Agenda item:	**AdHoc #24 HSDPA**
Source:	**Motorola**
Title:	**HSDPA system performance with/without FCS (faded but no motion)**
Document for:	**Discussion/Information**

Summary:
Similar to [1,2] the data throughput for best effort service is summarized in this contribution for the proposed HSDPA feature set. This contribution addresses the effect of fast cell selection (FCS) on down link throughput and residual FER.

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 [3]. Many assumptions are given again in **Annex B** for the reader's convenience.

Conclusion:
Fast Cell Selection (FCS) improves throughput and residual FER for UEs in multi-coverage regions (soft handoff regions). This is because a UE in a multi-coverage region typically has a weaker channel to any single serving cell compared to UEs closer to their serving cell. With FCS the multi-coverage UE has more opportunities to select a better link to one of the serving cells and be scheduled. The overall system benefit due to FCS is more significant with fair schedulers (such as Round Robin) compared to maximum C/I scheduler since the users with weak links are scheduled more often. With a maximum C/I scheduler the larger the load the less impact FCS has on performance. Without FCS it takes longer for UEs with weak links to finish a packet call and hence longer to release the dedicated control channel which results in further overhead and reduced system capacity. Future study will determine how much larger the FCS benefit is with motion.

FCS
Fast Cell Selection (FCS) allows a UE to rapidly choose any one cell in its active set (i.e. set of potential serving cells) for down link transmission. The potential benefit is that for each frame interval the active set cell with the best faded link can be chosen for frame transmission to the UE. The UE chooses the best cell by comparing each active set cell's estimated CPICH Ec/Io and transmits a cell indicator to be detected by the desired cell on a uplink dedicated control channel. Frame retransmissions can therefore take place by any active set cell if chosen and the resulting received signal energy from each frame is accumulated to model a Chase combining process. Note that the active set evolves with time as a UEs position changes. In this simulation the UEs experience fast (Rayleigh) fading but did not move from the initial location for a given Monte Carlo drop.

As part of the adaptive modulation and coding (AMC) schemes proposed for HSDPA, the UE also estimates CPICH Ec/Nt (C/I) for each cell in its pilot active set for the current slot. The pilot Ec/Nt information for the selected cell is then also fed back on an uplink dedicated control channel. The Node B then uses the C/I estimate to determine the modulation and coding level for that users subsequent frame and possibly also for setting scheduling priorities. Past system simulation contributions [1,2] by Motorola have had FCS effectively disabled since at the time, average Ec/Io was used for cell selection instead of faded Ec/Io. The simulation results presented below compare throughput and residual FER statistics with and without FCS enabled. The cell selection update rate is once every 3.33ms.

Measure CPICH Select cell	Transmit C/I and Cell indicator	Sched Decision MCS selection (C/I and/or PC info)	Frame Transmission	✍ Simulation Approach

|----------------------|----------------------|--------------------- ---|----------------------|------------------------|

Simulation Results

The packet data throughput for best effort service with and without FCS is summarized in the following section. **Tables 1** through **4** summarize performance for a data only HSDPA system with Maximum C/I and Round Robin schedulers using a modified ETSI source model [3]. The different throughput metrics presented are defined in **Annex A** (note the definition of OTA throughput has been modified from [1]). The MCS used were QPSK R=1/2, 16QAM R=1/2, 16QAM R=3/4, and 64QAM R=3/4.

From **Tables 1** and **2** for the Maximum C/I scheduler we see small improvements with FCS on. There is a small improvement in the per user packet call throughput cdf for low throughput users under low system loading. The columns marked "Residual FER" give the percentage of UEs whose frame error rate, after all retransmissions, is above 1% and 0.1%. FCS also reduces residual frame error rate for low throughput users, which is important for TCP/IP applications.

