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1. INTRODUCTION

This document discusses simulation results for HSDPA. Gains for FCS and STTD are investigated. In this document preliminary simulation results for FCS are shown.

2. SIMULATION TOOL

Details of the used simulation tool are presented in [1] and [4].

2.1 Simulation outputs

By simulations, cell throughput, DSCH throughput and downlink mean user throughput are measured. Also the corresponding standard deviations are recorded. Cell throughput is measured as

$$R = \frac{b}{k \cdot T \cdot B} \qquad (1)$$

, where

b is the total number of *correctly* transmitted bits from all BSs in the simulated system over the whole simulated time,

k is the number of cells in the simulation,

T is the simulated time

B is the bandwidth [5 MHz].

DSCH throughput is the same as cell throughput but excluding bits transmitted by using DCH.

Downlink user throughput is defined as

$$tp = \frac{\sum_{i=1}^{N} \frac{b_i}{t_i}}{N}, \qquad (2)$$

where

N is the total number of ended calls in simulation,

b_i is the number of correctly transmitted bits for user i during call,

t_i is the active time for user. Active time means the time when there was something to transmit for user *i.* Active time is running for a user even if the user doesn't have DSCH or DCH allocated whenever system has something to transmit for the user. Reading time is excluded from the active time.

3. ASSUMPTIONS FOR SIMULATIONS

The values of the parameters used in the simulations are like suggested in [2]. The following values were used:

Table 3.1 System level simulation assumptions for HSDPA simulations

Parameter	Explanation/Assumption	Comments
Cellular layout	Hexagonal cell grid	
Cell radius	933 m	corresponds to the site to site distance of 2 800 m
Source bit rate	2048 kbps	
Air interface data rate	1 kbps (DCH) and 120, 180, 240, 360 or 540 kbps (DSCH in AMC)	DSCH bitrate is different for different modulation and coding schemes (MCSs)
UE speed	3 kmph	
Antenna pattern	Both horizontal and vertical pattern used	
CPICH power	36 dBm	
Slow fading	-----	-----
Std. Deviation of slow fading	8 dB	
Correlation between sectors	1.0	
Correlation between sites	0.5	
Correlation distance of slow fading	50 m	
Carrier frequency	2000 MHz	
Minimum coupling loss	70 dB	
BS antenna gain	14 dB	
UE antenna gain	0 dB	
Noise power in the receiver for downlink	-99 dB	
Max. number of re-transmissions	10	
H-ARQ scheme	Type I H-ARQ with soft combining	
FER-target for downlink packet bearers	50%	
BS total Tx power	43 dBm	
Active set size	1	
window_add	1 dB	
window_drop	3 dB	
t_tdrop	250 ms	
branch deletion delay	100 ms	
softer addition delay	140 ms	
soft addition delay	280 ms	
HO measurement error deviation	0 dB	
Frame length	3.33 ms	
FCS sector update delay	2 frames	
MCS update rate	once per 3.33 ms	
AMC update delay	1 frame	
Number of subscribers	50 000	
The used modulation and coding schemes	QPSK R=½, QPSK R=¾, 16QAM R=½, 16QAM R=¾, 64QAM R=¾	
Packet scheduler	Round Robin scheduler	

3.1 Simulation Cases

The following simulations focus on the effects of FCS and STTD in the HSDPA. Packet scheduling and resource allocation is done frame by frame basis. The DSCH power allocation per connection is 4 W. The maximum number of DCH per sector is 20, and that of the DSCH is 1. The default DCH bitrate is set to be 1 kbps in order to minimize its effect, and to isolate the effect of the DSCH. Due to simulator limitations only one code can be allocated per user. **Figure 1** shows the link level simulation results for the different MCS.

