Agenda item:	**AdHoc #24 HSDPA**
Source:	**Motorola**
Title:	**HSDPA system performance based on simulation** (II)
Document for:	**Discussion/Information**

Summary:

Similar to [3] the data throughput for best effort service is summarized in this contribution for the proposed HSDPA feature set. The main differences between this study and [3] are that 30% of the power is allocated for overhead (CPICH, PICH, SCH, BCCH, etc.) and dedicated channels and that no implementation loss (1.5dB was used in [3]) is used. Throughput and other packet statistics are also shown for the single MCS level case of QPSK with a peak data rate of up to 2Mbit/s. The latter case is the first step in trying to establish release 99 throughput for best effort service. However, for this first step, the frame size is still 3.33ms and fast scheduling and acknowledgment is performed along with fast cell selection (FCS).

Results were obtained using a dynamic system simulation tool. The system simulator tool models Rayleigh and Rician fading, time evolution with discrete steps (0.667ms e.g.), adaptive modulation and coding (AMC), fast Hybrid ARQ, fast cell selection FCS, and open loop transmit diversity (STTD). The simulator also models Lognormal shadowing, delay spread, and fractional recovered power (per ray). Most of the system simulation assumptions used are described in the "Common HSDPA system simulation assumptions" contribution (TSG-R1 1094) presented in TSG-R1 meeting #15 [1]. Many assumptions are given again in **Appendix B** for the reader's convenience.

Simulation Results:

The packet data throughput for best effort service for is summarized in the following section. **Tables 1** and **2** summarize baseline performance for a data only HSDPA system with a Maximum C/I scheduler and a modified ETSI source model [1]. The different throughput metrics presented are defined in **Appendix A** (note the definition of OTA throughput has been modified from [3]). The MCS used were QPSK R=1/2, 16QAM R=1/2, 16QAM R=3/4, and 64QAM R=3/4.

Table 1. Baseline HSDPA Throughput Performance vs Load (entire system) with Max C/I Scheduler based on Modified ETSI source model and 30% Overhead

Single Rayleigh Ray, 3kph, FRP=0.98 Block Size=336 bytes Max C/I, Mod. ETSI 30% Overhead AMC, HARQ, FCS

#Users per sector, Max ovsf codes	Average Throughput - Entire System			Percent Utilization	Offered Load	User PktCall thruput cdf	%users with Res.
	OTA	Service	Packet call			<32k/64k/128k/384k/1M	FER >10-2 / 10-4
	(bps)	(bps)	(bps)	(%)	(bps)	(%)	(%)
012ue/sect, 20size32	2,363,084	402,067	1,569,877	17.9	402,628	0/0/0/1/23	0.0/ 0.9
037ue/sect, 20size32	1,976,833	1,130,675	1,228,870	59.9	1,133,783	0/0/1/13/47	0.1/ 7.7
056ue/sect, 20size32	2,091,348	1,660,774	1,075,564	79.4	1,664,775	1/3/8/27/56	0.5/11.2
075ue/sect, 20size32	2,373,411	2,065,421	1,016,820	85.2	2,066,855	4/9/16/36/61	0.6/ 9.7
100ue/sect, 20size32	2,783,349	2,572,591	983,691	89.0	2,579,717	10/16/25/43/64	0.8/ 7.9

Table 2. Baseline HSDPA Throughput Performance vs Load (center cell) with Max C/I Scheduler based on Modified ETSI source model and 30% Overhead

Single Rayleigh Ray, 3kph, FRP=0.98 Block Size=336 bytes Max C/I, Mod. ETSI 30% Overhead AMC, HARQ, FCS