TABLE 1 FCS Disabled with Max C/I Scheduler

Single Rayleigh Ray, 3kph, FRP=0.98 Block Size=336 bytes Max C/I, Mod. ETSI 30% Overhead AMC, HARQ, no FCS

#Users per sector, Max ovsf codes	Average Throughput Statistics Entire System OTA	Service	Packet call	Percent Utilization	Offered Load	User Packet Call Throughput CDF <32k/64k/128k/384k/1M	%UEs with Residual FER >10-2 / >10-4
	(bps)	(bps)	(bps)	(%)	(bps)	(%)	(%)
012ue/sect, 20size32	2,338,440	387,204	1,568,007	16.5	399,220	00/00/00/01/23	0.0 / 0.2
037ue/sect, 20size32	2,035,561	1,140,388	1,277,785	55.2	1,172,408	00/00/01/11/43	0.0 / 0.4
056ue/sect, 20size32	2,120,471	1,679,382	1,131,307	77.4	1,720,800	00/01/05/23/53	0.0 / 0.4
075ue/sect, 20size32	2,391,955	2,155,493	1,057,189	87.5	2,201,708	02/05/12/32/58	0.0 / 0.5
100ue/sect, 20size32	2,798,980	2,670,794	1,011,444	91.9	2,716,026	07/13/21/40/62	0.0 / 0.4

TABLE 2 FCS Enabled with Max C/I Scheduler

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 Statistics Entire System OTA	Service	Packet call	Percent Utilization	Offered Load	User Packet Call Throughput CDF <32k/64k/128k/384k/1M	%UEs with Residual FER >10-2 / >10-4
	(bps)	(bps)	(bps)	(%)	(bps)	(%)	(%)
012ue/sect, 20size32	2,420,614	393,447	1,588,520	16.2	405,329	00/00/00/00/21	0.0 / 0.0
037ue/sect, 20size32	1,997,291	1,148,252	1,274,242	56.4	1,181,163	00/00/00/08/43	0.0 / 0.0
056ue/sect, 20size32	2,049,253	1,699,108	1,109,216	80.7	1,742,468	00/01/04/22/53	0.0 / 0.0
075ue/sect, 20size32	2,345,164	2,171,345	1,041,938	89.6	2,213,770	02/05/12/32/58	0.0 / 0.0
100ue/sect, 20size32	2,766,521	2,692,171	996,139	93.5	2,739,260	07/13/21/40/63	0.0 / 0.0

From **Tables 3** and **4** for the Round Robin scheduler see somewhat larger throughput improvements with FCS on compared to the Maximum C/I scheduler. **Figure 1** illustrates FCS benefits by showing the %User Packet Cell throughput CDF with and without FCS at different loading. **Figure 2** shows the increase in the average number of dedicated channels required to support the users that are not in the dormant state (waiting for all the packets of a packet call). **Figures 3** and **4** compare throughput performance and fairness for Round Robin and Maximum C/I schedulers. **Annex C** gives the center cell results with and without FCS for the two schedulers.

TABLE 3 FCS Disabled with Round Robin Scheduler

Single Rayleigh Ray, 3kph, FRP=0.98 Block Size=336 bytes RRobin, Mod. ETSI 30% Overhead AMC, HARQ, no FCS

#Users per sector, Max ovsf codes	Average Throughput Statistics Entire System OTA	Service	Packet call	Percent Utilization	Offered Load	User Packet Call Throughput CDF <32k/64k/128k/384k/1M	%UEs with Residual FER >10-2 / >10-4
	(bps)	(bps)	(bps)	(%)	(bps)	(%)	(%)
012ue/sect, 20size32	2,157,079	389,284	1,507,379	17.9	401,654	00 / 00 / 00 / 01 / 23	0.0 / 0.1
037ue/sect, 20size32	1,497,979	1,111,120	904,903	72.8	1,136,996	00 / 00 / 02 / 21 / 64	0.0 / 0.6
056ue/sect, 20size32	1,328,442	1,470,168	446,527	100.0	1,476,561	02 / 11 / 30 / 65 / 91	0.0 / 1.6
075ue/sect, 20size32	1,308,320	1,630,910	254,732	100.0	1,598,901	17 / 40 / 60 / 88 / 96	0.0 / 1.3

