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Title : Impact of Hybrid type II/III ARQ on the physical layer

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1 Introduction

Work on the introduction of Hybrid Type II/III ARQ is currently progressing in RAN 2, which has the lead responsibility on this work item. The main features of Hybrid type II/III ARQ were discussed and possible impact on Layer 2 and layer 3 identified considering two main proposals for the transfer of user data and side information to support the RLC operation. Outcome of the discussion in RAN 2 and over the RAN 2 reflector is captured into a technical report drafted by the editor and contained into [1], submitted for RAN2#15. Detailed impact of Hybrid Type and in particular hybrid type II/III ARQ on the physical layer have currently not been addressed in the technical report.

A proposal for the multiplexing chain distributed at the last RAN1 meeting was discussed over the reflector [2]. In this contribution we discuss impact of HARQ onto the physical layer and in particular on the multiplexing chain, in relation with the draft technical report contained into [1]. Consequences onto the set of transport channel static parameters as well as restriction on the transport format combination and therefore MAC scheduling are identified. It is anticipated that outcome of the discussion on the impact on the physical layer based on this contribution and other contributions at RAN 1 should be reflected into the technical report.

2 Impact of HARQ II/III onto the physical layer

2.1 Transmission of user data

- Technical report assumptions

In [1], different Hybrid type II/III ARQ schemes are under consideration. In Section 6 Hybrid type II and hybrid type III are discussed. Hybrid type II is indicated to correspond to a case in which the *"retransmissions are typically not identical with the original transmission" and With type II hybrid ARQ, retransmissions containing additional incremental code bits sent for a RLC-PDU, which was initially received with errors, are in general not self decodable*. On the opposite for Hybrid type III ARQ*, In type III HARQ each retransmission is self-decodable*. For the latter two cases can be considered : either there is one redundancy version (in which case it is identical to the ARQ type I on the transmitter side, combining of retransmission of the same information taking place in the receiver) or there are several redundancy versions. Later on in the draft technical report redundancy versions are referred to, which tends to indicate that multiple redundancy version are assumed.

- Interpretation and impact on multiplexing chain in up and downlink FDD

Considering that redundancy version which is referred to in [1] characterises the channel coding and rate matching pattern (repetition or puncturing) applied onto an RLC PDU, It is therefore our understanding that the introduction of HARQ II/III requires to have some control of the RLC onto the channel coding including rate matching that is applied on a RLC PDU, which in turn means that the exact rate matching pattern applied performed onto a transport block can be controlled by the RLC assuming that one RLC maps into one transport block.

It is currently not full clear from the technical report whether multiple redundancy versions between which combination of soft bits can occur correspond to the same overall code rate or compatible code rates or may have not relation between each other.

Insight into the impact on the physical layer is discussed for up and downlink separately.

On the downlink

The rate matching is performed on the TTI basis after code block segmentation and concatenation and is transport format specific (transport block size, number of transport block) (for the flexible position case). In order to provide some visibility on rate matching on the transport block level , then code block concatenation is to be disabled for transport channels that apply HARQ. Currently code block concatenation is performed on all transport block of the transport block set of one TTI and then code block segmentation applied if the resulting code block size after concatenation is above a certain limit 504 respectively 5114 bits for convolutional respectively turbo codes). If we were to disable the code block concatenation then this should be done under the control of higher layers and hence this should be a static parameter of the transport channel.

Considering that the redundancy version characterises the rate matching pattern then it means that it is transport format specific. If additionally all redundancy version are to correspond to the same overall code rate, then it means that initial transmission and retransmission are to correspond to the same Transport format, which sets some strong requirements onto the MAC scheduling this means a constant bit rate for the transport channel on which HARQ is applied.

On the uplink

On the uplink the rate matching is performed at the radio frame level therefore after radio frame segmentation, that is the say segmentation of transport block onto the different radio frames contained in one TTI (considering TTI s larger than 10 ms) and is transport format combination specific. Therefore the rate matching pattern on a transport block is the result of the rate matching pattern on the transport channel on all radio frames within one TTI. How to accommodate the notion of redundancy version is not clear and leads to the following questions :

- Would a redundancy version correspond to a set of patterns possibly different on the different radio frames of a TTI or should the patterns be the same, meaning among other things that they should correspond to the same amount of puncturing/repetition for all radio frames of the TTI ?
- Considering that the rate matching is TFC specific does it means that all radio frames in the TTI of the transport channel on which HARQ is performed should correspond to the same TFC ? This set limits not only onto the transport formats for the initial transmission and retransmission as in the downlink case, but also on transport format of other transport channel simultaneously transmitted.
- If the redundancy versions correspond to the same overall code rate , than all TFC contained in the radio frames of the TTI for initial and retransmission should be the same ?

