Agenda item:	**AdHoc #24 HSDPA**
Source:	**Motorola**
Title:	**HSDPA system performance based on simulation**
Document for:	**Discussion**

Summary:

Data throughput for best effort service is summarized in this contribution for the proposed HSDPA feature set. 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 repeated here for the readers convenience.

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 applied with 1 frame delay after receiving measurement report
- ?? Std. dev. of CPICH measurement error: 0
- ?? CPICH measurement rate: once per 3.33 ms
- ?? 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])

Basic system level parameters:

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

Table 1. 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. 80% and 90 % of total cell power	
Slow fading	Similar to UMTS 30.03, B 1.4.1.4	
Std. deviation of slow fading	8.9 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	7	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

Simulation Results:

The packet data throughput for best effort service using HSDPA is summarized in **Tables 2-9**. The Maximum C/I Scheduler was used where the data source is modeled with a modified ETSI call model (see [1]). The ETSI source model was modified to make the simulations more tractable by reducing the number of packet data users necessary to provide load to the system. The modified ETSI model still exhibits the important characteristic that the read time is at least an order of magnitude larger than the service time of a packet call. Note that **Appendix A** includes probability plots of several statistics from the system simulation corresponding to the 37ue/sector case from **Table 3**. Plots of Average OTA throughput vs Geometry (^Ior/Ioc) are given in **Appendix C**.

Tables 2 & 3 summarize the throughput results for the Maximum C/I scheduler for the modified ETSI source model. The different throughput metrics presented are defined in Appendix C. The MCS used were QPSK R=1/2[1], 16QAM R=1/2, 16QAM R=3/4, 64QAM R=3/4. For the cases in **Table 2** the overhead due to CPICH and other common and control channels is 10%. In **Table 3** the overhead used is 20%.

Table 2. HSDPA Throughput Performance vs Load with Max C/I Scheduler based on Modified ETSI source model and 10% Overhead

Single Rayleigh Ray, 3kph, FRP=0.98 MTU Size=336 bytes Max C/I, Mod. ETSI 10% Overhead

#Users per sector,	Average Throughput			Percent	Offered	User PktCall throuput cdf
Max ovsf codes	OTA	Service	Packet call	Utilization	Load	<32k/64k/128k/384k/1M
	(bps)	(bps)	(bps)	(%)	(bps)	(%)
012ue/sect, 20chan	3,371,542	390,238	1,779,377	12.0	392,231	0/0/0/0/11
037ue/sect, 20chan	2,456,096	1,137,114	1,227,300	52.6	1,144,381	0/0/1/13/46
056ue/sect, 20chan	2,502,196	1,625,075	1,048,112	70.7	1,628,652	1/3/9/28/58
075ue/sect, 20chan	2,763,005	2,032,093	992,452	75.2	2,040,961	5/10/17/37/62
100ue/sect, 20chan	3,087,601	2,522,119	978,205	79.3	2,527,670	9/15/23/41/63

Table 3. HSDPA Throughput Performance vs Load with Max C/I Scheduler based on Modified ETSI source model and 20% Overhead

Single Rayleigh Ray, 3kph, FRP=0.98 MTU Size=336 bytes Max C/I, Mod. ETSI 20% Overhead

#Users per sector,	Average Throughput			Percent	Offered	User PktCall throuput cdf
Max ovsf codes	OTA	Service	Packet call	Utilization	Load	<32k/64k/128k/384k/1M
	(bps)	(bps)	(bps)	(%)	(bps)	(%)
012ue/sect, 20chan	2,665,890	395,993	1,547,303	16.3	398,521	0/0/0/1/25
037ue/sect, 20chan	2,209,284	1,118,629	1,094,124	59.6	1,126,819	0/0/3/21/53
056ue/sect, 20chan	2,368,924	1,577,969	987,811	73.2	1,580,466	2/6/13/34/61
075ue/sect, 20chan	2,635,694	1,994,473	947,443	77.3	2,004,872	7/12/21/41/65
100ue/sect, 20chan	2,980,596	2,466,648	946,503	80.6	2,479,291	13/19/27/45/64

From **Table 3** above, the service throughput averaged over all sectors for the Max C/I scheduler is about 2.5Mbit/s at 81% utilization while the averaged OTA frame throughput is about 3.0Mbit/s. The overall average Packet Call throughput drops from about 1.5Mbit/s to 940Kbit/s as the load increases. Fairness is shown in terms of the per user average packet call throughput outage cdf values given in the last column in **Table 3**. 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, 24% between 384kbit/s and 1Mbit/s, and 75% of the users achieve better than 1Mbit/s. For 56 users per sector 2% experience packet call throughput below 32kbit/s, 4% between 32kbit/s and 64kbits, 7% between 64kbit/s and 128kbit/s, 21% between 128kbit/s and 384kbit/s, 27% between 384kbit/s and 1Mbit/s, and 34% are better than 1Mbit/s.