TABLE 4 FCS Enabled with Round Robin Scheduler

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

#Users per sector, Max ovsf codes	Average Throughput Statistics Entire System OTA	Service	Packet call	Percent Utilization	Offered Load	User Packet Call Throughput CDF <32k/64k/128k/384k/1M	%UEs with Residual FER >10-2 / >10-4
	(bps)	(bps)	(bps)	(%)	(bps)	(%)	(%)
012ue/sect, 20size32	2,282,522	391,198	1,547,580	17.0	397,347	00 / 00 / 00 / 00 / 19	0.0 / 0.0
037ue/sect, 20size32	1,548,366	1,133,420	957,866	71.8	1,161,699	00 / 00 / 00 / 13 / 60	0.0 / 0.1
056ue/sect, 20size32	1,326,962	1,524,255	426,340	100.0	1,532,878	00 / 05 / 26 / 64 / 93	0.0 / 0.2
075ue/sect, 20size32	1,299,941	1,690,414	230,325	100.0	1,665,984	11 / 36 / 58 / 89 / 97	0.0 / 0.2

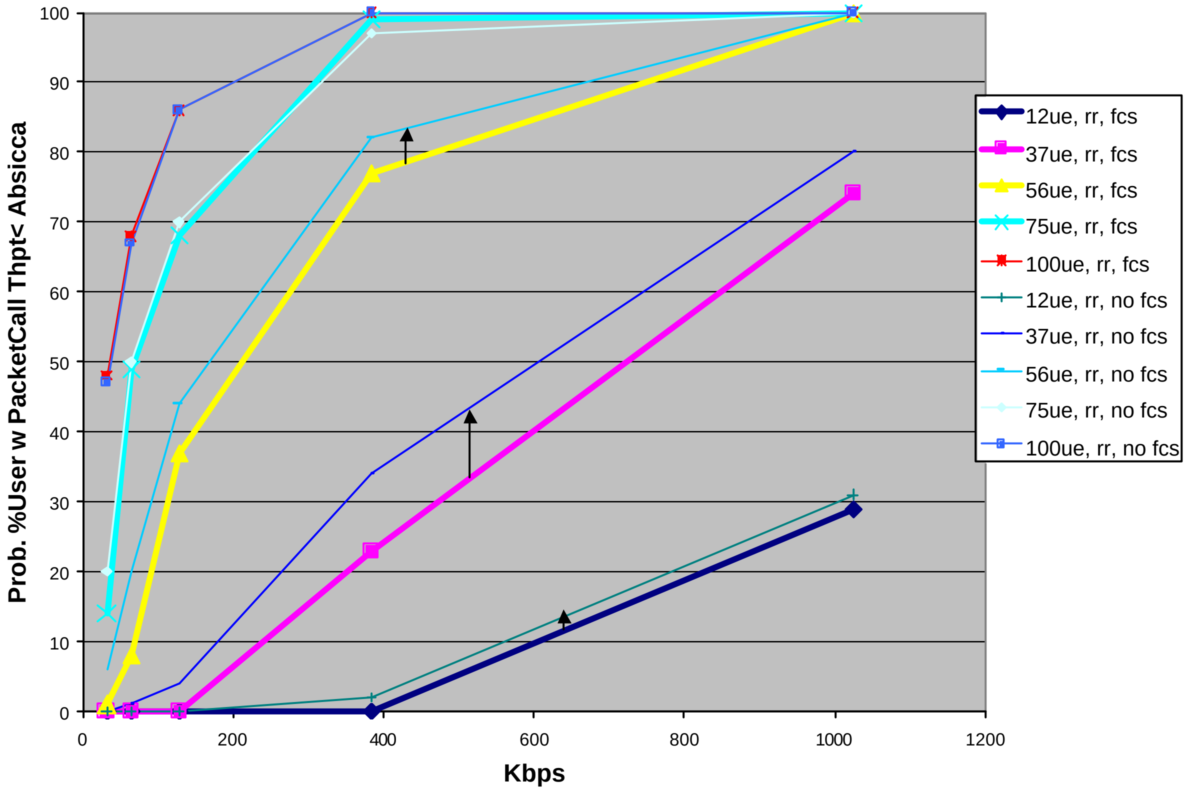


