TSG-RAN Working Group 1 meeting #19
Las Vegas, NE, USA
February 27 – March 2, 2001

TSGR1#19(01)0295

Agenda item: AH24 HSDPA
Source: Nokia
Title: HSDPA System Level Simulations
Document for: Discussion

1. INTRODUCTION

This document discusses first simulation results for HSDPA. Gains for AMC are investigated. In addition, the used simulator platform is presented.

2. SIMULATION TOOL

Details of the used simulation tool is presented in [1]. The simulator has models for propagation, mobility, traffic, cell deployment, maps, antennas, WCDMA BS and UE receivers etc. Typical simulation environment is a system with macro cell hexagonal base stations with 3 sectors. For each sector real 3-D antennas are assumed. The used propagation model is a modified Hata model specified in UMTS30.03 [2]. HSDPA related assumption are given in [3]. The simulated scenario and antenna pattern are given in Figure 1.

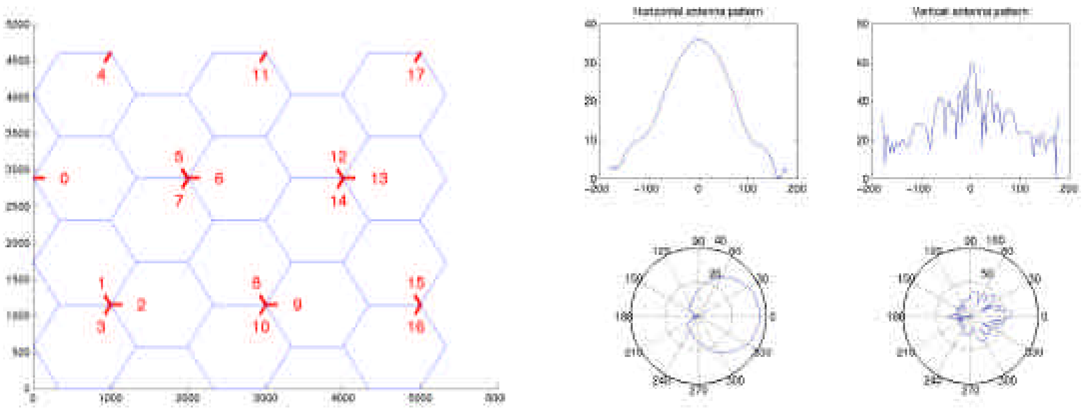

Figure 1 The simulated cell layout[*] and the used antenna pattern with BSs.

The shadowing modeling is adopted from [2]. The shadowing model is a time correlated process with mean value of 0 dB and standard deviation being as a parameter and separately defined for each environment. The decorrelation length of the process is an environment dependent parameter. There exists also correlation between cells and base stations.

The multipath propagation is modeled with the simulator. In the simulator each multipath component has its own fast fading process. The number of multipaths and the path gains can be obtained from the channels models such as ATDMA or ITU. The fading process is generated by using e.g. Jakes model. The sum of multipath components is normalized so that the average value of the sum is equal to one. In these simulations only one multipath component is used, i.e. single tap Rayleigh channel has been assumed**.**

The total interference power P_w received by a mobile station is calculated as follows:

---

[*] In the simulations presented in this document the cell radius is 933 m.

$$P_w = \sum_{n=1}^{N} \left(L_{n,k} \cdot \frac{\sum_{i=1}^{L} g_{i,n,k}}{\sum_{i=1}^{L} \hat{g}_{i,n,k}} \cdot Ptx_n \right) \qquad (2.1)$$

where N is the total number of base stations in the system and k is index for the observed user. $L_{n,k}$ is pathloss (attenuation due to distance and slow fading) between the base station n, and the mobile station k. $\sum g / \sum \hat{g}$ is the multipath fading normalized to having long term average equal to one and L is number of multipath components. Ptx_n is the total transmission power for the base station n.