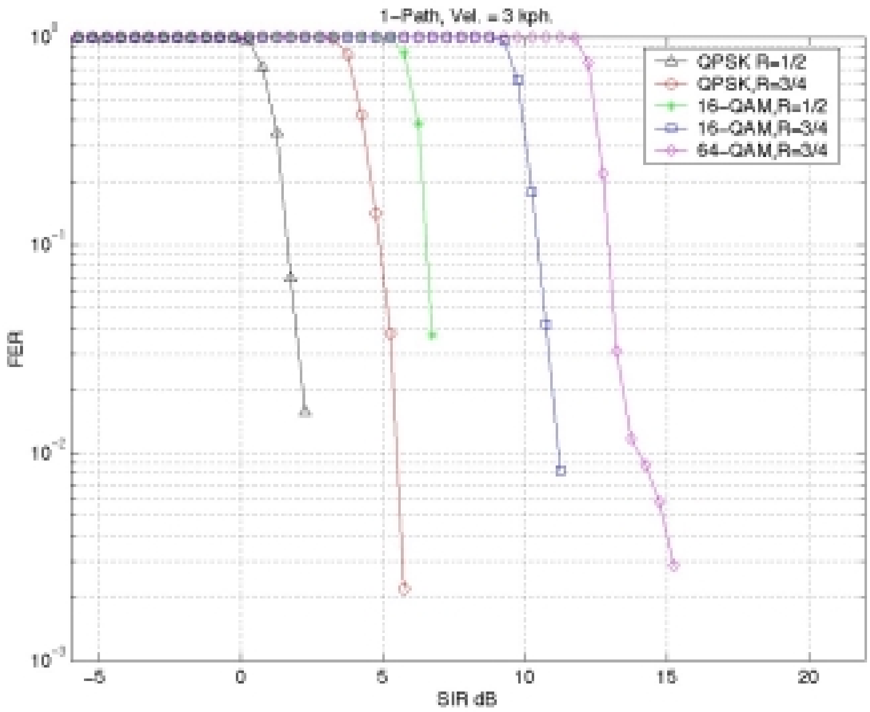

Figure 1 The link level results for the different MCS.

The bitrates used in the above link level results are tabulated in **Table 3.2**.

Table 3.2 Used Modulation and coding sets.

Modulation + Coding Scheme	Bitrate [kbps]	Spreading Factor
QPSK ½	120	32
QPSK ¾	180	32
16 QAM ½	240	32
16 QAM ¾	360	32
64 QAM ¾	540	32

All simulations with AMC were done with the above 5 MCS, with only 1 code channel per user. Thus, multi-code operation is not simulated. The following tabulates the simulation cases. In cases 9 – 12 packet scheduler was used to allocate the bitrates that range from 120 to 540 kbps. In these cases the AVI curve for every bitrate is the same, which corresponds to QPSK ½. Cases 13 – 14 are the same as cases 3 – 4, except the window_add and window_drop are 3 dB and 6 dB respectively instead of 1 dB and 3 dB as defined in the assumptions listed in **Table 3.1**. The purpose of these cases is to increase the chance of handover, and, thus, to increase the possibility of using FCS.

Table 3.3 Cases description.

Cases	AMC delay (Frames)	FCS delay (Frames)	FCS used	STTD used
Case 1	1	2	No	No
Case 2	1	2	Yes	No
Case 3	0	0	No	No
Case 4	0	0	Yes	No
Case 5	1	2	No	Yes
Case 6	1	2	Yes	Yes
Case 7	0	0	No	Yes
Case 8	0	0	Yes	Yes
Case 9	No AMC used	0	No	No
Case 10	No AMC used	0	Yes	No
Case 11	No AMC used	0	No	Yes
Case 12	No AMC used	0	Yes	Yes
Case 13*[*]	0	0	No	No
Case 14*	0	0	Yes	No

4. SIMULATION RESULTS

In the following table, cases with FCS are compared to those without FCS. The values shown are actually the percentage differences.

Table 4.1 The percentage difference of the system performance when FCS cases are compared to those without FCS.

	case 2 compared to case 1 [%]
Cell throughput	-1.4
DSCH throughput	-1.3
User throughput mean	1.3
User throughput std	0
DL FER mean	1.5
DL consecutive retransmissions mean	4.9
DL consecutive retransmission std	9.7
Token waiting time	1.3
	case 4 compared to case 3 [%]
Cell throughput	0.6
DSCH throughput	0.6

[*] The window_add is 3 dB instead of 1 dB, and window_drop is 6 dB instead of 3 dB. The former is the offset which must be exceeded beyond the existing Ec/Io before the base station is added to the active set, and the latter is the offset below the existing Ec/Io before the base station is dropped from the active set.