[1] R=1/4 QPSK was not used since the hull curve showed that there is no throughput advantage over R=1/2 code.

Note that going from 10% to a 20% overhead reduces throughput by up to 5%. Any common or dedicated control channels used are assumed to be part of the 20% overhead power allocation.

The benefit of a higher peak rate is shown in **Table 4** were the peak rate is increased by increasing the number of size 32 OVSF codes that can be used. From 20 codes which allows a peak rate of 10.8Mbit/s to 30 codes which allows 16.2Mbit/s there is only a small increase in throughput but the improvement in fairness as given by the user average packet call throughput cdf metric is more significant. However, with 30 codes not enough codes are left for control channels.

Table 4. HSDPA Throughput Performance vs number of OVSF codes (size 32) with Max C/I Scheduler based on Modified ETSI source model.

Single Rayleigh Ray, 3kph, FRP=0.98 MTU Size=336 bytes Max C/I, Mod. ETSI 10% Overhead

#Users per sector, Max ovsf codes	Average Throughput			Percentage Utilization	Offered Load	User PktCall throuput cdf <32k/64k/128k/384k/1M
	OTA (bps)	Service (bps)	Packet call (bps)	(%)	(bps)	(%)
056ue/sect, 20chan	2,502,196	1,625,075	1,048,112	70.7	1,628,652	1/3/9/28/58
056ue/sect, 25chan	2,834,888	1,670,936	1,126,544	68.9	1,679,603	1/2/6/24/54
056ue/sect, 30chan	3,143,587	1,675,107	1,202,909	65.7	1,700,419	0/1/4/19/49

Tables 5 – 10 show the performance for different MCS sets. Again the benefits of higher peak rates is illustrated by comparing the user average packet call throughput cdf (fairness) metric for the different techniques. There is significant improvement in the fairness metric by including QPSK R=3/4 with QPSK R=1/2. Another signifcant improvement in fairness occurs by having 16QAM as part of the MCS set.

Table 5. HSDPA Throughput Performance using QPSK R=1/2 with Max C/I Scheduler based on Modified ETSI source model.

Single Rayleigh Ray, 3kph, FRP=0.98 MTU Size=336 bytes Max C/I, Mod. ETSI 10% Overhead

#Users per sector, Max ovsf codes	Average Throughput			Percentage Utilization	Offered Load	User PktCall throuput cdf <32k/64k/128k/384k/1M
(per sector)	OTA (bps)	Service (bps)	Packet call (bps)	(%)	(bps)	(%)
012ue/sect, 20chan	1,477,001	387,768	877,319	26.9	388,996	0/0/0/4/64
037ue/sect, 20chan	1,514,552	1,017,419	602,221	67.5	1,013,400	1/2/9/34/92
057ue/sect,20 chan	1572284	1,260,122	508,468	75.8	1,353,352	8/16/25/54/95

Table 6. HSDPA Throughput Performance using QPSK R=1/2, QPSK R=3/4 with Max C/I Scheduler based on Modified ETSI source model.

Single Rayleigh Ray, 3kph, FRP=0.98 MTU Size=336 bytes Max C/I, Mod. ETSI 10% Overhead

#Users per sector, Max ovsf codes	Average Throughput			Percentage Utilization	Offered Load	User PktCall throuput cdf <32k/64k/128k/384k/1M
	OTA (bps)	Service (bps)	Packet call (bps)	(%)	(bps)	(%)
012ue/sect, 20chan	2,266,629	391,330	1,214,796	18.5	393,001	0/0/0/7/24
037ue/sect, 20chan	2,235,471	1,133,740	925,250	55.7	1,140,991	0/0/1/12/55
057ue/sect,20 chan	2,390,641	1,546,196	780,199	69.5	1,556,085	1/2/6/27/69
075ue/sect,20 chan	2,596,202	1,832,037	680,302	74.6	1,843,812	6/10/18/42/77

Table 7. HSDPA Throughput Performance using QPSK R=1/2, 16QAM R=1/2 & R=3/4 with Max C/I Scheduler based on Modified ETSI source model.