In downlink the effect due to orthogonal codes has to be considered. Because of the multi-path propagation perfect orthogonality cannot be assumed. Thus, the models for orthogonal reception and orthogonality losses are developed. For optimal maximal ratio combining, signal-to-noise-ratio can be calculated as

$$SNR = \sum_{n=1}^{N} \left(\sum_{i=1}^{L} \frac{G \cdot p_{n,k} \cdot L_{n,k} \cdot g_{i,n,k}}{P_W ? N ? P_n \cdot L_{n,k} \cdot g_{i,n,k}} \right) \qquad (2.2)$$

where P_w is the total interference power received by the mobile station. N is number of base stations in the active set (=1 when calculating SNR for DSCH), $p_{n,k}$ is the transmitting power for the observed user from base station n. P_n is the total power transmitted from the base station n. $\sqrt{L_{n,k} \cdot g_{i,n,k}}$ is amplitude of channel tap i from base station n.

Since the used simulator is a dynamic simulator the users are moving in the simulation area according to the mobility model. Separate mobility models are defined for each environment according [2]. When new users are generated in the macro cell simulation they are uniformly distributed over the simulation area. The direction to which a new user is moving is randomly selected when a new user is created. The direction of movement is updated for a user after every decorrelation length. A user may move freely to any directions with constant speed within the whole area. Probability for the direction update is independent of previous update. The probability for update is given in Table 2.1.

Table 2.1 The parameters for the mobility model in vehicular environment

Parameter	**Example value**
Mobile speed	120 kmph
Propability to change direction at position update	0.2
Maximal angle for direction update	45°
Decorrelation length	20 m

In these simulations pedestrian mobility model is used. The users move at the speed 3 kmph.

In the simulator the users are making calls and transmitting data according to the traffic models. Figure 2. depicts a typical WWW browsing session [2]. A session consists of sequence of packet calls that can be considered as web page downloading. The bursty nature of fixed network is modeled by assuming that one packet call constitutes of several packets. A packet service session contains one or several packet calls depending on the application. After the page is entirely downloaded to the terminal, the user spends a certain amount of time for studying the information. This time interval is called a reading time.

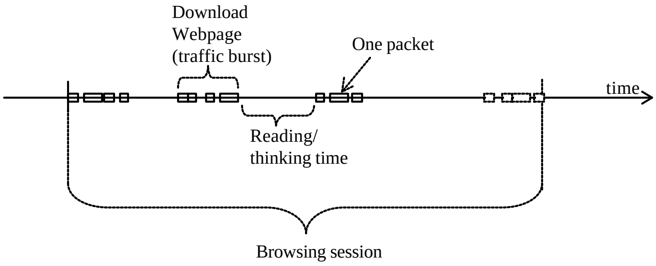

FIgure 2 Word Wide Web traffic characteristic.

To the simulator RRM (Radio Resource Management) algorithms are modeled in a detailed way. Realistic implementation for power control (inner loop, outer loop, open loop) and handover is done.

2.1 HSDPA modeling

When HSDPA is simulated length of radio frame is set equal to 5 slots that corresponds to 3.33 ms duration.

When HSDPA is simulated power control is switched off. Then the used power is the maximum power allocated for a single connection.

2.2 STTD

(STTD) Space time transmit diversity is modeled with a simple approach. Basically, STTD increases the number of resolvable multipath components. In the reception paths remain othogonal.

2.3 FCSS

FCSS (Fast Cell Site Selection) is based on CPICH Ec/Io measurements in the downlink. The UE continuously measures CPICH Ec/Io for each base station (or sector) added to the active set (in DCH mode). Single CPICH measurement can be obtained once per radio frame. The UE compares CPICH Ec/Io measurements from several base stations and communicates with the strongest one. If a non-active base station becomes the strongest one FCSS handover is made and the UE continues to communicate with that BS. Before the UE may communicate with the new base station certain time is elapsed due to signaling and processing delay.

When the UE changes the active base station, it continues its transmission in the new base station with the same data rate unless link adaptation algorithm changes its AMC set. Thus, packet scheduler is not invoked when active link is changed.

