Agenda item:	**AdHoc #24 HSDPA**
Source:	**Motorola**
Title:	**HSDPA system performance with/without CPICH errors and H-ARQ**
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 two additional issues: 1) The effect of CPICH measurement error on throughput and 2) The loss in throughput when Chase combining is not used, i.e., no Hybrid ARQ (H-ARQ). CPICH measurement errors of 0, 1 and 3 dB were evaluated with and without Chase combining.

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.

CPICH SIR Measurement Error

In the adaptive modulation and coding (AMC) schemes proposed for HSDPA, the UE uses the CPICH to estimate the downlink SIR (also known as C/I or Ec/Nt) in the current slot. This information is then fed back on an uplink control channel. Node B then uses this estimate to determine the modulation and coding level for that users subsequent frame and possibly also for setting scheduling priorities. Past contributions by Motorola have assumed perfect estimation of the downlink SIR. The simulation results presented below give throughput statistics when the measured CPICH SIR is modeled as:

$$\hat{SIR}_{CPICH} = SIR_{CPICH} + \varepsilon_{CPICH}$$

where SIR_{CPICH} and $\hat{SIR}_{CPICH}$ are the actual and estimated CPICH SIR respectively in dB and ε_{CPICH} is a Gaussian random variable with standard deviation σ_ε dB.

Hybrid ARQ

The system simulation tool models Chase combining process by accumulating the received signal energy of frame retransmissions. Based on this accumulated energy, a random number is drawn to determine if the frame is in error. In equation form, the energy used to determine a frame error, $Error\_Energy_{HARQ}(k)$, is accumulated across k transmissions:

$$Error\_Energy_{HARQ}(k) = \sum_{i=1}^{k} E_{DSCH}(i)$$

where $E_{DSCH}(k)$ is the received energy of the kth frame.

Hybrid ARQ is disabled by simply neglecting the accumulated energy and basing frame error determination on the current frame energy:

$$Error\_Energy_{NO\_HARQ}(k) = E_{DSCH}(k)$$

Simulation Results/Conclusions

The packet data throughput for best effort service is summarized in the following section. **Tables 1 - 6** summarize baseline performance for a data only HSDPA system with a Maximum C/I scheduler and 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 for the H-ARQ enabled case were QPSK R=1/2, 16QAM R=1/2, 16QAM R=3/4, and 64QAM R=3/4. The seven MCS used for the H-ARQ disabled case were QPSK R=1/4, QPSK R=1/2, QPSK R=3/4, 16QAM R=1/2, 8PSK R=1/2, 16QAM R=3/4, and 64QAM R=3/4. The minimum block size for the non-Hybrid ARQ case is set smaller (44 bytes versus 336 bytes) to allow more flexibility in allocating as small an MCS as needed for poor channels conditions which is important when H-ARQ is not available to help. This is needed to keep residual FER low.

From **Tables 1- 3** we see that with H-ARQ on, there is a drop in packet call throughput of between 5% and 10% with 1 dB CPICH measurement error. Sector throughput decreases by only about 5%. For 3dB CPICH measurement error, however, the packet call throughput drop approaches 50% and the sector throughput drop reaches 20%. The columns marked "Residual FER" give the percentage of users whose frame error rate, after all retransmissions, is above 1% and .1%. Estimation errors of 1 dB are seen to cause only very small increases in residual error rate.

Comparing **Tables 1 - 3** with H-ARQ to **Tables 4 - 6** without H-ARQ we see a significant drop in packet call throughput and residual FER without H-ARQ as also illustrated in **Figures 1-3**.

In general every effort should be made to find algorithms which keep the CPICH SIR measurement error smaller than 3dB and preferably no larger than 1 dB. In the future more accurate CPICH SIR measurement error models could account for dependency on SIR level.