#Users per sector, Max ovsf codes	Average Throughput - Center Cell			Percent Utilization	Offered Load	User PktCall throuput cdf	%users with Res.
	OTA	Service	Packet call			<32k/64k/128k/384k/1M	FER >10-2 / 10-4
	(bps)	(bps)	(bps)	(%)	(bps)	(%)	(%)
012ue/sect, 20size32	2,343,668	532,250	1,522,671	23.1	532,365	0/0/0/0/22	0.0/0.0
037ue/sect, 20size32	1,841,815	1,300,848	1,141,774	75.3	1,324,639	0/0/3/13/51	0.0/7.5
056ue/sect, 20size32	1,875,662	1,880,632	952,051	98.5	1,883,993	2/5/13/39/62	1.0/13.4
075ue/sect, 20size32	2,219,979	2,289,244	894,597	99.8	2,295,336	6/11/19/45/68	1.9/12.5
100ue/sect, 20size32	2,695,379	2,813,727	914,466	100.0	2,822,685	14/20/32/52/71	0.9/7.5

From **Table 1** above, the Service throughput averaged over all sectors for the Max C/I scheduler is about 2.5Mbit/s at 89% utilization while the OTA throughput is about 2.8Mbit/s. The overall average Packet Call throughput drops from about 1.6Mbit/s to 1.0Mbit/s as the load increases. Fairness is shown in terms of the per user average packet call throughput outage cdf values given in both tables. For example, for the 12 users per sector load 1% of the users achieve an average packet call throughput of between 128kbit/s and 384kbit/s, 22% between 384kbit/s and 1Mbit/s, and 77% of the users in the system achieve better than 1Mbit/s. Residual FER after Hybrid ARQ is given in terms of the percentage of users with packet loss (residual FER) greater than 10^{-2} and 10^{-4}. For the 75 users per sector load from **Table 1**, about 90% of the user's FER after ARQ (residual FER) is less than 10^{-4} and about 99% of the users have residual FER less than 10^{-2}. Small residual FER is important to TCP/IP performance.

Table 2 gives center cell only statistics, and shows that the average Service throughput reaches about 2.8Mbit/s at 100% channel utilization. Average Packet Call throughput drops to about 0.9Mbit/s at 100% channel utilization. Note that the service throughput statistic can still improve once 100% channel utilization is reached for a given sector if there are fewer retransmissions. As surrounding sectors reach 100% utilization the uncertainty of other cell interference level is reduced thus reducing AMC errors and resulting in fewer retransmissions.

WCDMA Release 99 throughput performance is bounded by the results given in **Table 3** and **4** below. QPSK modulation with a maximum peak rate of 2Mbit/s was modeled. Fast scheduling, a 3.33ms frame size, and conventional ARQ (no soft combining) were used. A tighter throughput bound is possible by increasing the frame size (TTI=10ms or 20ms) and increasing the scheduling and acknowledgement latency (this was not done for this study). HSDPA Packet Call throughput performance from **Tables 1** and **2** is about twice that of Release 99 throughput bound results in **Tables 3** and **4**. For the 56 user/sector load, 44% of the data users have packet call throughput better than 1Mbit/s (see **Table 1**) while the Release 99 bound case only has 5% of its users better than 1Mbit/s (see **Table 3**).

Table 3. QPSK with 2Mbit/s Pk Rate Throughput Performance vs Load (entire system) with Max C/I Scheduler based on Modified ETSI source model and 30% Overhead

#Users per sector, Max ovsf codes	Average Throughput - Entire System OTA (bps)	Service (bps)	Packet call (bps)	Percent Utilization (%)	Offered Load (bps)	User PktCall thruput cdf <32k/64k/128k/384k/1M (%)	%users with Res. FER >10-2 / 10-4 (%)
012ue/sect, 17size32	1,404,140	385,060	837,077	34.8	388,711	0/0/1/8/69	0.0/19.9
037ue/sect, 17size32	1,453,553	1,026,188	611,505	79.0	1,044,331	1/3/9/34/92	1.1/19.9
056ue/sect, 17size32	1,535,192	1,291,871	501,094	86.3	1,353,155	7/13/25/55/95	0.9/10.4
075ue/sect, 17size32	1,562,766	1,386,232	453,189	89.3	1,406,764	17/25/36/59/96	2.3/4.7
100ue/sect, 17size32	na	na	na	na	na	na	na