Figure 1. %User Packet Call Throughput CDF w/wo FCS for Round Robin

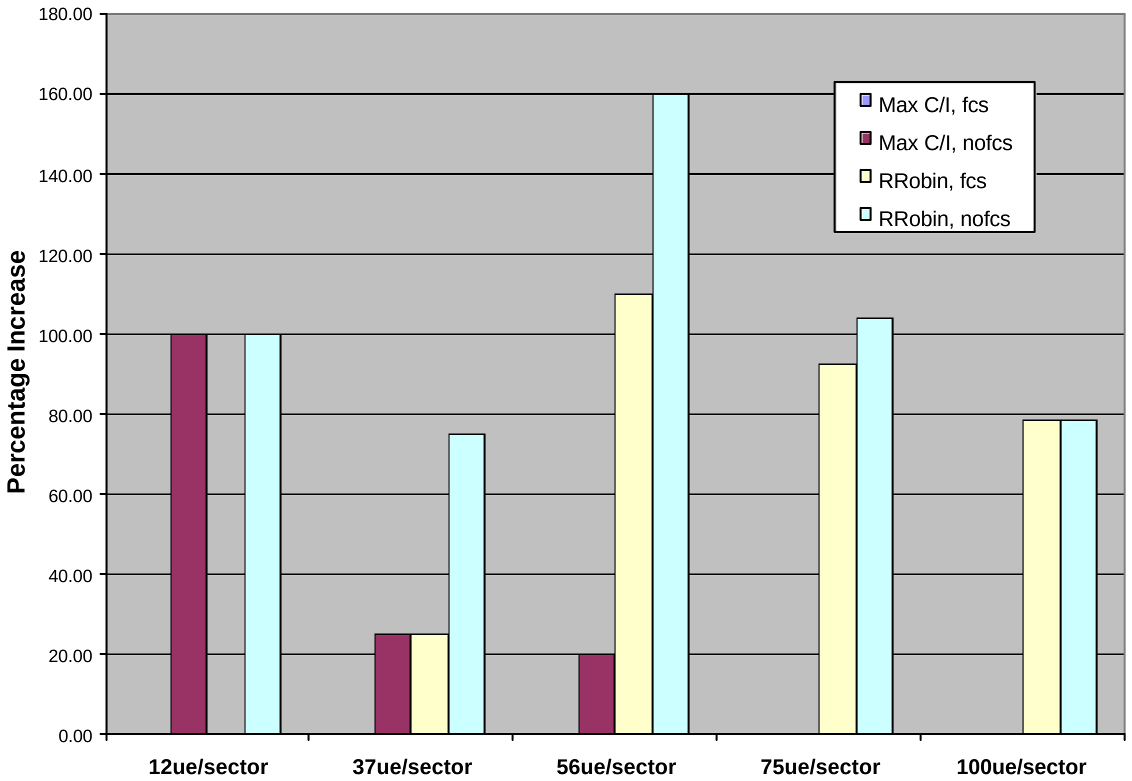


Figure 2. %Increase in required dedicated channels w/wo FCS

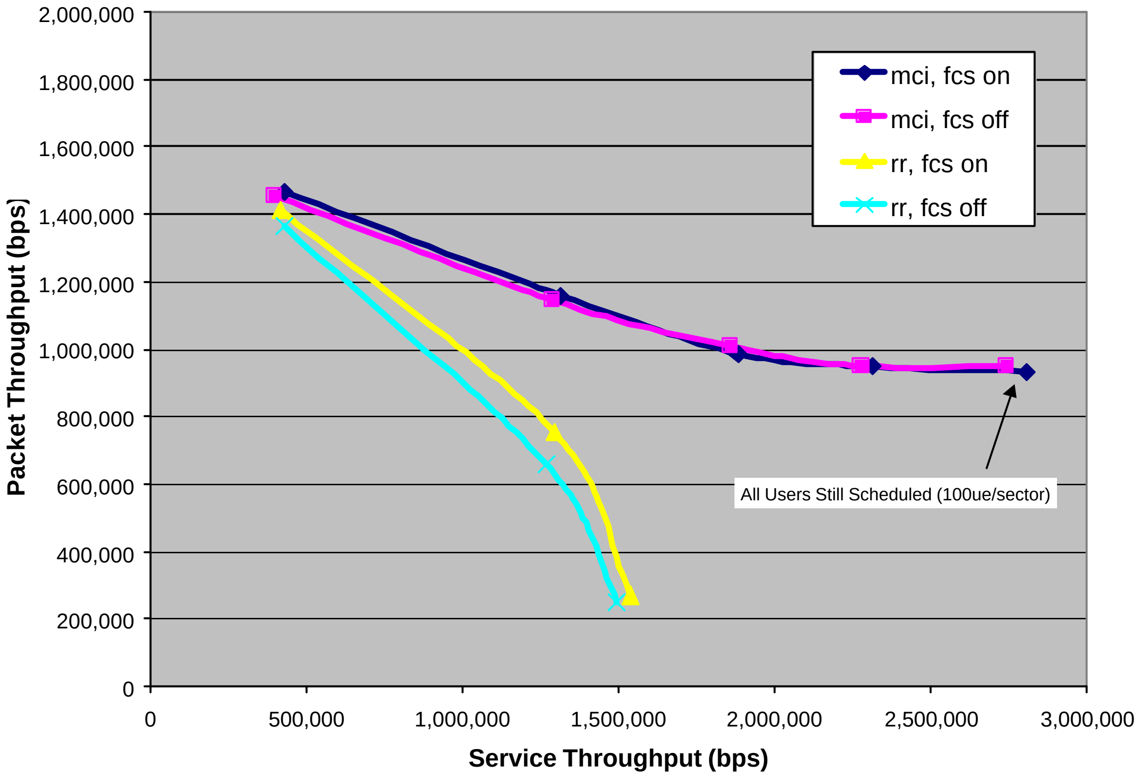


Figure 3. Packet Throughput vs Service Throughput for Max C/I and Round Robin

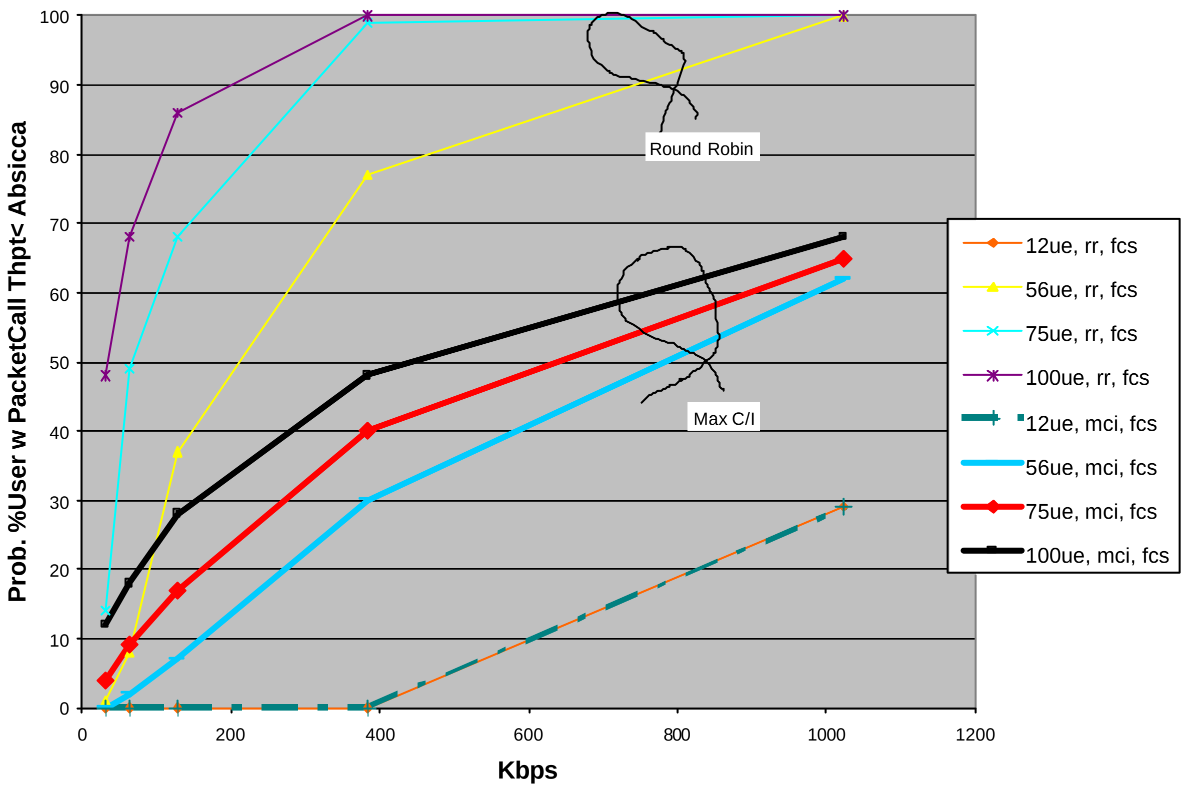


Figure 4. Fairness: %User Packet Call Throughput CDF comparing Maximum C/I with Round Robin Schedulers at 3kph.