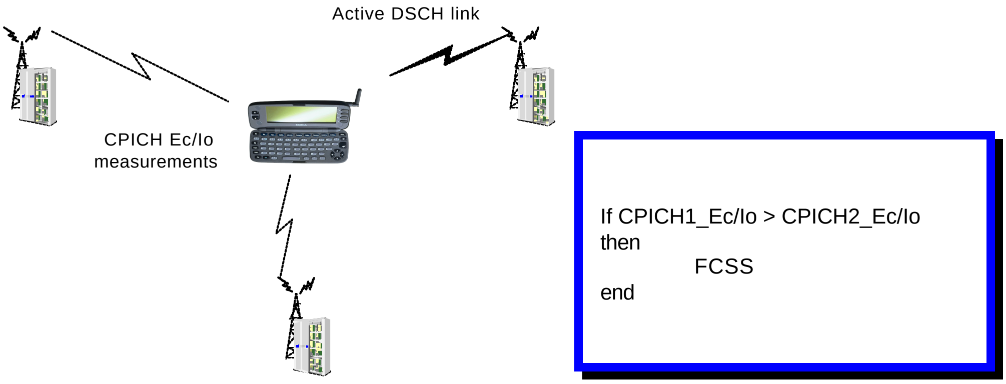

Figure 3 FCSS concept.

When time due to signaling and processing delays is elapsing, no CPICH Ec/Io measurements are sent to the network. During that time, the UE is transmitting data through the current base station.

To the CPICH Ec/Io measurements measurement errors are involved. The measured CPICH Ec/Io value is:

$$CPICH\_E_c / I_0 \; ? \; ideal\_CPICH\_E_c / I_0 \; ? \; ? \qquad (2.3.1)$$

where ideal_CPICH_Ec/I0 is ideal CPICH measurement given in decibels and ? is log-normally distributed error with standard deviation as a parameter.

2.4 HARQ

In these simulations H-ARQ type-I with soft combining is assumed. With this method SIR values of re-transmissions are summed together. This models maximum ratio combining used to combine re-transmitted packets.

With simulations not any kind of re-transmission protocol is assumed. This means that one packet is first transmitted as long as it has been correctly received by the UE. Feedback channel has been assumed error free and with no delay.

2.5 AMC and link adaptation

Simple link adaptation (LA) algorithm has been used to select proper AMC (Adaptive modulation and coding) set for existing radio environment. The implemented LA algorithm uses same measurements that are made for the FCSS. This means, DSCH Eb/Io measurements are made for the serving base station once per frame. To the ideal measurement log-normal error is added.

2.6 Packet scheduler

The used packet scheduler algorithm is a modified round-robin algorithm. When there is a need to transmit data to the UE (there is some data in the transmit buffer), a capacity allocation request is sent to the packet scheduler. Coming requests are put to a queue from which they are served with FIFO (first in - first out) principle. However, those users are served first who already had a channel (DCH or DSCH) allocated.

2.7 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

$$R \; ? \; \frac{b}{k ? T ? B} \qquad (2.7.1)$$

, 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

$$tp \; ? \; \frac{\overset{N}{\underset{i?1}{?}} \frac{b_i}{t_i}}{N}, \qquad (2.7.2)$$

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 [3]. 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	
FCSS sector update delay	3 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 AMC 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. Simulations are made with hard handover.

The bitrates used in the above link level result is tabulated in the following.

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

Table 3.1 Cases descriptions.

	Modulation and coding rate	Number of codes
Case 1	QPSK R = ½	1
Case 2	QPSK R = ½, QPSK R = ¾,	1, 1
Case 3	QPSK R = ½, QPSK R = ¾, 16 QAM R = ½,	1, 1, 1
Case 4	QPSK R = ½, QPSK R = ¾, 16 QAM R = ½, 16-QAM R = ¾, 64-QAM R = ¾	1, 1, 1, 1, 1

4. SIMULATION RESULTS

In Table 1 simulation results are shown. The selected loading was low explaining low throughput. Also, the used packet shceduler that is not able to schedule more than 1 code per user explain low value. The theoretical maximum throughput that could be achieved with single code was 108 kbps/MHz/cell in an ideal situation.

Table 1 Simulation statistics from the cases in which 1 to 5 MCS are used.

Simulations with only 1 MCS at a time				
	Case 1:	Case 2:	Case 3:	Case 4:
Cell throughput [kb/s/cell/MHz]	23.5	29.5	33.2	39.4
DSCH throughput [kb/s/cell/MHz]	22.0	28.1	31.6	38.0
DL throughput mean [kbps/user]	5.6	7.2	8.3	10.9
DL throughput std	2.7	3.7	6.2	14.1

Figure 4a shows the cell throughput and DSCH throughput per carrier in cases 1 to 4. As seen from the figure, there is an improvement of 28% of DSCH throughput using only 2 MCS. With 3 and 5 MCS, the DSCH throughput improvement reaches 44% and 73% respectively. The results obviously suggest that AMC can greatly enhance the DSCH throughput, as well as the total cell throughput.

