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Title: Adaptive HARQ proposal for HSDPA

Document for: Discussion and Decision

1 Introduction

Two different types of HARQ proposals are being considered for HSDPA: the schemes that do not allow change of data rate (MCS) on retransmissions [1] [2] and the scheme wherein the retransmissions can be performed at a different data rate (MCS) than the original transmission [3]. The HARQ schemes that allow change of MCS on retransmissions provides the following benefits:

?? A transparent HARQ operation when the channel conditions, codes and/or power allocated to HS-DSCH changes in the same cell. Note that the non-adaptive schemes have to abort transmission when the number of codes is different at the time of retransmission and/or the channel conditions, available power is different from the time of the original transmission.

?? Transparent cell site switching operation i.e., any modulation and coding scheme (supported by channel conditions, available power and number of codes in the new cell) can be used to recover outstanding (ongoing transmission) code blocks in the new cell.

?? Flexibility of selecting different Transport Block Set sizes for the same data rate (to avoid frame-fill inefficiency) [3].

2 Adaptive HARQ

The power available for HS-DSCH is continuously changing (on a slot-by-slot basis) due to large variations in the power used by power-controlled circuit switched users. The C/I seen by a user is also varying quickly due to varying interference from neighboring cells and/or large changes in channel quality due to fading etc. Furthermore, with asynchronous IR operation, the time between the transmissions/retransmissions could be longer because a retransmission to a user can be preempted by a transmission/retransmission to another user. Therefore, it is highly likely that the channel conditions, available power and code space are different between transmissions/retransmissions that need to be IR/combined. Under these conditions non-adaptive schemes that do not allow change of MCS on retransmissions will have to abort transmission that will result in degraded system performance. Note that even if the number of codes available for HS-DSCH changes comparatively slowly, a small change in the number of codes makes it impossible to perform a retransmission at the same MCS for non-adaptive HARQ schemes.

2.1 Encoding and sub-block formation

An example of code block encoding and sub-block (unit for incremental redundancy operation) formation is depicted in Figure 1. The code block of size 5120 bits (consisting of 16 transport blocks of size 320 bits) is rate 1/5 Turbo coded to 25600 bits. The sub-blocks for 480 and 960 Kb/s contain the entire sequence of 25600 coded bits i.e., a single sub-block transmission at one of these rates allows 1/5 rate decoding. The subsequent sub-block transmissions at one of these data rates are simply repetitions of the same sequence of bits.

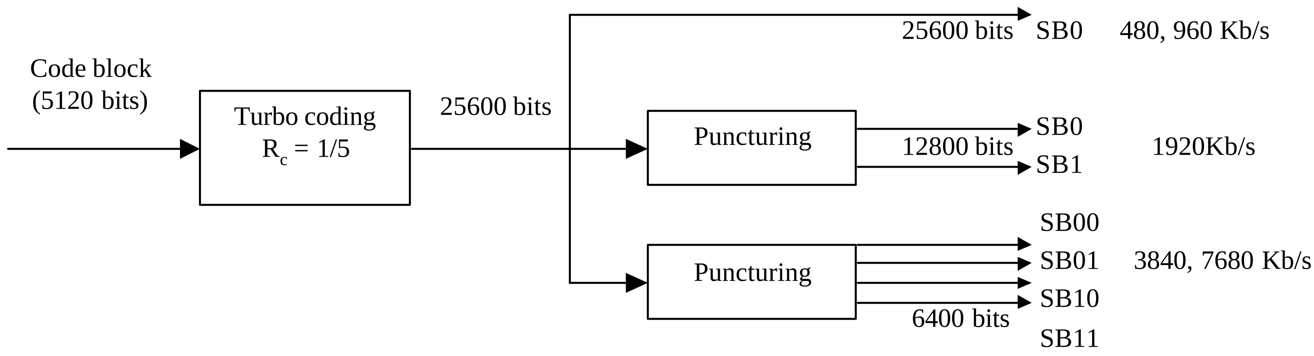

Figure 1. Code block encoding and sub-block formation

For data rates of 1920 Kb/s, two different sub-blocks are obtained by puncturing the 25600 coded bits. The two sub-blocks contain complementary bits. Therefore, the first sub-block transmission will provide coding rate of 0.4 and the first and second sub-block transmissions together provide 1/5 coding rate. If more than two sub-blocks need to be transmitted, the subsequent sub-blocks transmissions will simply be the repetitions of these two types of sub-blocks. For 3840 and 7680 Kb/s, 4 different types (complementary) of sub-blocks of size 6400 bits are obtained by complementary puncturing of 25600 coded bits.