User throughput mean User throughput std DL FER mean DL consecutive retransmissions mean DL consecutive retransmission std Token waiting time	0.5 -2.5 1.7 4.5 6.8 -2.2
	case 6 compared to case 5 [%]
Cell throughput DSCH throughput User throughput mean User throughput std DL FER mean DL consecutive retransmissions mean DL consecutive retransmission std Token waiting time	-3.7 -3.8 -0.8 -1.6 1.8 4.8 8.2 0.7
	case 8 compared to case 7 [%]
Cell throughput DSCH throughput User throughput mean User throughput std DL FER mean DL consecutive retransmissions mean DL consecutive retransmission std Token waiting time	-0.4 -0.2 0.3 -1.6 1.6 1.7 2.8 -0.7
	case 10 compared to case 9 [%]
Cell throughput DSCH throughput User throughput mean User throughput std DL FER mean DL consecutive retransmissions mean DL consecutive retransmission std Token waiting time	10.0 10.2 -1.1 4.7 0.0 3.2 5.9 -13.8
	case 12 compared to case 11 [%]
Cell throughput DSCH throughput User throughput mean User throughput std DL FER mean DL consecutive retransmissions mean DL consecutive retransmission std Token waiting time	3.6 3.7 -0.4 2.5 0.2 0.0 0.6 -7.6
	case 14 compared to case 13 [%]
Cell throughput DSCH throughput User throughput mean User throughput std DL FER mean DL consecutive retransmissions mean DL consecutive retransmission std Token waiting time	4.6 4.7 0.5 -4.2 1.3 -2.5 4.3 3.2

In the following table the cases with STTD are compared to those without STTD. The values shown are actually the percentage differences.

Table 4.2 The percentage difference of the system performance when STTD cases are compared with those without STTD.

	case 5 compared to case 1 [%]
Cell throughput	16.5
DSCH throughput	16.8
User throughput mean	3.7
User throughput std	4.8
DL FER mean	-3.4
DL consecutive retransmissions mean	-5.1
DL consecutive retransmission std	-7.6
Token waiting time	-10.3
	case 6 compared to case 2 [%]
Cell throughput	13.8
DSCH throughput	13.9
User throughput mean	1.8
User throughput std	3.2
DL FER mean	-3.2
DL consecutive retransmissions mean	-5.2
DL consecutive retransmission std	-8.9
Token waiting time	-10.8
	case 7 compared to case 3 [%]
Cell throughput	15.7
DSCH throughput	15.7
User throughput mean	3.0
User throughput std	3.2
DL FER mean	-3.0
DL consecutive retransmissions mean	-4.5
DL consecutive retransmission std	-7.4
Token waiting time	-6.4
	case 8 compared to case 4 [%]
Cell throughput	14.5
DSCH throughput	14.8
User throughput mean	2.7
User throughput std	4.1
DL FER mean	-3.2
DL consecutive retransmissions mean	-7.0
DL consecutive retransmission std	-10.8
Token waiting time	-4.9
	case 11 compared to case 9 [%]
Cell throughput	7.1
DSCH throughput	7.3
User throughput mean	3.1
User throughput std	-3.8
DL FER mean	-2.3
DL consecutive retransmissions mean	-1.6
DL consecutive retransmission std	-4.3
Token waiting time	-4.8
	case 12 compared to case 10 [%]

Cell throughput	0.9
DSCH throughput	0.9
User throughput mean	3.7
User throughput std	-6.1
DL FER mean	-2.1
DL consecutive retransmissions mean	-4.7
DL consecutive retransmission std	-9.2
Token waiting time	2.1

Because one-tap channel is simulated, STTD gives a big improvement on the cell and user throughputs due to the nature of the diversity. **Table 4.2**. shows that STTD can provide between 10% to 20% gain, whether FCS is used or not. Such gain is possible even with AMC and FCS delays.

By increasing the chance of handover as in cases 13 and 14, the cell and user throughput shown in **Table 4.1** are increased slightly as compared to cases 3 and 4 when using FCS.

As we can see in **Table 4.1**, cell throughput gain from FCS is possible when STTD is not used and AMC and FCS delays are not present.

Some of the gain from FCS can partly be explained by the shorter token waiting times(time when in queue) when FCS is used. In this case, more users can be served during the whole simulation time.

The results presented here are quite consistent with the FCS simulation results presented in [3]. From those simulation results with Round Robin scheduler, it can be calculated that the achieved gain from FCS in the system throughput is 0.5–3.6%.

Figure 2 shows the DSCH throughput as a function of distance in case 3 and case 4. The x-axis shows the averaged distance of the group of terminals that lie between a specified distance interval. The y-axis shows the averaged DSCH bitrate of the group of terminals that lie between a specified distance interval. The effect of FCS upon the DSCH throughput as a function of distance is minimal.