In Figure 4b, the average user connection throughputs and their standard deviations are shown. With 2, 3, and 5 MCS, the improvement in the user throughput is 29%, 48%, and 95%. Thus, the network can make good use of the channel conditions to enhance the throughput. On the other hand, one obvious consequence of MCS selection is the variability of the bitrate, which brings about an increase in the user throughput standard deviation. With 2, 3, and 5 MCS, the increase in the user throughput standard deviation is 37%, 130%, and 422% respectively.

Figure 5. show the DSCH Eb/Io distributions and the MCS selection probability. Note that the MCS selection directly depends upon the Eb/Io distribution. If the Eb/Io distribution has a large variance, more MCS can be accommodated.

Figure 6 shows the number of consecutive re-transmissions in case 4 and the user throughput CDFs of cases 1–4. It can be seen that the majority of the packets are correctly received after the first re-transmission. The bigger variance of throughputs with more MCSs can be noticed from the figure on the right.

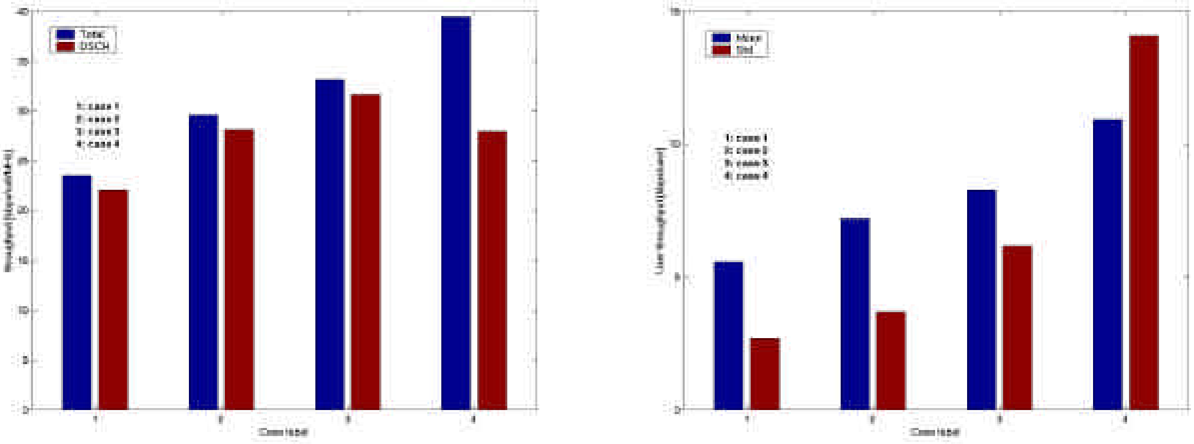

Figure 4 Cell throughput and DSCH throughput per carrier(a) and User throughput and standard deviation (b) for case 1 - case 4.

