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Source: Qualcomm Europe

Title: Rate matching details for control and data multiplexing

Document for: Discussion and Decision

1 Introduction

The UL of E-UTRA is based on SC-FDM and this waveform is to be respected irrespective of whether control only, data only, or control and data are both transmitted in a given subframe.

It was agreed in RAN1#46bis (Oct. 2006) as a working assumption the multiplexing of control and data prior to DFT, however more details on how to do it have not been agreed to date.

This contribution covers two aspects:

1. Impact on the PUSCH coding chain when control information is multiplexed
2. Transmission strategy for the control when embedded within the PUSCH transmission

This document is written under the premise that the CQI reporting by the UE is configured by the network and therefore the UL scheduler residing in the eNB knows when to expect CQI transmissions. The same happens with the sounding reference signal (SRS) transmissions from the UE. However, the ACK/NAK transmissions by the UE depend on the correct detection of a DL grant (if it exists) and a subsequent decoding result of the data transmission.

2 Background

2.1 CQI transmission

The transmission of the CQI by the UE is configured by the eNB. The reporting cycle is configured through L3 signalling and is periodic.

Therefore, the eNB knows when to expect a CQI transmission by the UE. As a result, once the eNB receiver determines that there is data transmission on the PUSCH it will unambiguously know that the CQI is embedded into the PUSCH transmission.

2.2 ACK transmission

The ACK/NAK transmissions by the UE are the response of a DL reception. Time asynchronous and adaptive DL transmissions require a PDCCH with each (re-)transmission.

- The UE transmits “ACK” if the PDCCH and the subsequent PDSCH are both correctly received
- The UE transmits “NAK” if the CRC of the PDCCH checks and the PDSCH decoding fails. The PDCCH CRC checks if the PDCCH is correctly received or if there is an undetected CRC-pass event.
- The UE “transmits” DTX if the CRC of the PDCCH does not check, i.e., if the PDCCH is missed or received in error.

In case of DL persistent assignments, the UE will “transmit” DTX if the PDSCH CRC does not pass, while it will transmit “ACK” if the PDSCH CRC checks.

3 Control-Data Multiplexing Alternatives

This section presents control-data multiplexing alternatives when they are both transmitted over the PUSCH:

- **Alternative 1**: multiplexes control and data at the coded symbol level. The coding of the control information depends on the data MCS. The stream with the control and data multiplexed is scrambled and modulated together, and the power gain on the PUSCH transmission is agnostic of whether control or data modulation symbols are transmitted. This alternative is fully compatible with the current functional partition of the relevant PHY layer specifications, i.e., 36.211 and 36.212.
- **Alternative 2**: multiplexes control and data at the modulation symbol level. Fixed coding and modulation is used for the control part. Different protection levels for the control information are achieved by way of power offsetting the control information transmission with respect to the data part.

3.1 Alternative 1 (coded symbol level multiplexing)

Figure 1 shows a block diagram for the control and data multiplexing transmission chain for Alternative 1.