Single Rayleigh Ray, 3kph, FRP=0.98 MTU Size=336 bytes Max C/I, Mod. ETSI 10% Overhead

#Users per sector, Max ovsf codes	Average Throughput			Percentage Utilization	Offered Load	User PktCall throuput cdf <32k/64k/128k/384k/1M
	OTA (bps)	Service (bps)	Packet call (bps)	(%)	(bps)	(%)
012ue/sect, 20chan	2,649,552	396,823	1,530,953	16.5	399292	0/0/0/1/25
037ue/sect, 20chan	2,457,174	1,133,128	1,210,016	52.3	1,140,856	0/0/0/12/46
057ue/sect,20 chan	2,480,396	1,625,039	1,034,605	71.1	1,723,109	1/3/9/28/57
075/ue/sect,20 chan	2,709,639	2,012,465	981,113	75.9	2,133,916	5/10/17/37/61

Table 8. HSDPA Throughput Performance using QPSK R=1/2, 16QAM R=1/2, 16QAM R=3/4, 8PSK R=3/4 with Max C/I Sch. based on Modified ETSI source model.

Single Rayleigh Ray, 3kph, FRP=0.98 MTU Size=336 bytes Max C/I, Mod. ETSI 10% Overhead

#Users per sector, Max ovsf codes	Average Throughput			Percentage Utilization	Offered Load	User PktCall throuput cdf
	OTA	Service	Packet call			<32k/64k/128k/384k/1M
	(bps)	(bps)	(bps)	(%)	(bps)	(%)
012ue/sect, 20chan	2,698,895	405,264	1,545,004	16.4	407,649	0/0/0/1/25
037ue/sect, 20chan	2,437,674	1,128,415	1,214,118	52.5	1,136,715	0/0/0/12/46
057ue/sect,20 chan	2,477,106	1,624,013	1,043,012	71.0	1,629,430	1/3/9/28/57
075/ue/sect,20 chan	2,747,253	2,056,080	989,572	76.0	1,966,998	5/10/18/37/62

Table 9. HSDPA Throughput Performance using QPSK R=1/2, 16QAM R=1/2, 16QAM R=3/4, 64QAM R=3/4 with Max C/I Sch. based on Mod. ETSI source model.

Single Rayleigh Ray, 3kph, FRP=0.98 MTU Size=336 bytes Max C/I, Mod. ETSI 10% Overhead

#Users per sector, Max ovsf codes	Average Throughput			Percent Utilization	Offered Load	User PktCall throuput cdf
	OTA	Service	Packet call			<32k/64k/128k/384k/1M
	(bps)	(bps)	(bps)	(%)	(bps)	(%)
012ue/sect, 20chan	3,371,542	390,238	1,779,377	12.0	392,231	0/0/0/0/11
037ue/sect, 20chan	2,456,096	1,137,114	1,227,300	52.6	1,144,381	0/0/1/13/46
056ue/sect, 20chan	2,502,196	1,625,075	1,048,112	70.7	1,628,652	1/3/9/28/58
075ue/sect, 20chan	2,763,005	2,032,093	992,452	75.2	2,040,961	5/10/17/37/62
100ue/sect, 20chan	3,087,601	2,522,119	978,205	79.3	2,527,670	9/15/23/41/63

Conclusion:

Best effort packet data average sector service throughput for a HSDPA system using a maximum C/I scheduler was shown to achieve 2.5Mbit/s based on 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 exeeding 1Mbit/s and less than 13% achieved throughput below 32kbit/s (from Table 3). Results show that 20 size 32 OVSF codes were enough to support these throughput levels therefore leaving 12/32 of the OVSF tree for all other channels including control channel associated with HSDPA. Finally, results indicate that no more than four MCS levels (perhaps only 3) are needed to support the high sector throughput given the use of a fast Hybrid ARQ scheme.

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.