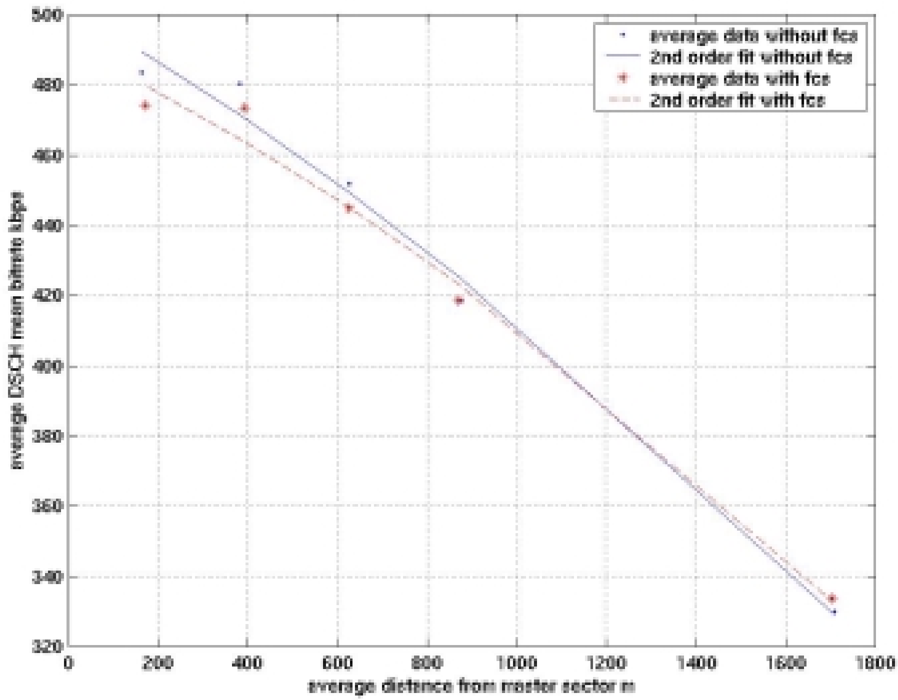

Figure 2 The average DSCH throughput as a function of distance in cases 3 and 4.

Figure 3 shows the average DSCH throughput as a function of distance in cases 13 and 14. Compared to **Figure 2**, **Figure 3** seems to suggest that when the soft-handover window is enlarged, higher gain is observed when the terminals are far from their master sector. On the other hand, slightly lower bitrate is observed for those terminals that are closer to the base station.

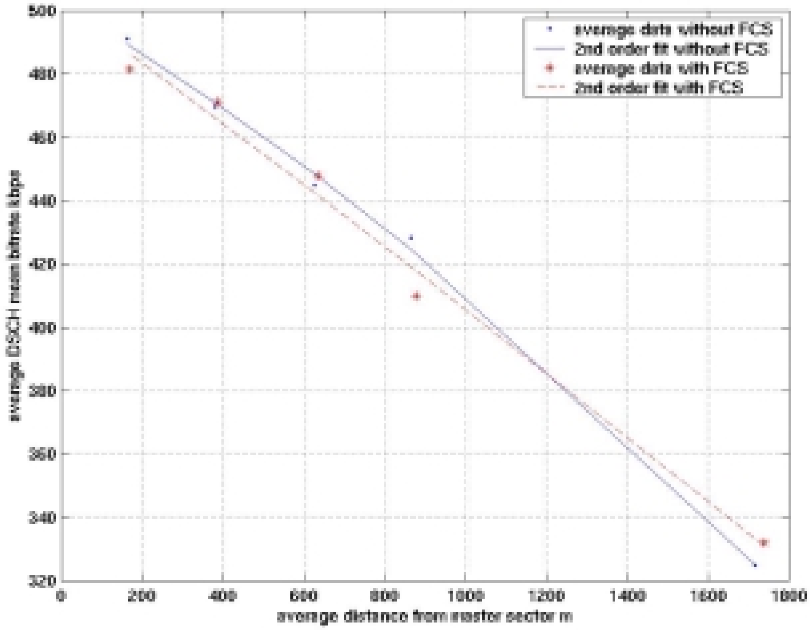

Figure 3 The average DSCH throughput as a function of distance in cases 13 and 14.

Figure 4 shows the DSCH throughput as a function of distance in cases 9 and 10. In these cases, the allocation of the bitrate is based on the packet scheduler using only QPSK ½. Recall that among the MCS, QPSK ½ has the best error performance. The results show that FCS yields no improvement for the DSCH bitrate.