On the rate matching algorithm

Currently the puncturing/repetition pattern is solely parametrised by the number of bits to puncture or repeat, meaning that for a given transport block size, the pattern is identical if the number of bits or add /remove is the same. In order to obtain multiple redundancy version, the rate matching pattern determination need to be enhanced. Compatible patterns should be optimised as function of the maximum number of redundancy versions assumed by the protocol.

2.2 Transmission of side information

In [1] two main approaches are documented for the transfer of side information, where side information corresponds to the RLC PDU sequence number and the redundancy version :

1) The side information is carried over the same Logical channel as user data (RLC-PDU). This is referred to case A. 3 cases are to be considered in terms of mapping onto the transport channel for FDD only, depending on which transport channel the DTCH is mapped (TDD is left out this study so far)
    a) if the DTCH is mapped onto a DCH, then the side information is mapped onto that same DCH
    b) if the DTCH is mapped onto a DSCH, then the side information can be mapped onto the DSCH as well
    c) if the DTCH is mapped onto a DSCH, then the side information can be mapped onto the DCH
2) The side information is carried over a separate logical channel and transport channel. This is referred to as case B. Two cases can be considered
    a) If the DTCH is mapped onto a DCH, then the side information is carried over a DCH mapped onto the same physical channel
    b) If the DTCH is mapped on a DSCH in a DCH+DSCH configuration, side information can be mapped onto the DCH.

Impact on the physical layer for case A and B is as follows :

Case A
For sub case a and b the side information is carried over the same transport channel as the user data. However the side information needs better protection and needs to be encoded separately so that the redundancy version and sequence number can be separately decoded before soft bit combinations for user data. Impact is several fold
1. This means that unequal error protection is to be added to allow different protection scheme for the same transport channel.
2. Side information would typically correspond to short block. Block code are typically more appropriate than convolutional code or Turbo codes for short blocks, so code block may need to be introduced. RAN 2 should provide some indication as to what would the side information size.
3. It is to be checked whether rate matching can apply onto this sub-flow of a transport channel bits (is puncturing allowed for example ?).

Case B
In the case B the side information is carried over a separate transport channel so unequal protection is not needed. However items 2 and 3 for case A are valid as far as the use of short block and the rate matching is concerned.

3 Conclusion

The present contribution evaluated some of the impacts of the introduction of hybrid type II/III ARQ onto the physical layer. Emphasis was put on the impact of the multiplexing and channel coding and possible restrictions onto the MAC scheduling, on the basis of the proposed content of the technical report in [1] to be reviewed this week in RAN WG2.

Impact of the transfer of user data was first addressed. We based our analysis on the assumption that HARQ II/III corresponds to a RLC terminating in SRNC and is based on the control by the RLC of the channel coding and possibly multiple redundancy versions, where the redundancy version characterises the rate matching applied. It was clarified that code block concatenation is to be disabled for transport channel using HARQ, which should correspond to the introduction of a new static parameter for a transport channel (code block concatenation allowed/not allowed). The rate matching algorithm (pattern determination part) would required some enhancement in order to provide multiple redundancy versions. Besides, if multiple redundancy versions correspond to the same overall code rate (or related code rate) then there is impact on the MAC in the form of restrictions on the TFC for initial transmission and retransmission for the uplink and transport formats for initial transmission and retransmission for the downlink.

In a second step impact of the transfer of side information was also discussed, and two case of side information transfer (case A and case B) as in [1] were considered. For both the encoding of the sequence number of redundancy version may require the introduction of code blocks for optimisation reasons. It is to be analyse whether Rate matching can applied on the flow of side information bits. Finally in the case A, unequal error protection is to be introduced as one transport channel carries bits which require a different level of protection.

4 References

[1] : R2-001672 : Draft of technical report 25.835 on Hybrid AQ type II/III from e-mail discussion, Siemens (Rapporteur)

[2] : R1-00-0962, Multiplexing Chain for HARQ, Siemens

[3] : 3G TS 25.212, Technical Specification Group Radio Access Network, Multiplexing and channel coding (FDD)