Appendix A

Simulation Output Statistics for 100ue/sector Case in Table 3

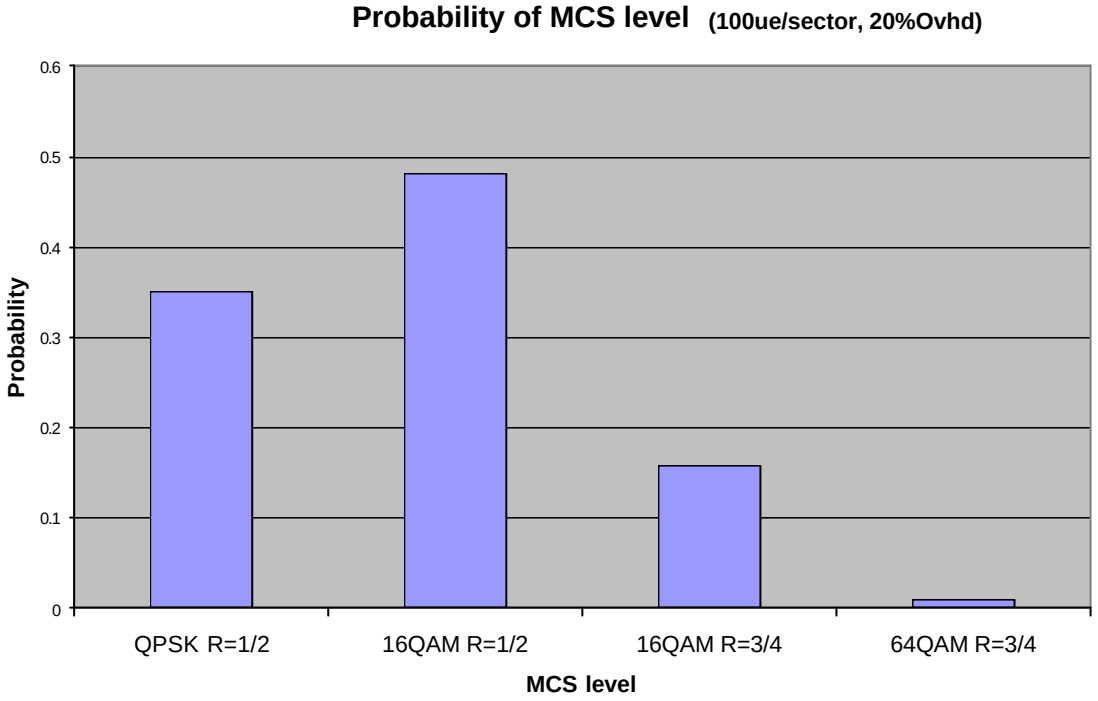

Figure A1. Probability MCS level chosen for 100ue/sector case.

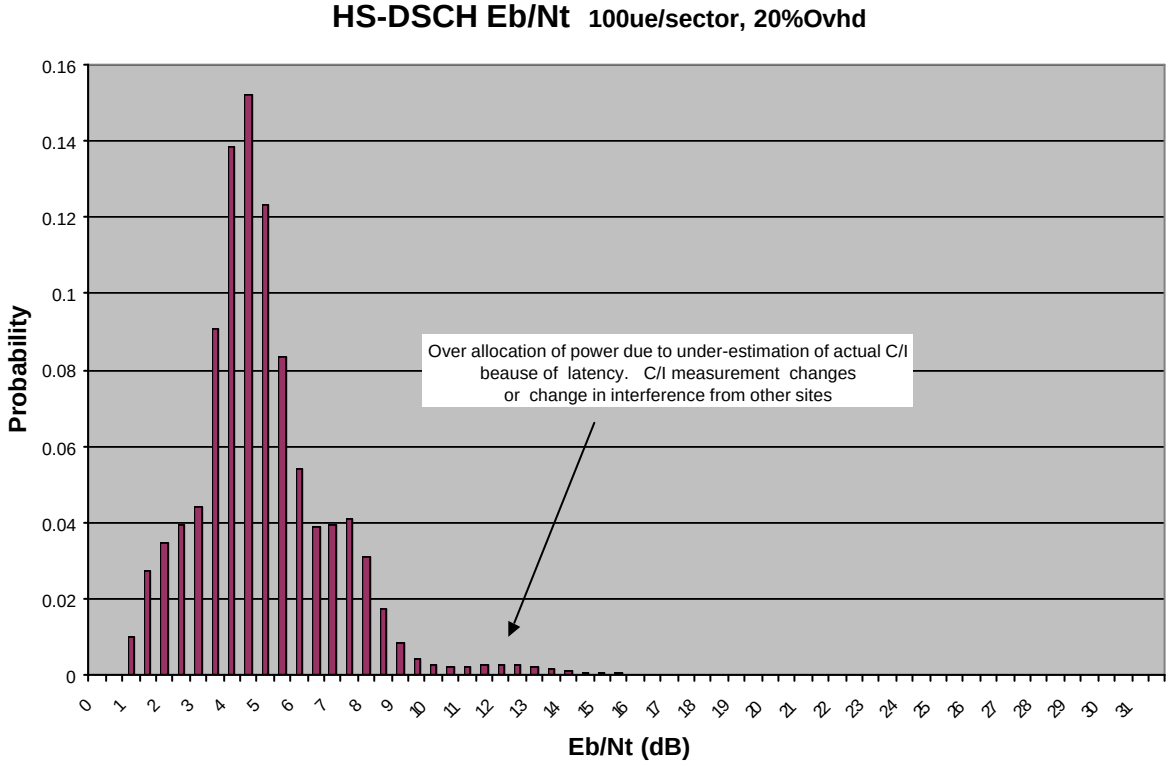

Figure A2. Probability mass function for HS-DSCH Eb/Nt for 100ue/sector case.