TABLE 1 H-ARQ Enabled with CPICH Error ? =0dB

Single Rayleigh Ray, 3kph, FRP=0.98 Blk Size=336 bytes Max C/I, Mod. ETSI 30% Overhead AMC, no FCS, HARQ, ? =0dB

#Users per sector, Max ovsf codes	Average Throughput Statistics Center Cell OTA (bps)	Service (bps)	Packet call (bps)	Percent Utilization (%)	Offered Load (bps)	User Packet Call Throughput CDF <32k/64k/128k/384k/1M (%)	%UEs with Residual FER >10-2 / >10-4 (%)
012ue/sect, 20size32	2,189,367	476,764	1,494,552	21.7	492,820	00 / 00 / 00 / 02 / 29	0.0 / 0.0
037ue/sect, 20size32	1,934,215	1,422,217	1,164,068	72.0	1,475,268	00 / 00 / 02 / 16 / 49	0.0 / 1.0
056ue/sect, 20size32	1,985,243	1,872,642	1,008,999	91.6	1,934,544	01 / 03 / 10 / 32 / 61	0.0 / 1.2
075ue/sect, 20size32	2,251,443	2,312,162	943,371	99.2	2,371,219	05 / 09 / 21 / 43 / 65	0.3 / 2.0
100ue/sect, 20size32	2,787,112	2,890,511	924,114	99.7	2,935,203	12 / 19 / 29 / 49 / 67	0.0 / 0.9

TABLE 2 H-ARQ Enabled with CPICH Error ? =1dB

Single Rayleigh Ray, 3kph, FRP=0.98 Blk Size=336 bytes Max C/I, Mod. ETSI 30% Overhead AMC, no FCS, HARQ, ? =1dB

#Users per sector, Max ovsf codes	Average Throughput Statistics Center Cell OTA (bps)	Service (bps)	Packet call (bps)	Percent Utilization (%)	Offered Load (bps)	User Packet Call Throughput CDF <32k/64k/128k/384k/1M (%)	%UEs with Residual FER >10-2 / >10-4 (%)
012ue/sect, 20size32	2,041,386	468,907	1,439,111	23.0	489,320	00 / 00 / 00 / 02 / 29	0.0 / 0.7
037ue/sect, 20size32	1,769,061	1,359,925	1,091,056	74.8	1,396,482	00 / 00 / 02 / 18 / 53	0.0 / 2.0
056ue/sect, 20size32	1,918,134	1,885,656	915,797	94.4	1,853,439	03 / 06 / 14 / 38 / 64	0.0 / 3.1
075ue/sect, 20size32	2,106,633	2,186,367	841,139	99.0	2,188,733	05 / 11 / 23 / 46 / 69	0.3 / 2.4
100ue/sect, 20size32	2,546,921	2,697,633	821,589	99.7	2,748,435	16 / 24 / 34 / 53 / 71	0.1 / 1.1

TABLE 3 H-ARQ Disabled with CPICH Error ? =3dB

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

#Users per sector, Max ovsf codes	Average Throughput Statistics Center Cell OTA (bps)	Service (bps)	Packet call (bps)	Percent Utilization (%)	Offered Load (bps)	User Packet Call Throughput CDF <32k/64k/128k/384k/1M (%)	%UEs with Residual FER >10-2 / >10-4 (%)
012ue/sect, 20size32	1,800,245	468,615	1,268,680	25.9	485,515	00 / 00 / 00 / 03 / 38	0.0 / 6.6
037ue/sect, 20size32	1,539,392	1,327,651	857,181	81.6	1,367,491	00 / 01 / 05 / 28 / 65	0.1 / 21.6
056ue/sect, 20size32	1,596,800	1,733,146	650,307	97.9	1,755,674	03 / 10 / 25 / 51 / 79	3.8 / 37.5
075ue/sect, 20size32	1,739,118	2,010,782	548,694	99.7	2,028,803	17 / 28 / 41 / 62 / 84	10.8 / 45.1
100ue/sect, 20size32	1,984,111	2,344,356	488,986	100.0	1,685,867	29 / 40 / 51 / 70 / 88	19.2 / 43.1

TABLE 4 H-ARQ Disabled with CPICH Error ? =0dB

Single Rayleigh Ray, 3kph, FRP=0.98 Blk Size=44 bytes Max C/I, Mod. ETSI 30% Overhead AMC, no FCS, no HARQ, ?=0dB