References:

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

[2] Motorola. HSDPA system performance based on simulation II. TSG-R1 document, TSGR#17(00)1397, 20-24th November 2000, Stockholm Sweden, 8pp.

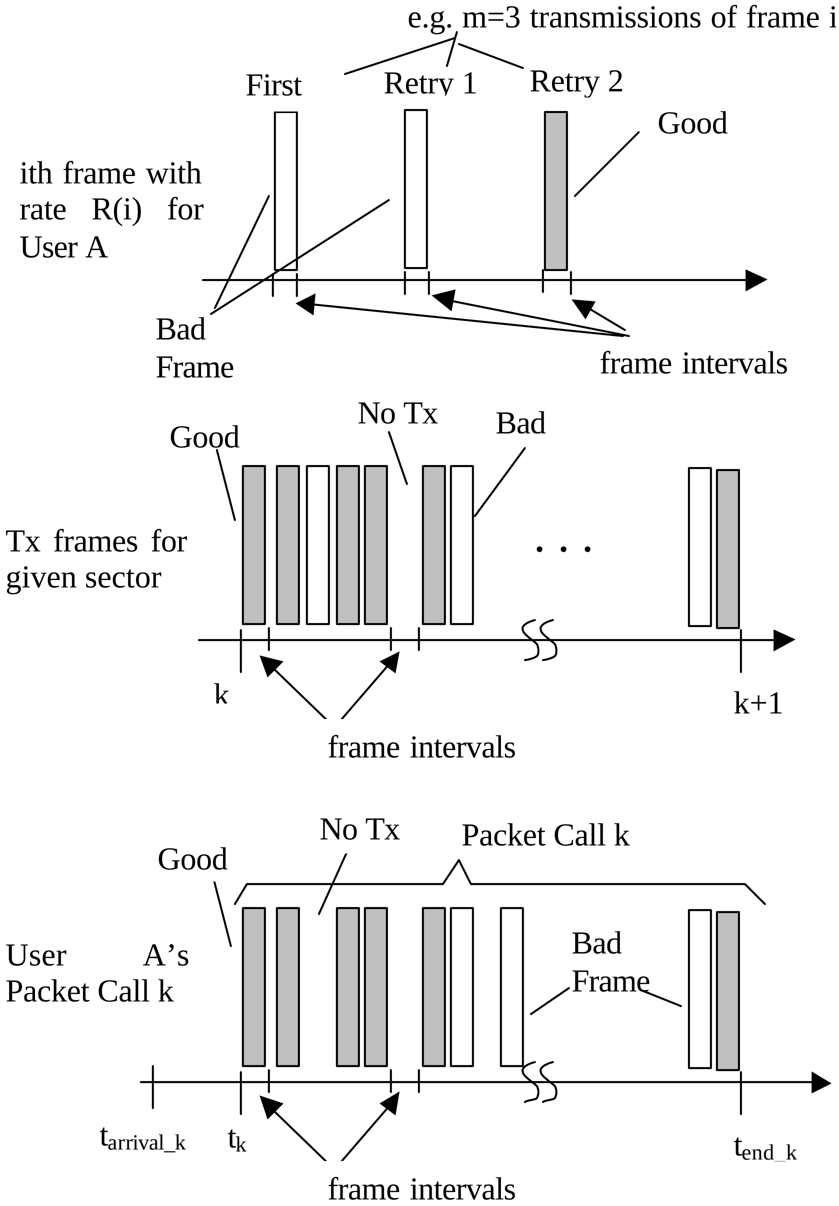
[3] Nokia, Ericsson, Motorola. Common HSDPA system simulation assumptions. TSG-R1 document, TSGR#15(00)1094, 22-25th, August, 2000, Berlin, Germany, 12 pp.

