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Title: **Further Simulation Results on HARQ with Signal Constellation Rearrangement**

Agenda Item: **AH24 (HSDPA)**

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1 Introduction

This contribution provides further link-level simulation results on the HARQ method with signal constellation rearrangement including adaptive MCS in a fading environment. The method was presented and evaluated regarding performance and complexity previously in the last meeting [1], where its significant performance gain compared to conventional Chase Combining was shown at pure link-level. Here, additional link-level results are provided considering adaptive MCS and imperfect MCS selection due to SIR report delay and SIR estimation errors. Simulations under fading conditions with adaptive MCS show that the proposed method can achieve a gain in throughput compared to conventional Chase Combining [2]. Furthermore, signaling requirements are given in Annex A.

2 Description of Proposed Method

For QAM modulations with an alphabet size higher than 4 the reliabilities of the bits Gray-mapped onto the modulated symbols vary from the most significant bits to the least significant bits. These variations reduce the performance of the Turbo decoder with respect to having equal bit reliabilities.

In case of retransmitting copies of the initially sent packet and soft-combining its symbols using maximum ratio combining (conventional Chase Combining) the variations in bit reliabilities remain biased. By rearranging the signal constellations for retransmissions the proposed method performs an averaging of the bit reliabilities over the retransmissions.

As a result of the rearrangement the data within the multiple received packets cannot be combined on a symbol-by-symbol basis. However, the soft-combining can be performed on bit-by-bit basis by adding up the log-likelihood ratios (*LLR*s).

More details on the proposed method are provided in [1], where the HARQ link-level performance for BLER and throughput is evaluated. It is shown that the proposed method clearly outperforms conventional Chase Combining while the complexity requirements are lower than for full IR.

3 Simulation Details

3.1 Adaptive MCS

Table 1 shows the set of MCS levels which were used for the simulations. The MCS was chosen based on a delayed instantaneous SIR estimation according to AWGN "Hull" characteristics. Due to its minor performance contribution and additional complexity MCS 4 (8-PSK, code rate ¾) was not considered. As suggested earlier in [3] also a reduction of the number of MCS levels was considered. This makes the MCS selection more robust against SIR estimation errors and further reduces complexity and signaling overhead.

The following cases according to Table 1 were simulated:

1. Using 6 MCS levels
2. Using 4 MCS levels without MCS 2 and MCS 5

MCS	Modulation	Turbo Code Rate	Information bits per packet	Coded bits per packet	No. of Signal Constellations
1	QPSK	¼	200	800	1
2	QPSK	½	400	800	1
3	QPSK	¾	600	800	1
5	16-QAM	½	800	1600	4
6	16-QAM	¾	1200	1600	4
7	64-QAM	¾	1800	2400	4

Table 1. List of MCS parameters.

The reporting/estimation of the instantaneous SIR was modeled without feedback loss including the following options:

1. Perfect SIR estimation - 10 ms (3 frames) delay
2. Erroneous SIR estimation, normal distributed in dB ($\mu = 0$ dB, $\sigma^2 = 3$ dB) - 10 ms (3 frames) delay

Results in [4] from RAN WG4 show that an 3 dB estimation error for the SIR measurement is a realistic assumption.

3.2 HARQ

We compared the HARQ method using the signal constellation rearrangement (CoRe) for 16-QAM and 64-QAM using 4 different mappings (see [1]) to Chase Combining (CC). Considering a frame length of 5 slots and a 4 channel SAW ARQ protocol, a time separation of 13.33 ms (4·5 slots) between successive retransmissions was used for simulations. The chosen MCS level for the initial transmission was kept over retransmissions.

3.3 Further Link-Level Assumptions

Table 2 provides a list of further simulation parameters.

Parameter	Value	Comment
Chip-rate	3.84Mcps	
Spreading Factor	32	
Number of codes for HS-DSCH	1	
CPICH Ec/Ior	-10dB(10% of Ior)	
DSCH Ec/Ior	-1dB (80% of Ior)	
Channel Model	1-Path Rayleigh	Jakes spectrum v = 3 km/h (5.6 Hz), 50 km/h (92.6 Hz)
Carrier Frequency	2 GHz	
Channel Estimation	Ideal	
HSDPA Frame Length	3.33ms (5 slots)	transmission unit interval.
Interleaver	Length: 5 slots	symbol interleaver with random pattern
Tail bits	6	in each transmission unit
No. of Iterations for Turbo Decoding	8	
Number of maximum retransmission	9	
STTD	Off	
Channel Coding	Turbo Code (rate ¼, ½, ¾)	Generated from rate 1/3 Turbo Code.
Log-Likelihood Calculation	Approximation	according to [5]
Modulation	QPSK, 16-QAM, 64-QAM	

Table 2. List of simulation parameters.