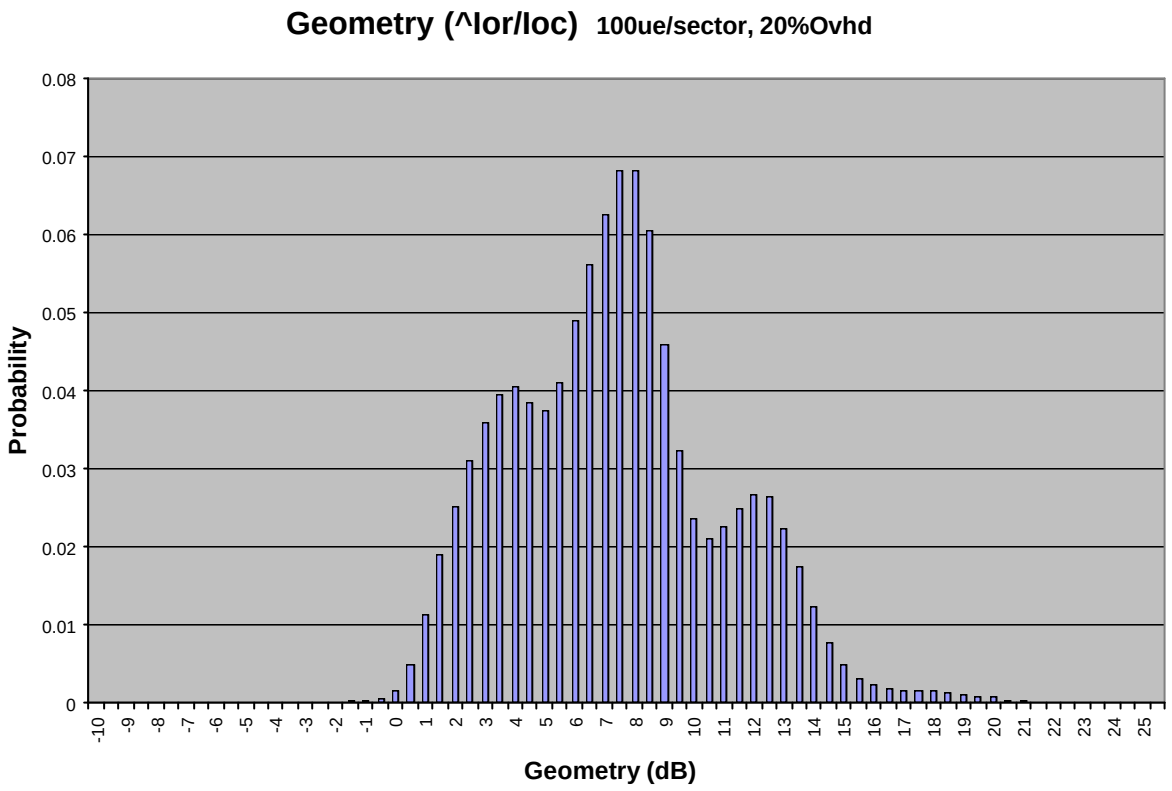

Figure A3. Probability mass function for Geometry (^Ior/Ioc) for 100ue/sector case.

