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1. Introduction

Recently, there have been several proposals on the implementation of incremental redundancy for HSDPA [1][2][3][4][5][6]. There have also been some proposals on the mapping of the coded bits onto higher-order modulation symbols [7][8]. This contribution is an attempt to summarize the different proposals and to propose a way forward for a decision on the IR scheme to be used for HSDPA. In [7] and [8] it is stated that the proposed methods for mapping of coded bits onto higher-order modulation symbols are equally applicable to all different IR schemes. Therefore, the contribution compares the IR schemes and does not address the modulation aspects as these are covered by other contributions. The comparison focuses on the following aspects:

- Generation, properties and the number of different redundancy versions.
- Signaling of puncturing scheme used, i.e., whether the parameters necessary for a decoding attempt depends on previous transmission attempts or not.
- UE buffering requirements, i.e., if and how the schemes adjust to the buffering memory available.
- Support for a variable number of channel bits (N_{chan}). According to the current working assumptions, the modulation scheme and the number of spreading codes can change between retransmissions.

2. Proposals

2.1. Ericsson [1]

The basis for this proposal is the R99 rate matching scheme. Two different redundancy versions are proposed to be sufficient, although the scheme can be generalized to more versions. The first redundancy version contains the systematic bits and some parity bits, while the second one contains parity bits only. Different initial values of the parameter e_{ini} in the R99 rate matching algorithm are used to generate the redundancy versions. The redundancy versions are explicitly signaled, i.e., the coding scheme is determined solely by the signaling on the shared control channel and does not depend on the coding scheme used for previous transmissions. The number of coded bits carried on the HS-PDSCH can vary between transmissions, e.g., if the number of spreading codes are changed. Two-stage rate matching is used to adapt to the buffering capability available in the UE.

2.2. Texas Instruments [2]

The proposal is based on R99 rate matching. Three redundancy versions are proposed, one with systematic and parity bits and two with (primarily) parity bits only. The second (third) redundancy version transmit all parity bits from the first (second) constituent encoder and puncture the systematic and the parity bits from the second (first) encoder, starting with puncturing the systematic bits. This will in essence create unequal puncturing between the two constituent encoders. Different parameters in the R99 rate matching algorithm are used to create the different redundancy versions. There is no discussion on signaling of the different redundancy versions, but there is no parameter dependence between the two alternatives. In principle, the shared control channel can therefore carry all the necessary information for decoding. The number of transmitted bits on the channel can vary between retransmissions although there is a lower bound (equal to the number of information bits) implied by the fact that at least all the parity bits from one encoder must be transmitted (this restriction can be removed). Two-stage rate matching is proposed for adaptation to the buffering available in the UE.

2.3. Siemens [3]

Rate matching is used as the basis in this proposal. Multiple redundancy versions are proposed, all of them including systematic bits (although this is easily changed according to the contribution). Different values of the

parameter e_{ini} are used to create the different redundancy versions. The value of e_{ini} for a particular transmission depends on the value used in the previous transmission attempt, i.e., the information on the shared control channel alone is not sufficient to determine the coding scheme. Coupling the redundancy version number to the SFN is proposed, although explicit signaling is also possible. The computation of the parameter e_{ini} assumes that the number of channel bits remains unchanged between retransmissions. It is assumed that the UE can buffer all the coded bits, i.e., there is no adaptation to the available UE buffering.

2.4. Motorola [4]

This proposal is not based on the R99 rate matching, but on a new “ring buffer” scheme. The systematic bits and the parity bits from the $R=1/3$ mother code are interleaved separately. A transmitter buffer is defined, where the interleaved systematic bits are stored, followed by the interleaved parity bits. Eight different initial positions are defined in the buffer, giving at maximum eight (non-self-decodable) redundancy versions. At transmission, bits are sequentially transmitted from the buffer, starting at the selected initial position (wrap around is used at the end of the buffer). The number of coded bits transmitted on the channel can vary by transmitting as many bits as desired from the buffer. Adaptation to the available UE buffering memory is done by setting the wrap-around point in the ring buffer (the end-of-buffer point) according to the available UE memory.

2.5. Nokia [5]

The proposed scheme is based on rate matching. Different techniques for generating the redundancy versions are used depending on the initial code rate R :

- Initial code rate $R > 2/3$: two redundancy versions are proposed, generated by the introduction of a puncturing block between the bit separation and the rate matching algorithm. The first redundancy version contains systematic bits and some parity bits, while the other version contains only parity bits.
- Initial code rate $1/3 < R < 2/3$: two self-decodable redundancy versions generated by different parameter choices in the rate matching algorithm, i.e., a scheme different compared to the case $R > 2/3$
- Initial code rate $R < 1/3$: only one redundancy version, but with the possibility to retransmit every second bit only if the initial transmission used 16-QAM (two partial-Chase versions).

All information necessary for the decoding is available on the shared control channel. Adaptation to the available UE memory is achieved by allowing IR on the lowest data rates only, i.e., Chase combining is used for $R > 1/3$ if the available memory does not allow IR. The number of transmitted bits on the channel can vary between retransmissions.