Table 4. QPSK with 2Mbit/s Pk Rate Throughput Performance vs Load (center cell) with Max C/I Scheduler based on Modified ETSI source model and 30% Overhead

Single Rayleigh Ray, 3kph, FRP=0.98 Block Size=336 bytes Max C/I, Mod. ETSI 30% Overhead QPSK, 2Mbit/s peak rate, noHARQ

#Users per sector, Max ovsf codes	Average Throughput - Center Cell OTA (bps)	Service (bps)	Packet call (bps)	Percent Utilization (%)	Offered Load (bps)	User PktCall thruput cdf <32k/64k/128k/384k/1M (%)	%users with Res. FER >10-2 / 10-4 (%)
012ue/sect, 17size32	1,423,765	547,474	830,334	43.5	548,755	0/0/0/4/69	0.0/20.4
037ue/sect, 17size32	1,450,735	1,266,567	604,962	96.2	1,296,810	0/3/10/37/90	0.0/15.7
056ue/sect, 17size32	1,556,237	1,560,540	464,713	99.9	1,583,330	8/12/31/64/96	2.4/9.1
075ue/sect, 17size32	1,584,900	1,599,731	440,446	100.0	1,657,337	23/32/48/70/96	8.0/8.4
100ue/sect, 17size32	na	na	na	na	na	na	na

Conclusion:

Best effort packet data average sector service throughput for a HSDPA system with 30% overhead using a maximum C/I scheduler was shown to about 2.5Mbit/s based on quasi-static system simulations. A single ray 3kph Rayleigh faded channel was modeled for each user. At this load level up to 36% of the users in the system still achieved a packet call throughput exceeding 1Mbit/s and less than 10% achieved throughput below 32kbit/s (from Table 1). HSDPA has twice the throughput of the Release 99 WCDMA throughput bound (see Table 3).

References:

[1] Nokia, Ericsson, Motorola. Common HSDPA system simulation assumptions. TSG-R1 document, TSGR#15(00)1094, 22-25th, August, 2000, Berlin, Germany, 12 pp.

[2] Motorola. Evaluation Methods for High Speed Downlink Packet Access (HSDPA). TSG-R1 document, TSGR#14(00)0909, 4-7th, July, 2000, Oulu, Finland, 15 pp.

[3] Motorola. HSDPA system performance based on simulation. TSG-R1 document, TSGR#16(00)1240, 10-13th October 2000, Pusan Korea, 12pp.

Appendix A

Throughput Statistic Descriptions

OTA – over the air per frame throughput, Frame Rate/#transmissions. (Unaffected by time between retries.)
Service – total good (successful) frame bits transmitted per second for a given sector. As observed from BTS including all users and idle time. (Affected by time between retries).
Packet Call - total bits per packet call divided by total time to transmit packet call.
Utilization – percentage of time that frame intervals are active for a given sector.
(active = transmission occurs on downlink shared channel).