#Users per sector, Max ovsf codes	Average Throughput Statistics Center Cell OTA (bps)	Service (bps)	Packet call (bps)	Percent Utilization (%)	Offered Load (bps)	User Packet Call Throughput CDF <32k/64k/128k/384k/1M (%)	%UEs with Residual FER >10-2 / >10-4 (%)
012ue/sect, 20size32	1,520,408	485,743	1,308,356	32.0	504,649	00 / 00 / 00 / 08 / 39	0.0 / 12.9
037ue/sect, 20size32	1,416,810	1,288,633	967,353	89.7	1,326,531	01 / 03 / 09 / 29 / 60	0.4 / 8.5
056ue/sect, 20size32	1,749,294	1,769,641	874,218	98.7	1,800,613	05 / 11 / 22 / 43 / 66	0.8 / 5.5
075ue/sect, 20size32	2,002,801	2,069,836	862,819	99.9	2,131,931	10 / 16 / 25 / 46 / 70	1.1 / 3.1
100ue/sect, 20size32	2,486,878	2,594,540	842,428	100.0	2,624,878	21 / 29 / 39 / 56 / 73	1.7 / 2.6

TABLE 5 H-ARQ Disabled with CPICH Error ? =1dB

Single Rayleigh Ray, 3kph, FRP=0.98 Blk Size=44 bytes Max C/I, Mod. ETSI 30% Overhead AMC, no FCS, no HARQ, ?=1dB

#Users per sector, Max ovsf codes	Average Throughput Statistics Center Cell OTA (bps)	Service (bps)	Packet call (bps)	Percent Utilization (%)	Offered Load (bps)	User Packet Call Throughput CDF <32k/64k/128k/384k/1M (%)	%UEs with Residual FER >10-2 / >10-4 (%)
012ue/sect, 20size32	1,530,806	481,501	1,286,691	31.7	499,832	00 / 00 / 00 / 08 / 40	0.4 / 29.2
037ue/sect, 20size32	1,454,641	1,282,069	970,561	87.4	1,319,830	01 / 02 / 08 / 28 / 60	0.1 / 28.1
056ue/sect, 20size32	1,765,049	1,779,992	863,970	98.7	1,808,100	05 / 11 / 22 / 44 / 67	1.2 / 21.8
075ue/sect, 20size32	2,113,291	2,171,857	829,287	99.7	2,191,233	12 / 20 / 31 / 49 / 70	1.9 / 19.1
100ue/sect, 20size32	2,545,747	2,647,440	811,905	99.9	2,684,573	20 / 28 / 39 / 56 / 74	2.7 / 17.5

TABLE 6 H-ARQ Disabled with CPICH Error ? =3dB

Single Rayleigh Ray, 3kph, FRP=0.98 Blk Size=44 bytes Max C/I, Mod. ETSI 30% Overhead AMC, no FCS, no HARQ, ?=3dB

#Users per sector, Max ovsf codes	Average Throughput Statistics Center Cell OTA (bps)	Service (bps)	Packet call (bps)	Percent Utilization (%)	Offered Load (bps)	User Packet Call Throughput CDF <32k/64k/128k/384k/1M (%)	%UEs with Residual FER >10-2 / >10-4 (%)
012ue/sect, 20size32	651,769	421,017	562,266	64.7	428,874	02 / 12 / 22 / 50 / 85	0.0 / 27.3
037ue/sect, 20size32	1,001,833	994,474	441,438	98.8	996,024	20 / 32 / 44 / 66 / 92	0.4 / 34.5
056ue/sect, 20size32	1,289,235	1,299,310	404,842	99.9	1,318,800	32 / 42 / 53 / 73 / 93	1.8 / 33.2
075ue/sect, 20size32	1,534,659	1,549,681	388,628	99.9	1,583,774	39 / 49 / 59 / 77 / 94	3.6 / 41.9
100ue/sect, 20size32	1,856,090	1,887,593	379,859	100.0	1,932,895	46 / 56 / 64 / 80 / 95	6.2 / 33.7