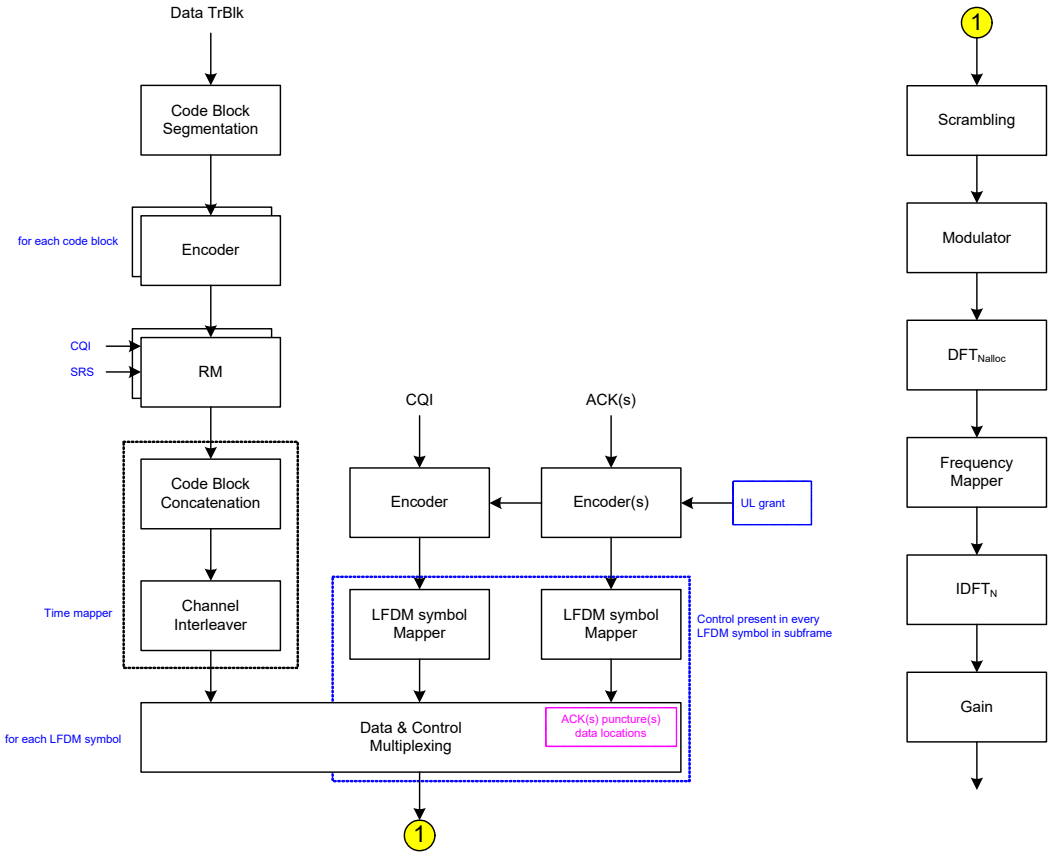

Figure 1. Block diagram for control and data multiplexing in PUSCH – Alternative 1

The most salient features of this alternative include:

- Rate matching of UL-SCH depending on transmission of CQI and SRS.
  - UL-SCH is rate matched around the CQI and SRS transmission
  - ACK/NAK transmissions do not affect the rate matching of UL-SCH
- The CQI and ACK/NAK coding depends on the UL grant. Note that the varying coding protection will provide different protection levels to the control information when embedded into the PUSCH transmission.

- The data and control multiplexing is such that the control information is placed in all the LFDM symbols used for PUSCH transmission. Note that the transmission of the control information in LFDM symbols of the two slots in the subframe is critical to benefit from the frequency diversity that could be available for a hopped transmission.
- The transmission of the CQI does not compete with the data transmission as the UL-SCH has been rate matched around it. The ACK/NAK transmission punctures the data in the control-data multiplexing stage to facilitate the turn around of the ACK transmission keeping it separate from the RM stage.
- The multiplexed stream of control and data coded and interleaved symbols undergoes the same transmit chain:
    - Common scrambling
    - Common modulation
    - Common SC-FDMA transmission (DFT precoding followed by frequency mapping and IDFT operations)
    - Single gain stage for the PUSCH transmission

Note that this transmission strategy is fully compatible with the current functional partitioning of the relevant PHY layer specifications, namely, TS 36.211 and TS 36.212.

3.2 Alternative 2 (modulation symbol level multiplexing)

Figure 2 shows a block diagram for the control and data multiplexing transmission chain for Alternative 2.