4 Simulation Results

In the following sections the link-level simulation results including MCS selection for the 1-path Rayleigh fading channel are presented. The ranges for the selection of the MCS levels are defined according to the “Hull characteristics” obtained from AWGN link-level simulations. The MCS selection is based on the estimation of the instantaneous SIR with a delay of 10 ms.

4.1 6 MCS Levels

Figure 1 and Figure 2 show the results for 6 MCS levels over a fading channel with 3 km/h (5.6 Hz) and 50 km/h (92.6 Hz) respectively.

In case of 3 km/h the fading is slow compared to the SIR feedback delay and the frame length. The MCS selection is working properly and the number of requested retransmissions is low. Hence, the throughput performance does barely depend on the performance of the HARQ method. In case of a 3 dB estimation error the retransmission ratio increases slightly due to wrong MCS selections. The throughput can be slightly increased (e.g. ~ 5 % at 10 dB) using the proposed HARQ method.

In case of 50 km/h the channel fades significantly within a frame and within the SIR feedback delay. The Turbo decoder and MCS selection performance decrease, which leads to an increasing number of retransmissions. This makes the throughput more dependent on the performance of the HARQ method. Under the constraint of performing MCS selection based on the AWGN “Hull characteristics”, which might not be the optimum rule for high Doppler frequencies, a large gain can be achieved (e.g. ~ 30 % at 10 dB). Considering a better MCS selection rule retransmissions can be reduced, however, still the faster fading will introduce more MCS selection errors causing more retransmissions.

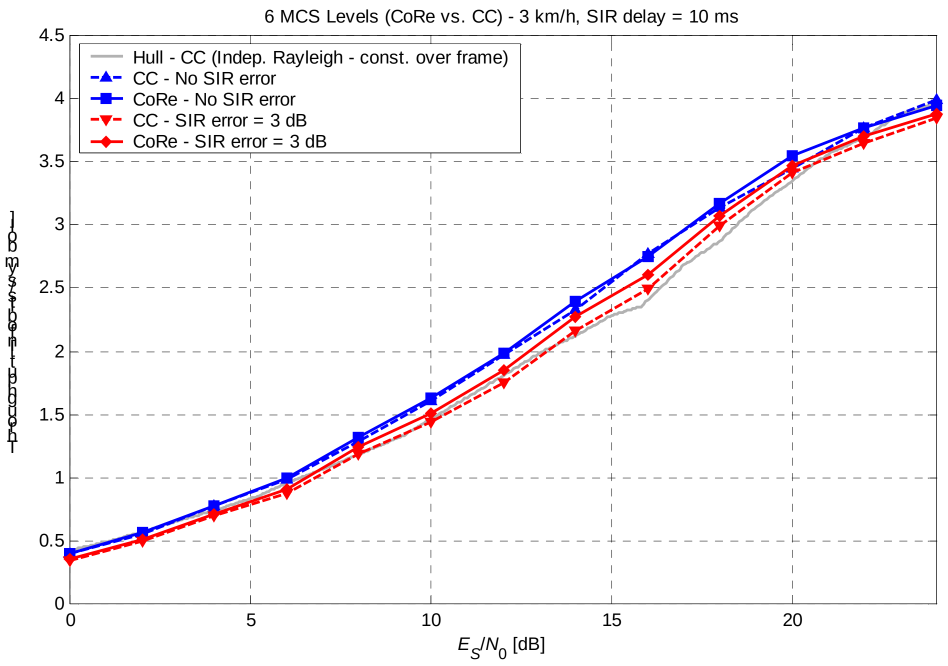

Figure 1. Throughput for 6 MCS levels, UE Speed = 3 km/h.