Note that the code block encoding and sub-block formation strategy used here allows for Chase combining at lower coding rates and lower order modulations and the use of incremental redundancy (IR) at higher coding rates and higher order modulations.

An example of mapping of sub-blocks to slots for code blocks of size 5120 bits and different MCS types is shown in Table 1.

Table 1. Mapping of sub-blocks to slots for 5120 bits code block [assumes 20 channelization codes at SF=32]

MCS	Data Rate [Kb/s]	sub-block size [bits]	Modulation	Repetition factor	Modulated symbols	Symbols after spreading	Number of slots/sub-block
4	480	25600	QPSK	2	25600	40960	16
5	960	25600	QPSK	1	12800	20480	8
6	1920	12800	QPSK	1	6400	10240	4
7	3840	6400	QPSK	1	3200	5120	2
8	7680	6400	16-QAM	1	1600	2560	1

2.2 Data Rates

Table 2 and summarise different modulation and coding schemes supported in A^2IR [3]. Note that different code block sizes (number of transport blocks) can be selected for the same data rate depending upon the data backlog in the user's buffer in order to minimise frame-fill inefficiency. The data rates lower than 60 Kb/s are achieved by repeating the 60 Kb/s code sub-blocks using the A^2IR scheme.

Table 2. Data Rates [assumes 20 channelization codes of SF=32]

MCS	Data Rate [Kb/s]	Modulation	Effective coding rate [actual coding + repetition]	Transmission Time Interval (TTI) [number of slots]			
				16 Transport blocks per TTI [code block = 5120 bits]	8 Transport blocks per TTI [code block = 2560 bits]	4 Transport blocks per TTI [code block = 1280 bits]	2 Transport blocks per TTI [code block = 640 bits]
1	60	QPSK	0.0125				16
2	120	QPSK	0.0250			16	8
3	240	QPSK	0.0500		16	8	4
4	480	QPSK	0.1000	16	8	4	2
5	960	QPSK	0.2000	8	4	2	1
6	1920	QPSK	0.4000	4	2	1	
7	3840	QPSK	0.8000	2	1		
8	7680	16-QAM	0.8000	1			

Figure 2 shows an example of HARQ operation where the sub-blocks from the same code block of size 5120 bits are transmitted at different modulation and coding schemes.