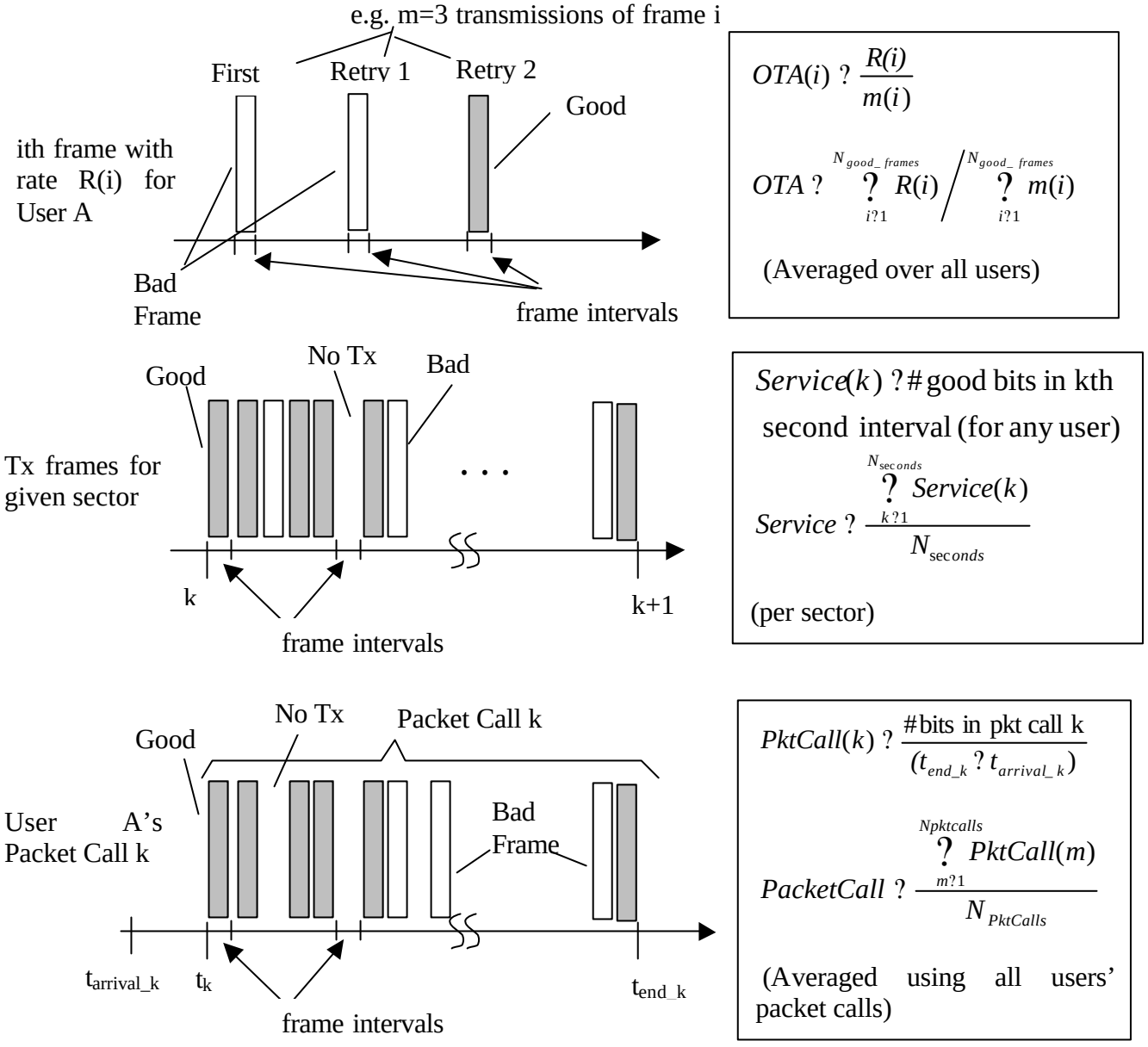

Figure A1. Throughput Statistic Description for System Simulations.

The service throughput for a given sector j is

$$ServiceSector(j) = \frac{1}{N_{seconds}} \sum_{k=1}^{N_{seconds}} \#\text{good bits for kth second inverval for sector j} \quad (1)$$

The service throughput averaged over all sectors in the system is

$$ServiceSystem = \frac{1}{N_{sectors}} \sum_{j=1}^{N_{sectors}} ServiceSector(j) \quad (2)$$