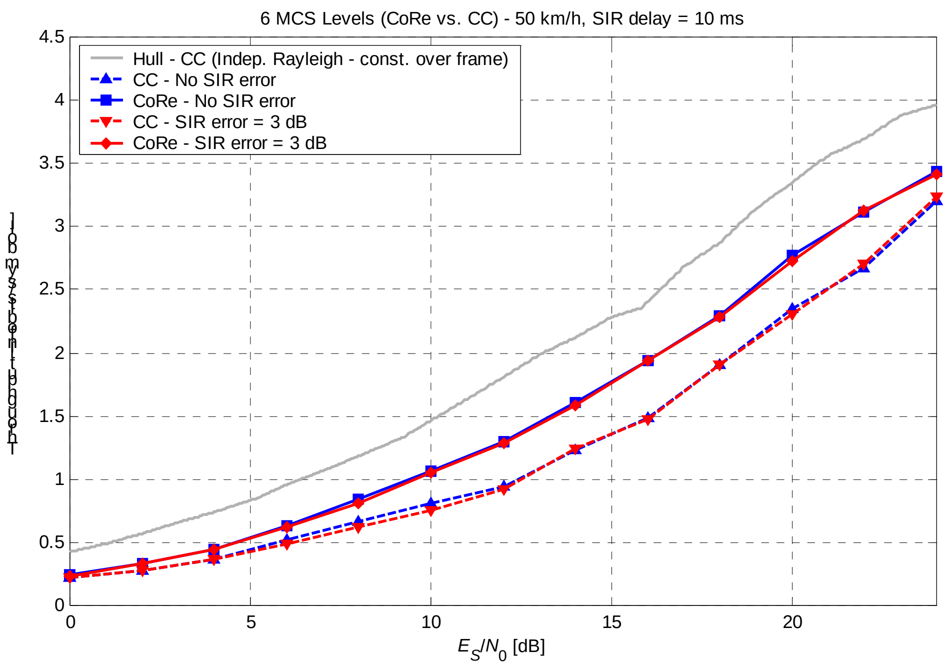

Figure 2. Throughput for 6 MCS levels, UE Speed = 50 km/h.

4.2 4 MCS Levels

Figure 3 and Figure 4 depict the simulation results using 4 instead of 6 MCS levels. Note that the throughput loss compared to the corresponding results using 6 MCS levels is very small.

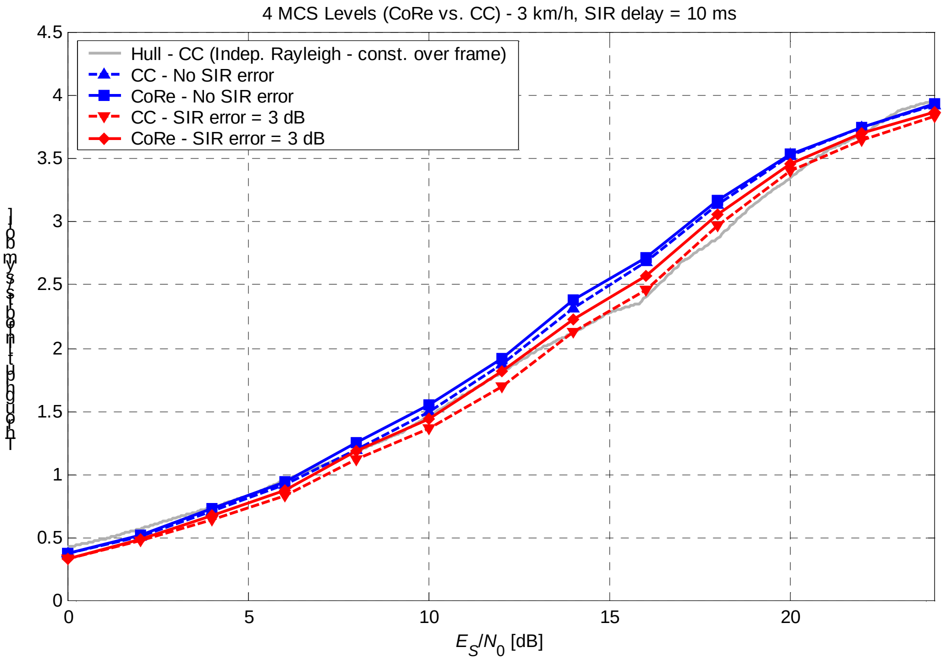

Figure 3. Throughput for 4 MCS levels, UE Speed = 3 km/h.