[4] 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.

Annex 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).



$$OTA(i) = \frac{R(i)}{m(i)}$$

$$OTA = \sum_{i=1}^{N_{good\_frames}} R(i) \Big/ \sum_{i=1}^{N_{good\_frames}} m(i)$$

(Averaged over all users)

$$Service(k) = \text{\# good bits in kth second interval (for any user)}$$

$$Service = \frac{\sum_{k=1}^{N_{seconds}} Service(k)}{N_{seconds}}$$

(per sector)

$$PktCall(k) = \frac{\text{\#bits in pkt call k}}{(t_{end\_k} - t_{arrival\_k})}$$

$$PacketCall = \frac{\sum_{m=1}^{Npktcalls} PktCall(m)}{N_{PktCalls}}$$

(Averaged using all users' packet calls)

Figure A1. Throughput Statistic Description for System Simulations.

The service throughput for a given sector j is

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

The service throughput averaged over all sectors in the system is

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

Also

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

or

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

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

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

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

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

Therefore

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

The packet call throughput is given by

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

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 10 are described in Figure A1.

The user packet call throughput for user i and Monteo Carlo drop j becomes

$$UserPktCall(i,j) ? \frac{1}{K} \overset{K}{\underset{k?1}{?}} PktCall(k,i,j) \quad (10)$$

ANNEX B

System Simulation Assumptions

The following parameters related to HSDPA features were used:

?? MCS selection based on CPICH measurement (RSCP/ISCP, also refered to as pilot Ec/Nt or C/I)

?? 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: 0,1, and 3 dB

?? 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 [3])

?? Modified ETSI Call model (see [3])

?? No implementation loss (Note [1] had implementation loss of 1.5dB)

?? Throughput measurements are over the entire system.

?? Fast Cell Selection is based on other CPICH measurement (pilot Ec/Io)

Basic system level parameters:
The basic system level simulation parameters are listed in Table B1 [3] 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 [4]	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

ANNEX C
Center Cell Results

TABLE C1 FCS enabled with Round Robin Scheduler

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

#Users per sector, Max ovsf codes	Average Throughput Statistics Center Cell			Percent Utilization	Offered Load	User Packet Call Throughput CDF <32k/64k/128k/384k/1M	%UEs with Residual FER >10-2 / >10-4
	OTA	Service	Packet call				
	(bps)	(bps)	(bps)	(%)	(bps)	(%)	(%)
012ue/sect, 20size32	1,982,657	415,306	1,413,348	20.8	429,053	00 / 00 / 00 / 00 / 29	0.0 / 0.0
037ue/sect, 20size32	1,368,515	1,293,143	755,675	92.7	1,318,958	00 / 00 / 00 / 23 / 74	0.0 / 0.1
056ue/sect, 20size32	1,170,690	1,536,627	270,263	100.0	1,564,606	01 / 08 / 37 / 77 / 100	0.0 / 0.1
075ue/sect, 20size32	1,153,368	1,643,038	131,571	100.0	1,607,811	14 / 49 / 68 / 99 / 100	0.0 / 0.0
100ue/sect, 20size32	1,241,680	1,814,308	72,039	100.0	1,710,995	48 / 68 / 86 / 100 / 100	0.0 / 0.0