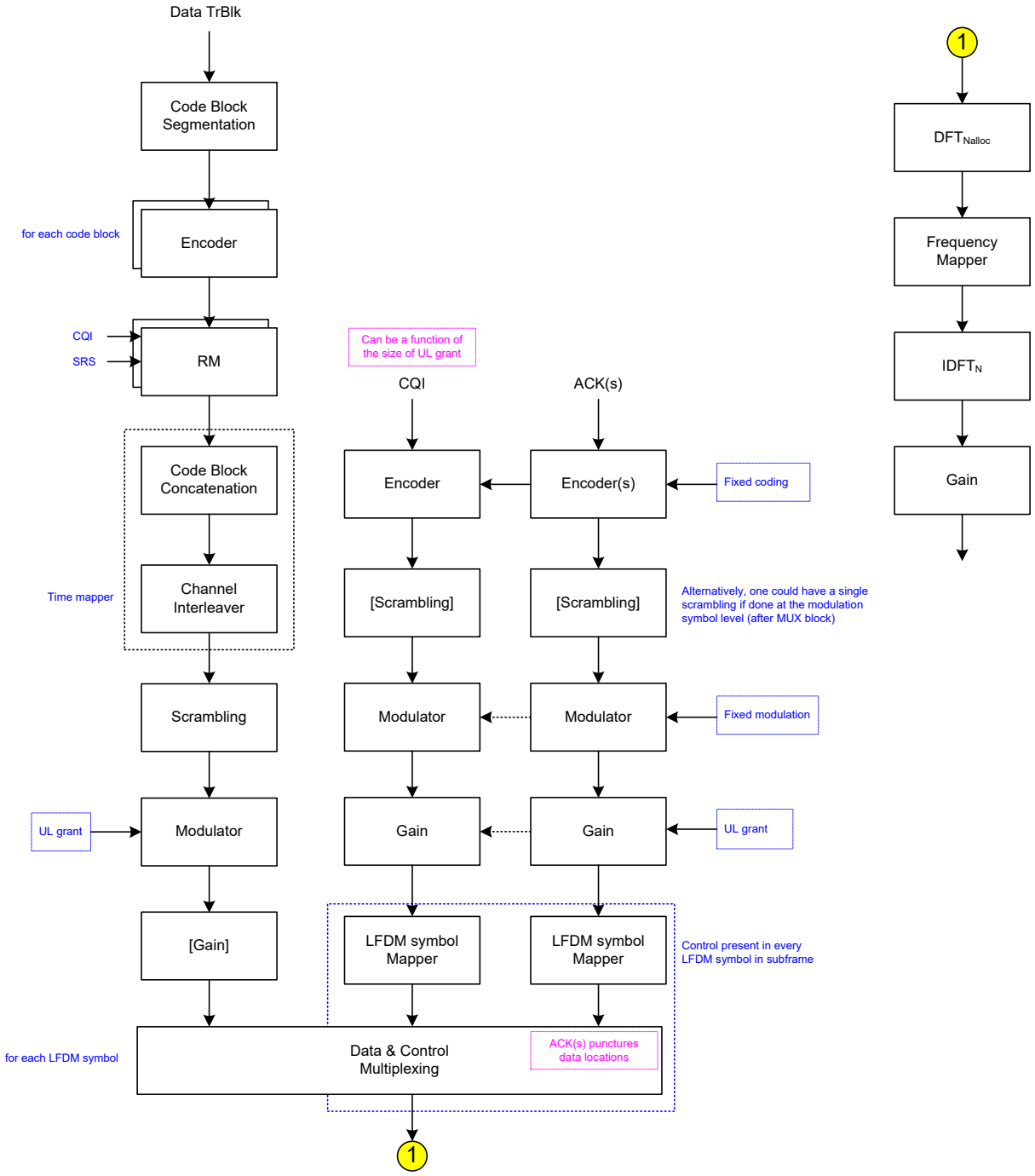

Figure 2. Block diagram for control and data multiplexing in PUSCH – Alternative 2

The most salient features of this alternative include:

- Rate matching of UL-SCH depending on transmission of CQI and SRS.
  - Note that this is common with Alternative 1
  - UL-SCH is rate matched around the CQI and SRS transmission
- ACK/NAK transmissions do not affect the rate matching of UL-SCH
- Fixed CQI and ACK/NAK coding irrespective of the PUSCH transmission format (MCS)

- Fixed CQI and ACK/NAK modulation format irrespective of the PUSCH transmission format (PUSCH)
    - Effectively this signifies that different modulation symbols may use different modulation schemes (control and data)
- Multiplexing of control and data at the modulation-symbol level
    - Gain applied to control information prior to multiplexing with the data – this is providing the different protection levels for the control information
        - Note that this gain stage depends on the UL grant
    - Gain application for the data information may occur before the control-data multiplexing (in which case there is no need of another gain stage later in the transmit chain) or could be done after SC-FDM modulation (applying to control and data)
- Scrambling
    - If applied at the coded symbol level: the scrambling of data and control are independent (as data and control are multiplex at the modulation symbol level)
        - Note that scrambling of control information may not be necessary
    - If applied at the modulation symbol level:
        - Note that TS 36.211 currently specifies scrambling at the coded-symbol level
- The data and control multiplexing is such that the modulation symbols for control information is placed in all the LFDM symbols used for PUSCH transmission. Note that the transmission of the control information in LFDM symbols of the two slots in the subframe is critical to benefit from the frequency diversity that could be available for a hopped transmission.
    - Note that this is common with Alternative 1 with the caveat that the multiplexing now is at the modulation-symbol level
- The transmission of the CQI does not compete with the data transmission as the UL-SCH has been rate matched around it. The ACK/NAK transmission punctures the data in the control-data multiplexing stage.
    - Note that this is common with Alternative 1 with the caveat that the multiplexing now is at the modulation-symbol level
- The multiplexed stream of control and data coded and interleaved symbols undergoes the same SC-FDMA transmission (DFT precoding followed by frequency mapping and IDFT operations)
- Gain stage after the SC-FDM modulator for the PUSCH transmission if the data transmission has not undergone its own gain stage prior to the multiplexing

Note that this transmission strategy violates in multiple instances the current partitioning of the relevant PHY layer specifications, namely, TS 36.211 and TS 36.212.

4 Conclusions

This document has presented and discussed two control and data multiplexing strategies for the case when the control is embedded as part of the PUSCH transmission.

The different protection levels for the control information are provided by different means in both alternatives. Alternative 1 exploits variable coding and fixed power level, while alternative 2 exploits different power settings with fixed coding.

It is important to consider the eNB receiver complexity in conjunction with the overall reliability in the reception of the control information.

In regards to the rate-matching and de-rate matching both alternatives are the same. In other aspects:

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