Also

$$ServiceSystem = \frac{\text{total good bits all sectors}}{N_{seconds} N_{sectors}} \quad (3)$$

or

$$ServiceSystem = \frac{\text{total good bits all sectors}}{(N_{good\_frames} + N_{retries} + N_{empty}) T_{frame}} \quad (4)$$

where

N_{good_frames} – total good frames over all sectors sent during simulation
$N_{retries}$ – total unsuccessful (“bad”) frames over all sectors transmitted during simulation
N_{empty} – total frame intervals over all sectors where there was no transmission during sim.
N_{lost} – total frame intervals over all sectors where the corresponding frame was aborted during sim.
T_{frame} – frame time interval

$$OTASystem = \frac{\text{total good bits all users}}{N_{good\_frames} + N_{retries}} \quad (5)$$

$$Utilization = \frac{N_{good\_frames} + N_{retries} + N_{lost}}{N_{good\_frames} + N_{retries} + N_{empty} + N_{lost}} \quad (6)$$

$$\frac{ServiceSystem}{OTASystem} = \frac{N_{good\_frames} + N_{retries}}{N_{good\_frames} + N_{retries} + N_{empty}} \quad (7)$$

Therefore

$$\boxed{Utilization = \frac{ServiceSystem}{OTASystem}} \quad (8)$$

The packet call throughput is given by

$$PktCall(k,i,j) \;?\; \frac{\#\,\text{bits in pkt call k}}{(t_{end\_k} \;?\; t_{arrival\_k})} \tag{9}$$

where

k = denotes the k^{th} packet call from a group of K packet calls

i = denotes the i^{th} user from a group of N users

j = denotes the j^{th} drop from a group of J drops

the time parameters in Equation **Error! Reference source not found.** are described in Figure A1.

The user packet call throughput becomes

$$UserPktCall(i,j) \;?\; \frac{1}{K} \sum_{k?1}^{K} PktCall(k,i,j) \tag{10}$$

APPENDIX B

System Simulation Assumptions

The following parameters related to HSDPA features were used:

- ?? MCS selection based on CPICH measurement (RSCP/ISCP)
- ?? MCS update rate: once per 3.33 ms (5 slots)
- ?? CPICH measurement transmission delay: 1 frame
- ?? Selected MCS can be applied after 1 frame delay upon receiving measurement report
- ?? Std. dev. of CPICH measurement error: 0
- ?? CPICH measurement rate: once per 3.33 ms (sampling is 0.67ms, IIR filter sampled once per 3.33ms using IIR filter with coefficient of 0.3 (new data weighted by 0.7))
- ?? CPICH measurement report error rate: 0 %
- ?? Frame length for fast HARQ: 3.33 ms
- ?? Fast HARQ feedback error rate: 0%
- ?? Channel Model: 3kph, single Rayleigh ray with 0.98 fraction of recovered power
- ?? STTD enabled.
- ?? Maximum C/I scheduler (see [1])
- ?? Modified ETSI Call model (see [1])
- ?? No implementation loss (Note [3] had implementation loss of 1.5dB)
- ?? Throughput measurements are over the entire two-ring system and the center cell.

Basic system level parameters:

The basic system level simulation parameters are listed in the Table [1] below.

Table B1. Basic system level simulation assumptions.

Parameter	**Explanation/Assumption**	**Comments**
Cellular layout	Hexagonal grid, 3-sector sites	19 sites
Site to Site distance	2800 m	
Antenna pattern	As proposed in [2]	Only horizontal pattern specified
Propagation model	$L = 128.1 + 37.6\ Log_{10}(R)$	R in kilometres
CPICH power	-10 dB	
Other common channels	- 10 dB	
Power allocated to HSDPA transmission, including associated signaling	Max. 70% of total cell power	
Slow fading	Similar to UMTS 30.03, B 1.4.1.4	
Std. deviation of slow fading	8.0 dB	
Correlation between sectors	1.0	
Correlation between sites	0.5	
Correlation distance of slow fading	50 m	See D,4 in UMTS 30.03.
Carrier frequency	2000 MHz	
BS antenna gain	14 dB	
UE antenna gain	0 dBi	
UE noise figure	9 dB	
Max. # of retransmissions	15	Retransmissions by fast HARQ
Fast HARQ scheme	Chase combining	Dual stop-and-wait
BS total Tx power	42.3 dBm	
Active set size	3	Maximum size
Specify Fast Fading model	Jakes spectrum	Generated by Filter approach