TABLE C2 FCS disabled with Round Robin Scheduler

Single Rayleigh Ray, 3kph, FRP=0.98 Block Size=336 bytes RRobin, Mod. ETSI 30% Overhead AMC, HARQ, no FCS

#Users per sector, Max ovsf codes	Average Throughput Statistics Center Cell			Percent Utilization	Offered Load	User Packet Call Throughput CDF <32k/64k/128k/384k/1M	%UEs with Residual FER >10-2 / >10-4
	OTA	Service	Packet call				
	(bps)	(bps)	(bps)	(%)	(bps)	(%)	(%)
012ue/sect, 20size32	1,851,645	430,126	1,362,667	23.1	444,246	00 / 00 / 00 / 02 / 31	0.0 / 0.0
037ue/sect, 20size32	1,284,689	1,267,335	660,490	96.8	1,298,350	00 / 01 / 04 / 34 / 80	0.0 / 0.6
056ue/sect, 20size32	1,142,682	1,495,718	249,990	100.0	1,485,697	06 / 20 / 44 / 82 / 100	0.0 / 2.6
075ue/sect, 20size32	1,152,082	1,596,640	133,097	100.0	1,545,042	20 / 50 / 70 / 97 / 100	0.0 / 1.3
100ue/sect, 20size32	1,206,321	1,724,802	77,184	100.0	1,656,422	47 / 67 / 86 / 100 / 100	0.0 / 1.8

TABLE C3 FCS enabled with Max C/I Scheduler

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 Statistics Center Cell			Percent Utilization	Offered Load	User Packet Call Throughput CDF <32k/64k/128k/384k/1M	%UEs with Residual FER >10-2 / >10-4
	OTA	Service	Packet call				
	(bps)	(bps)	(bps)	(%)	(bps)	(%)	(%)
012ue/sect, 20size32	2,118,458	427,956	1,466,449	20.1	454,575	00 / 00 / 00 / 00 / 29	0.0 / 0.0
037ue/sect, 20size32	1,836,760	1,313,060	1,159,096	70.9	1,336,101	00 / 00 / 00 / 10 / 51	0.0 / 0.0
056ue/sect, 20size32	1,887,865	1,880,098	987,084	95.8	1,935,522	00 / 02 / 07 / 30 / 62	0.0 / 0.0
075ue/sect, 20size32	2,229,414	2,311,716	947,773	99.9	2,360,019	04 / 09 / 17 / 40 / 65	0.0 / 0.0
100ue/sect, 20size32	2,700,551	2,806,070	933,943	100.0	2,867,221	12 / 18 / 28 / 48 / 68	0.0 / 0.0

TABLE C4 FCS disabled with Max C/I Scheduler

Single Rayleigh Ray, 3kph, FRP=0.98 Blk Size=336 bytes Max C/I, Mod. ETSI 30% Overhead AMC, HARQ, no FCS

#Users per sector, Max ovsf codes	Average Throughput Statistics Center Cell			Percent Utilization	Offered Load	User Packet Call Throughput CDF <32k/64k/128k/384k/1M	%UEs with Residual FER >10-2 / >10-4
	OTA	Service	Packet call				
	(bps)	(bps)	(bps)	(%)	(bps)	(%)	(%)
012ue/sect, 20size32	2,016,602	399,988	1,453,708	20.0	412,128	00/00/00/02/30	0.0 / 0.4
037ue/sect, 20size32	1,818,217	1,288,837	1,143,915	69.4	1,324,342	00/00/02/15/52	0.0 / 0.4
056ue/sect, 20size32	1,939,603	1,859,168	1,006,686	93.1	1,904,112	01/02/09/30/61	0.0 / 0.8
075ue/sect, 20size32	2,227,333	2,276,803	950,520	99.1	2,325,396	04/10/17/39/65	0.0 / 0.7
100ue/sect, 20size32	2,642,199	2,738,313	949,156	100.0	2,791,936	11/18/28/46/68	0.0 / 0.4