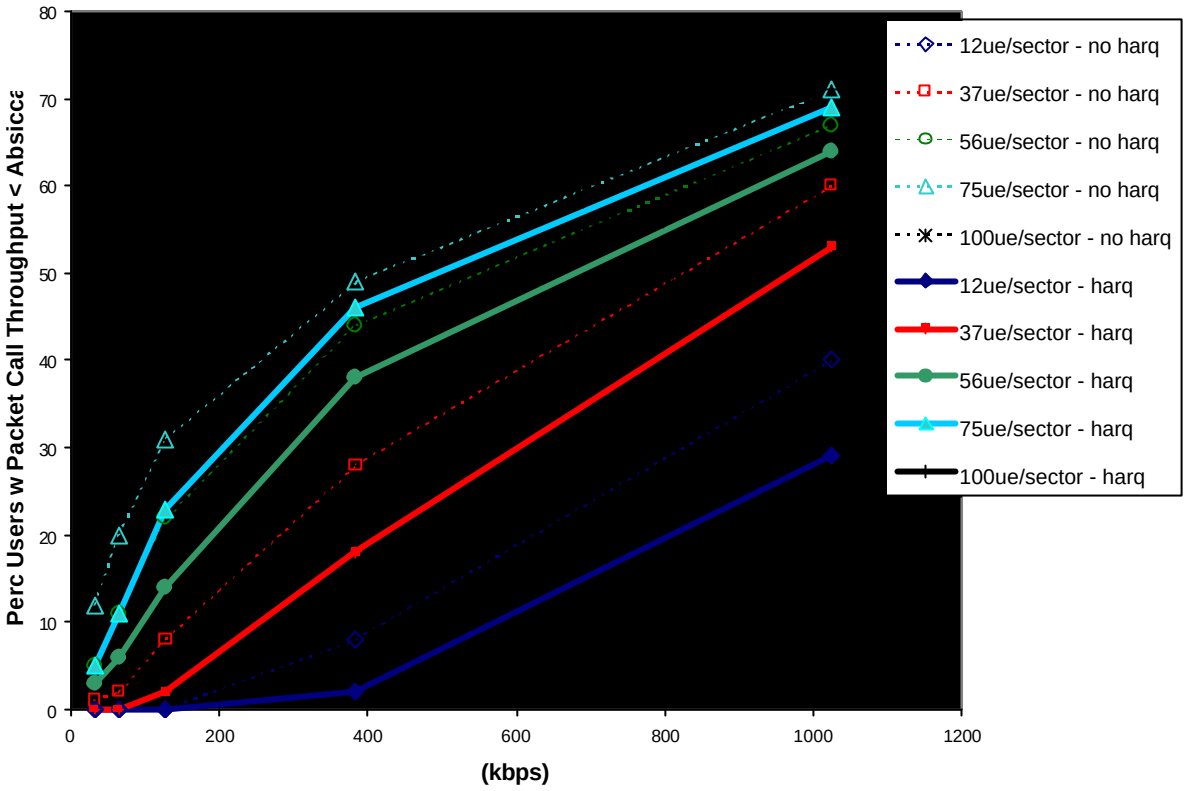

Figure 1 %User Packet Call Throughput CDF w/wo H-ARQ for the 1dB CPICH SIR measurement error case using a Max C/I Scheduler