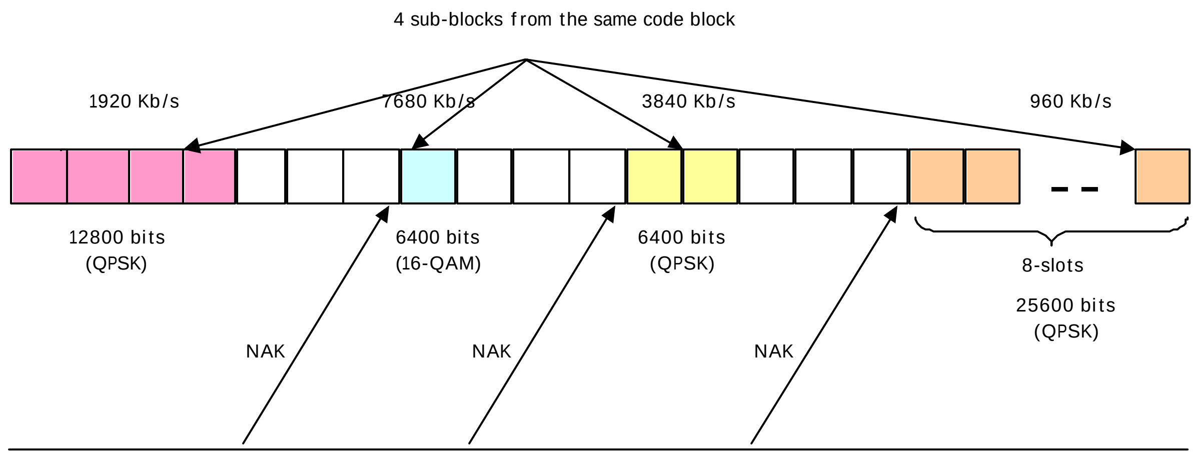

Figure 2. Sub-blocks from the same code block are transmitted at 4 different MCS.

The fact that all sub-blocks are derived from the same coded sequence of 25600 bits makes it possible to perform HARQ across these sub-blocks in order to recover the original code block as depicted in Figure 3. The first sub-block contains half of the coded bits i.e., 12800 provides a coding rate of 0.4. The second sub-block contains 6400 bits that are complementary to 12800 bits received in the first sub-block. The first and second sub-blocks jointly provide a coding rate of 0.266. The third sub-block contains 6400 bits that are complementary to 12800 bits received in the first sub-block and 6400 bits received in the second sub-block. The fourth sub-block transmission at 960 Kb/s provides all the 25600 coded bits. The bits from first, second and third sub-blocks also provide the entire sequence of 25600 coded bits. Therefore, the first three transmissions can be Maximal ratio combined with the 4th sub-block transmission.

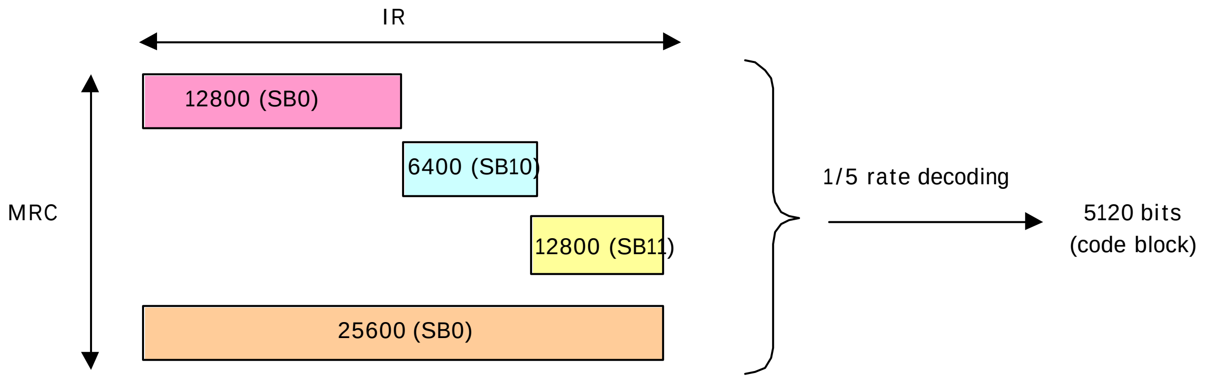

Figure 3. IR/MRC of sub-blocks received at different MCS.

3 Conclusion

An adaptive HARQ proposal for HSDPA is discussed. The scheme provides enhanced flexibility in retransmissions when the channel conditions, available power and/or number of codes is different at the time of retransmission than the original transmission. Therefore, it is recommended that Adaptive HARQ be considered for HSDPA.

4 References

[1] "Performance Comparison of Hybrid-ARQ Schemes", TSG-RAN #17(00) 1396, Motorola.

[2] "Performance Comparison of Chase Combining and Incremental Redundancy", TSG-RAN #17(00) 1428, Ericsson.

[3] "A^{2}IR – An asynchronous and adaptive HARQ scheme for HSDPA", TSG-RAN WG2#18, R2-A010021, Lucent Technologies.

[4] "Variable TTI for HSDPA", TSG-RAN #18(01) 0079, Lucent Technologies.