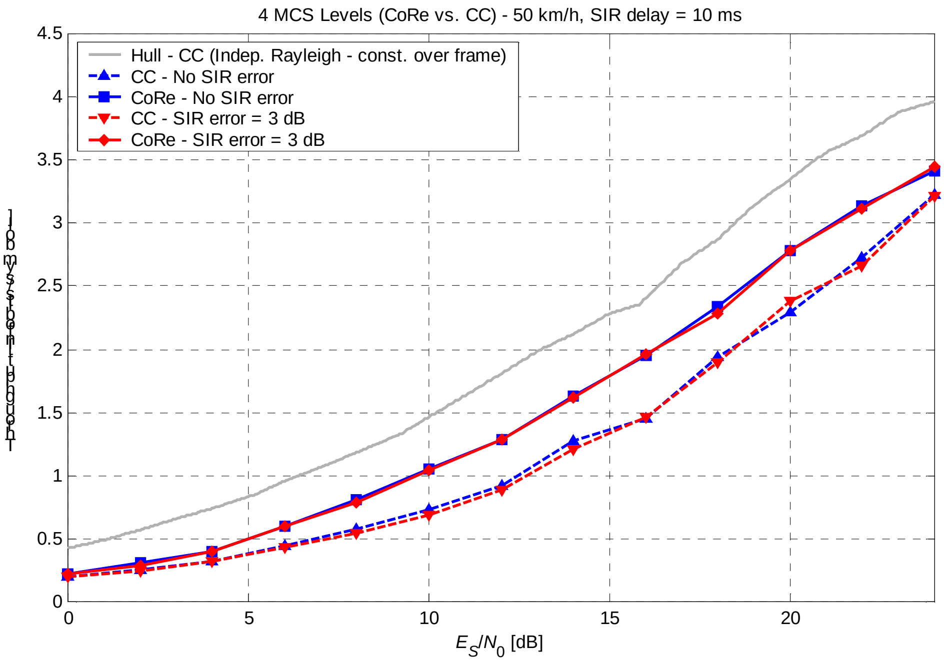

Figure 4. Throughput for 4 MCS levels, UE Speed = 50 km/h.

5 Conclusions

In this contribution the throughput performance at link-level of the HARQ method using a signal constellation rearrangement in conjunction with adaptive MCS selection was evaluated in a fading environment. The results show that for erroneous MCS selection due to fast fading and/or erroneous SIR estimation a high performance HARQ method is important. In a previous contribution [1] it was shown that the proposed HARQ method clearly outperforms conventional Chase Combining at pure link-level, while introducing less complexity than full IR. Comparisons in this contribution showed that also at link-level including adaptive MCS a gain with respect to conventional Chase Combining can be achieved. The gain increases with less accurate MCS selection and with increasing Doppler frequency.

6 References

[1] R1-01-0237, Panasonic "Enhanced HARQ Method with Signal Constellation Rearrangement," Las Vegas, USA, February 27th-March 2nd 2001.

[2] D. Chase, "Code combining: A maximum-likelihood decoding approach for combining an arbitrary number of noisy packets," IEEE Trans. Commun., Vol. COM-33, pp. 385-393, May 1985.

[3] R1-00-1238, Sony "Simulation Results for Enhanced DSCH," Busan, Korea, September 10th-13th, 2000.

[4] R4-000264, Further Simulation Results of CPICH RSCP/RSSI vs. CPICH RSCP/ISCP," San Diego, USA, February 29th-March 3rd, 2000, San Diego, California, USA.

[5] R1-00-1093, Ericsson, Motorola and Nokia, "Link Evaluation Methods for High Speed Downlink Packet Access (HSDPA)," Berlin, Germany, August 21st-24th, 2000.

Annex A

In order to use the correct mapping for the demodulation at the receiver, a FHARQ redundancy version number needs to be transmitted for 16-QAM and 64-QAM. As it can bee seen in [1] for 16-QAM 4 different mappings are needed. In case of 64-QAM 6 mappings provide best performance, however, using 4 mappings should be sufficient. Therefore, for operation at high datarates (16-QAM and 64-QAM) only 2 bits for the FHARQ redundancy version are needed.

Parameter	**Before the HSDSCH data packet**			**Simultaneously with HSDSCH data packet**		
	Min	**Prop**	**Max**	**Min**	**Prop**	**Max**
FHARQ redundancy version				0	0 2*	2

*16-QAM and 64-QAM

Table 3. Required Signaling for HARQ with Signal Constellation Rearrangement.