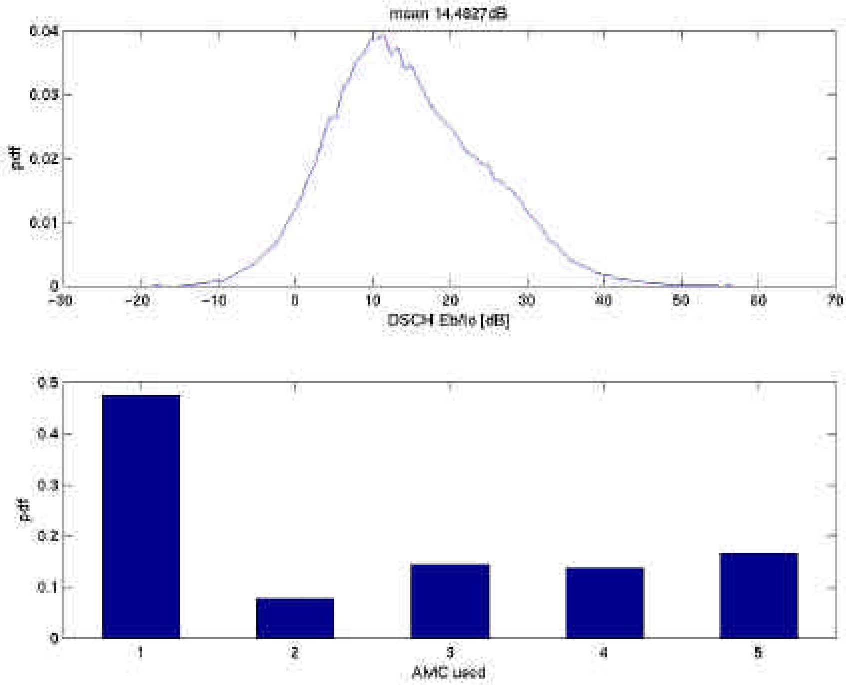

Figure 5 DSCH Eb/Io and the AMC selection probability in case 4.

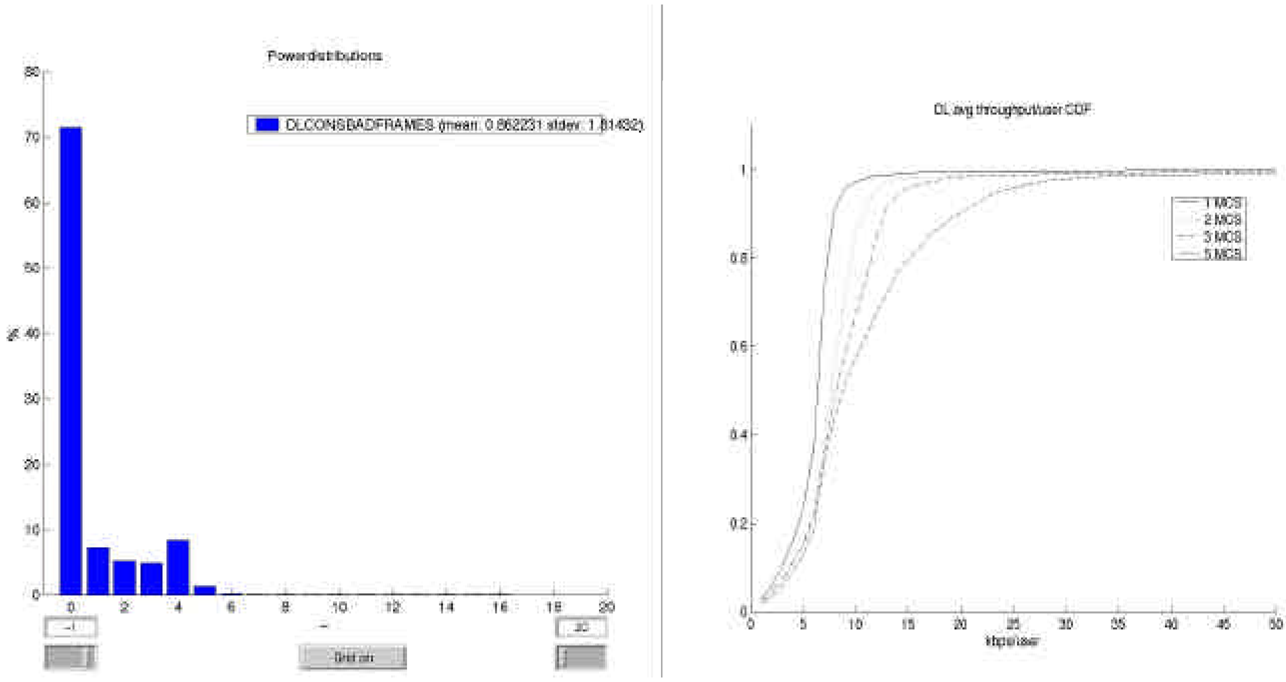

Figure 6 Left: The number of consecutive re-transmissions in case 4. Right: The user throughput CDFs in cases 1–4.

5. CONCLUSION

The simulation results suggest that the use of AMC is beneficial to increase the network throughput as well as user throughput.

These simulations were made for single code case and with hard handover. A flexible packet scheduler, which can allocate different number of multi-codes with AMC, should be implemented to the simulator to see the more optimal effect of AMC. Simulation results for such scheduler will be shown later on. Also, simulation in which DCH can be in soft handover need to be made with and without FCSS for DSCH. Those simulation are shown later on, as well.

6. REFERENCES

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

[2] UMTS 30. 03

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