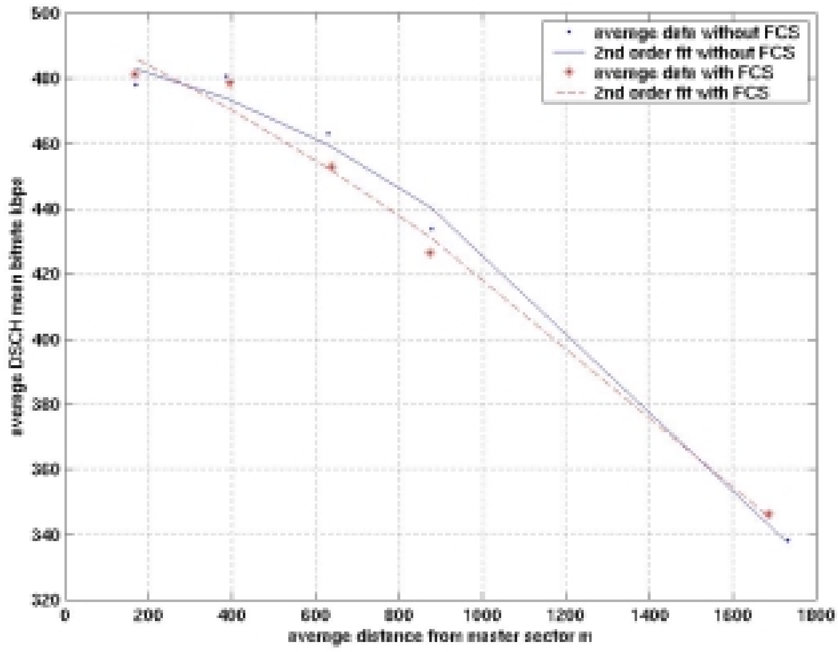

Figure 4 The average DSCH throughput as a function of distance in cases 9 and 10.

Figure 5 shows the DSCH throughput as a function of distance in case 3 and case 7. Comparing **Figure 2** and **Figure 5**, STTD seems to be able to provide a slightly higher bitrate than the use of FCS as a function of distance. Note the difference between the DSCH bitrate increases slightly as a function of distance.

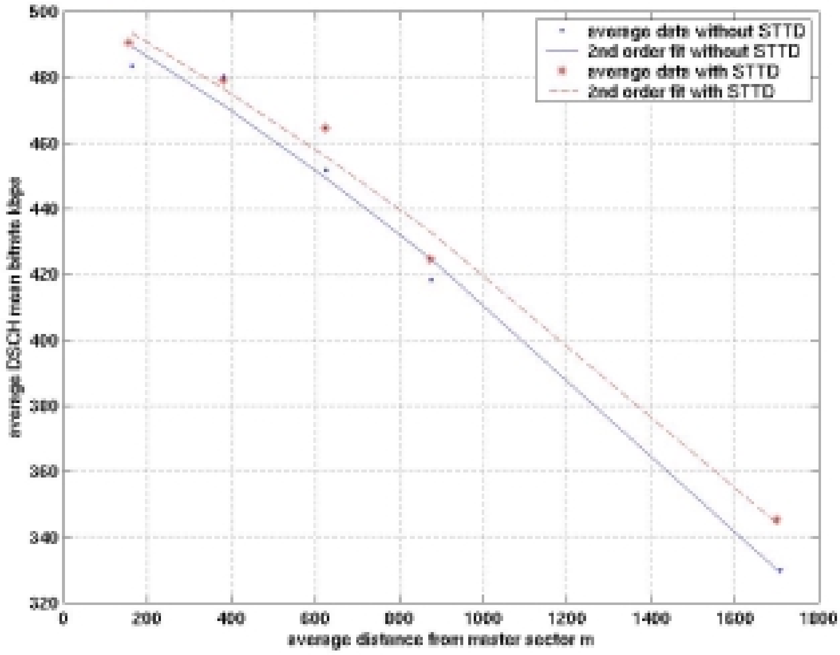

Figure 5 The average DSCH throughput as a function of distance in cases 3 and 7.

5. CONCLUSION

As these preliminary results imply, the use of FCS does not give any reasonable cell throughput gain (if any) when AMC is used. In addition, no user throughput gain is observed. STTD, on the other hand, yields a much higher gain in both the cell throughput and user throughput.

An intelligent packet scheduling algorithm which can allocate the number of DSCH together with the appropriate modulation and coding set is in a process of development.

6. REFERENCES

[1] Hämäläinen, S., Holma, H. and Sipilä, K., "Advanced WCDMA Radio Network Simulator", in proceedings of PIMRC99 conference, 1999

[2] Nokia, Ericsson, Motorola. Common HSDPA system simulation assumptions. TSG-R1 document, TSGR#15(00)2094, 22–25th, August, 2000, Berlin, Germany, 12 pp

[3] 3GPP technical specification report, Physical Layer Aspects of UTRA High Speed Downlink Packet Access (Release 2000), TR25.848, version 0.3.1

[4] Nokia, HSDPA System Level Simulations. TSGR1#19(01)0295, Las Vegas, February 27 – March 2, 2001