discussed forward compatibility aspects related to the control channel. Two cases were considered. First, we considered reusing Phase 1 control signaling for future designs focused on data transmission. The following observations were made:

Observation 1: Reusing Phase 1 control channels and protocols may significantly speed up the introduction of a Future Design that targets improvements on physical data transmission and data channels, since there are much less components to design.

Observation 2: Reusing Phase 1 control channels may have operational advantages, since only FWC regions for data transmission must be reserved.

Next, we considered the case where there is no reuse of Phase 1 control signals. The following observations were made.

Observation 3: In order to achieve good performance of future designs utilizing resources reserved for forward compatibility, it should be possible to reserve resources in the control region as well as the data region. This is particularly important to minimize latency in self-contained subframes.

Observation 4: A variable/configurable size of the Phase 1 control region is necessary to allow allocation of resources for forward compatibility in the subframe control regions.

In view of these observations, the following is proposed:

Proposal 1: Phase 1 control channel design should be designed to support, in a forward compatible way, data transmission using a Future Design.

Proposal 2: NR supports the allocation of resources for forward compatibility in the control regions, including for self-contained subframes. To that effect, the size of the control region for Phase 1 should be configurable.

6. References

[1] Final Report of 3GPP TSG RAN WG1 #85 v1.0.0, Nanjing, China, 23rd – 27th May 2016.