2.6. OKI [6]

Generation of different redundancy versions in this proposal is achieved by bit reordering prior to the R99 rate matching block. Denote the input to the rate matching by (S, P_1, P_2) , where S denotes the systematic bits and P_1 and P_2 the parity bits from the two constituent encoder. In R99, the rate matching performs equal puncturing on P_1 and P_2 , while S is not punctured. By permuting the three inputs to the rate matching algorithm, different redundancy versions are generated through different puncturing patterns. In [5], four different redundancy versions, (S, P_1, P_2) , (P_1, P_2, S) , (P_1, S, P_2) , and (S, P_2, P_1) are proposed. This will typically imply unequal puncturing among the two parity streams. The number of coded bits carried on the HS-PDSCH can vary between transmissions, e.g., if the number of spreading codes are changed, since the rate matching will perform any puncturing necessary. Adaptation to the available UE buffering memory is not addressed.

2.7. Summary

In Table 1, a brief summary of the different proposals is given.

3. Conclusion and Recommendations

Most of the proposals seem to have a lot in common and it should therefore be possible to agree upon a scheme based on the commonalities in the different proposals.

3.1. Basic Structure

Chase combining must be supported and is an inherent part of the scheme in [1][2][3][4][6], while [5] has certain restrictions for retransmissions using partial Chase.

A majority of the proposals [1][2][3][6] are very similar and based on R99 rate matching. Soft buffering capabilities in the UE must be addressed and [1][2] are very similar in that respect, using two-stage rate matching. There are also several similarities between [2] and [6] on the puncturing for the redundancy schemes.

The proposal in [3], although similar in the other respects, does currently not address the soft buffering capability, but two-stage rate matching can easily be included. Therefore, it is proposed to adopt Figure 1 in [2] for the basic structure of the IR scheme.

3.2. Redundancy Versions

The number of redundancy versions proposed includes two [1], three [2], four [6], and multiple (non-predetermined number) [3], [4]. Based upon this, supporting four different redundancy versions seems reasonable, using two bits of signaling.

The exact structure of the redundancy versions remains to be decided on. Both [1] and [3] use different values of the initial value e_{ini} to generate different puncturing patterns, with a specific rule given in [3]. It is believed that the rule in [3] can be a good starting point for the decision on the parameters used for the generation of different redundancy versions.

It is further believed that full IR (non-self-decodable) should be supported and the scheme not restricted to partial IR only as the gain with partial IR is rather limited compared to Chase. The only occasion when partial IR is useful for a retransmission is if the initial transmission with the systematic bits is seriously corrupted. However, in this case the first redundancy version can be used for the retransmission as well as the systematic bits anyway are lost. The proposal in [3] uses partial IR, although the contribution states it easily can be modified into using full IR.

4. References

- [1] “Rate Matching for Incremental Redundancy in HSDPA”, Ericsson, R1-01-1045
- [2] “Two stage rate matching for 3GPP HSDPA”, Texas Instruments, R1-01-1026
- [3] “Implementation of Incremental Redundancy by means of Rate Matching”, Siemens, R1-01-1028
- [4] “A New Hybrid-ARQ Scheme Using Incremental Redundancy”, Motorola, R1-01-1014
- [5] “Hybrid ARQ Scheme for HSDPA”, Nokia, R1-01-1023
- [6] “A Simple Incremental Redundancy Scheme for HSDPA”, OKI, R1-01-1070
- [7] “Harmonization of SMP and the advanced retransmission technologies”, Samsung, R1-01-1041
- [8] “Comparison of HARQ Schemes for 16-QAM”, Panasonic, R1-01-1059

	Ericsson	TI	Siemens	Motorola	Nokia	OKI
Scheme	based on RM	based on RM	based on RM	new scheme	RM + extension	based on RM
#redundancy versions	2	3	multiple, depends on the number of channel bits	8	2, restricted choices, different generation methods	4
Amount of puncturing of the two parity streams	approx. equal	unequal	approx. equal	approx. equal	approx. equal	unequal
All transmissions self-decodable	no	no	yes	no	yes/no (depends on initial code rate)	no
Puncturing parameters	explicit signaling	explicit signaling	previous transmissions + implicit from SFN	explicit signaling	explicit signaling	not addressed (explicit signaling?)
UE buffering requirements	adaptive, 2-stage RM	adaptive, 2-stage RM	IR requires full buffering	adaptive, selection of "wrap around" point	restrictions on the use of IR	not addressed (requires full buffering)
Requirements on N_{chan}	fully flexible	flexible, requires $N_{chan} > N_{info}$	fixed	fully flexible	restrictions on modulation changes, otherwise fully flexible	fully flexible
Mapping onto higher-order modulation	not addressed	random interleaving tied to SFN	SMP	priority mapping	briefly addressed	not addressed

Table 1: Brief comparison of the different schemes.