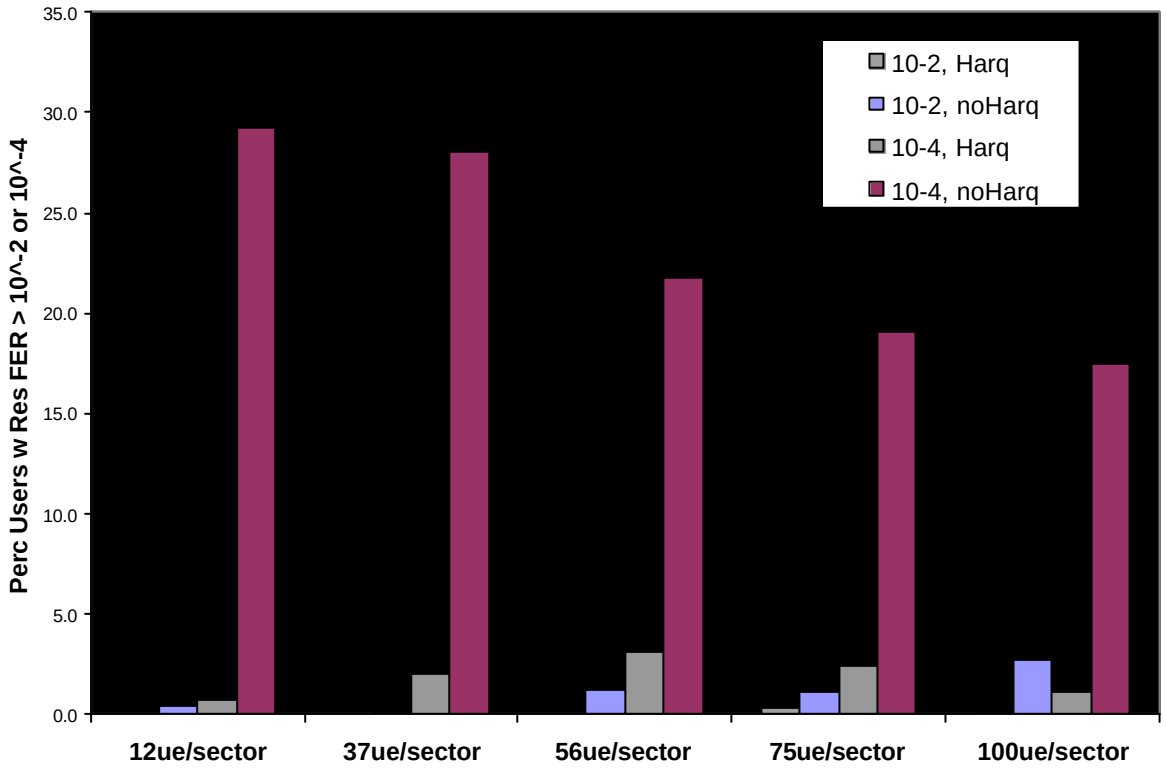

Figure 2. Residual FER with and without H-ARQ for the 1dB CPICH SIR measurement error case using a Max C/I Scheduler

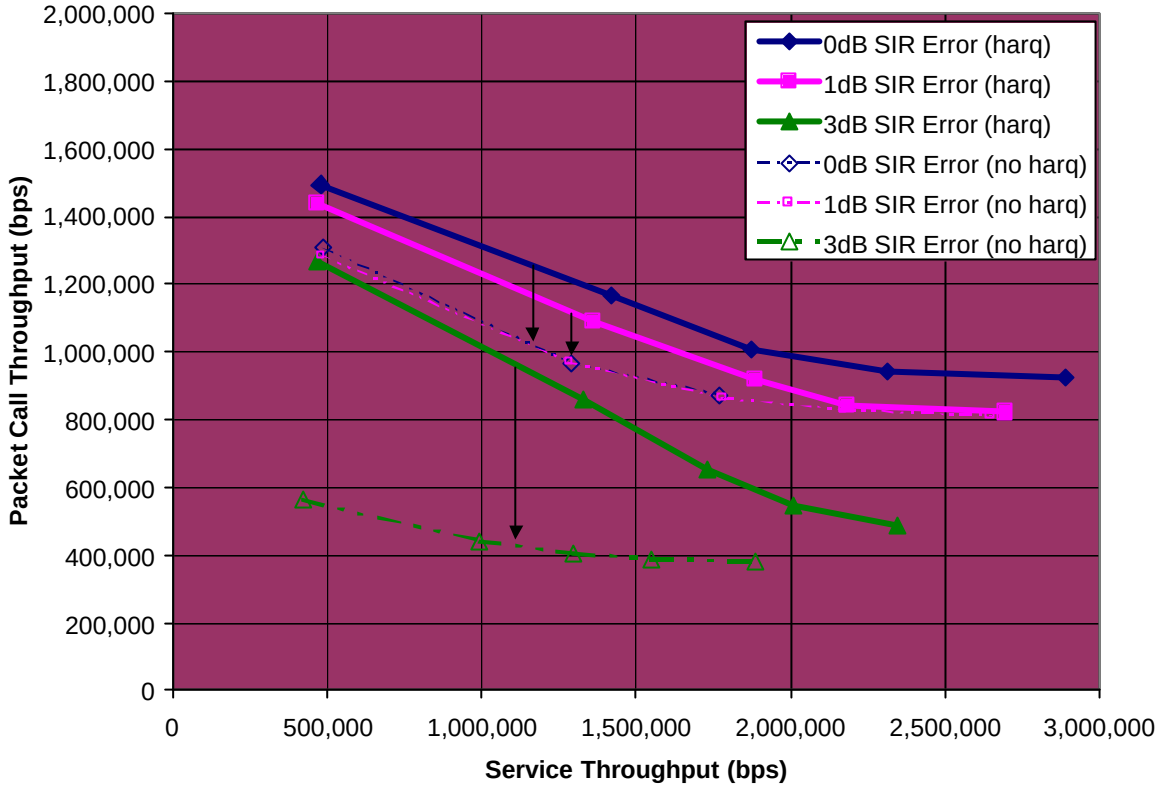

Figure 3 Packet Throughput vs Service Throughput w/wo H-ARQ for different CPICH SIR Measurement Errors using a Max C/I Scheduler.

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).

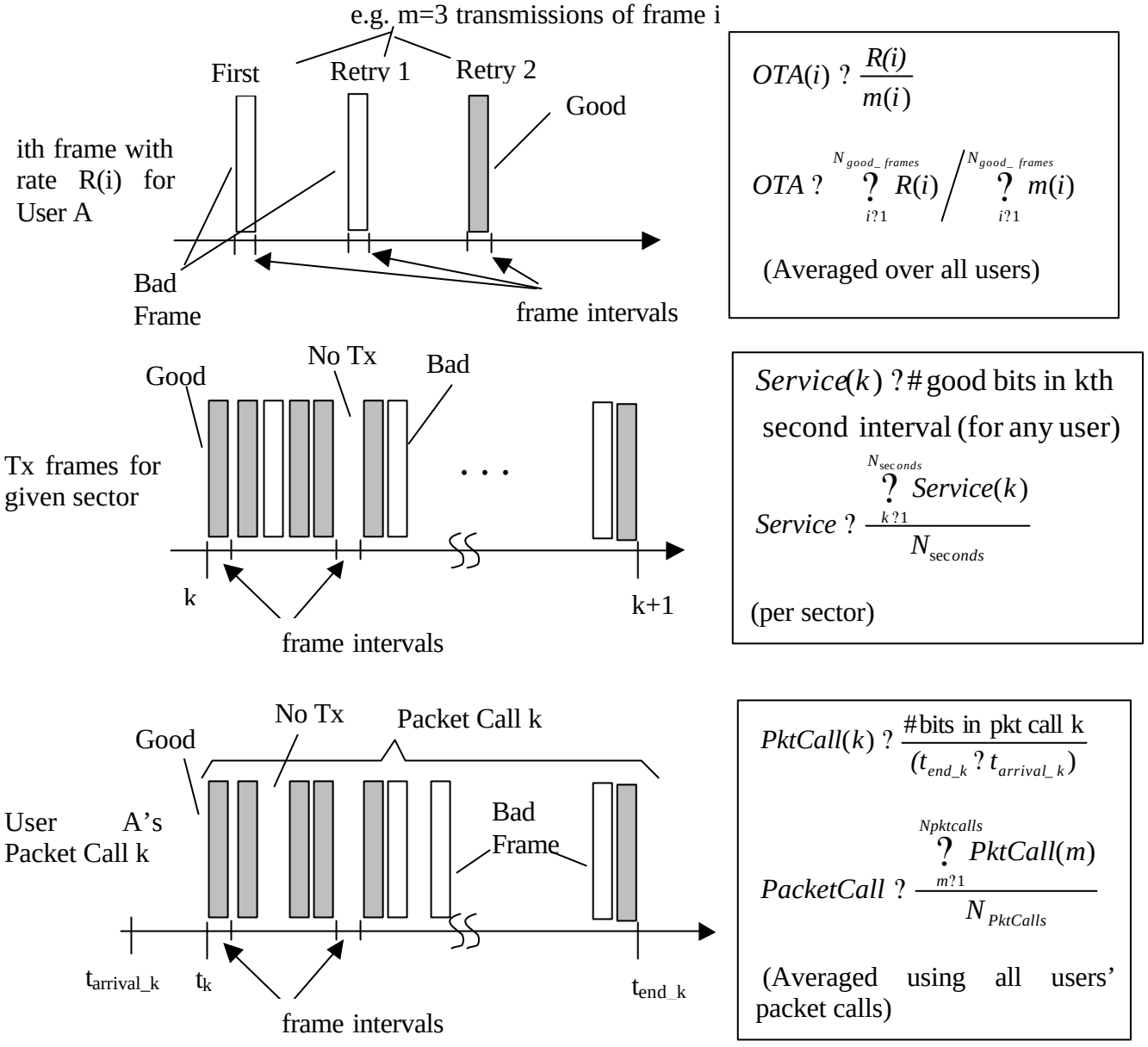

Figure A1. Throughput Statistic Description for System Simulations.

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

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

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

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

Therefore

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

The packet call throughput is given by

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

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

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

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 center cell.
- ?? 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