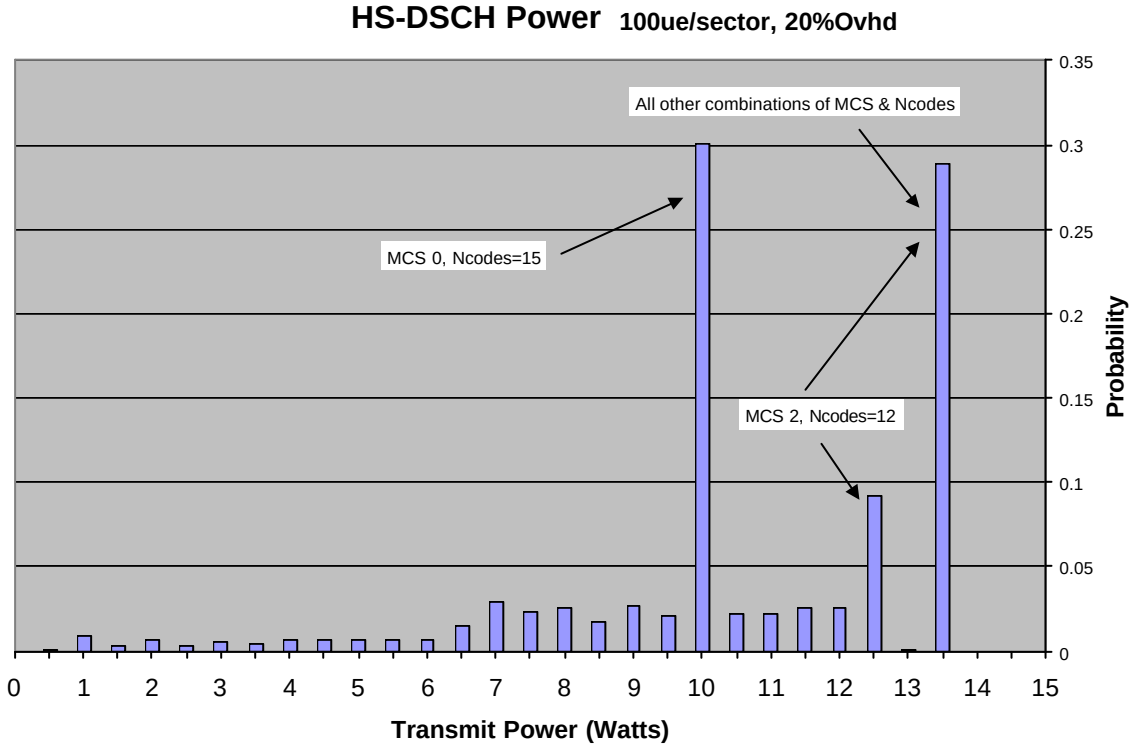

Figure A4. Probability mass function for HS-DSCH power.

Appendix B

Data Throughput Mesh Coverage Plots

The mesh plots (B1 through B4) below show the average Packet Call throughput achievable at each (100 meter by 100 meter) location bin.

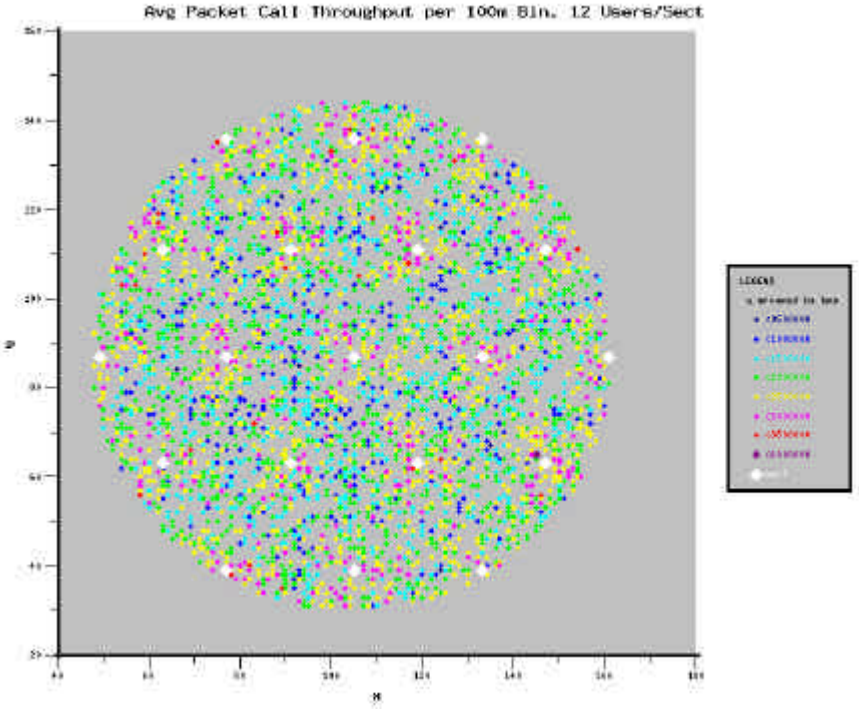

Figure B1. Avg Packet Call Throughput mesh plot for 12 users per sector. (MaxC/I)

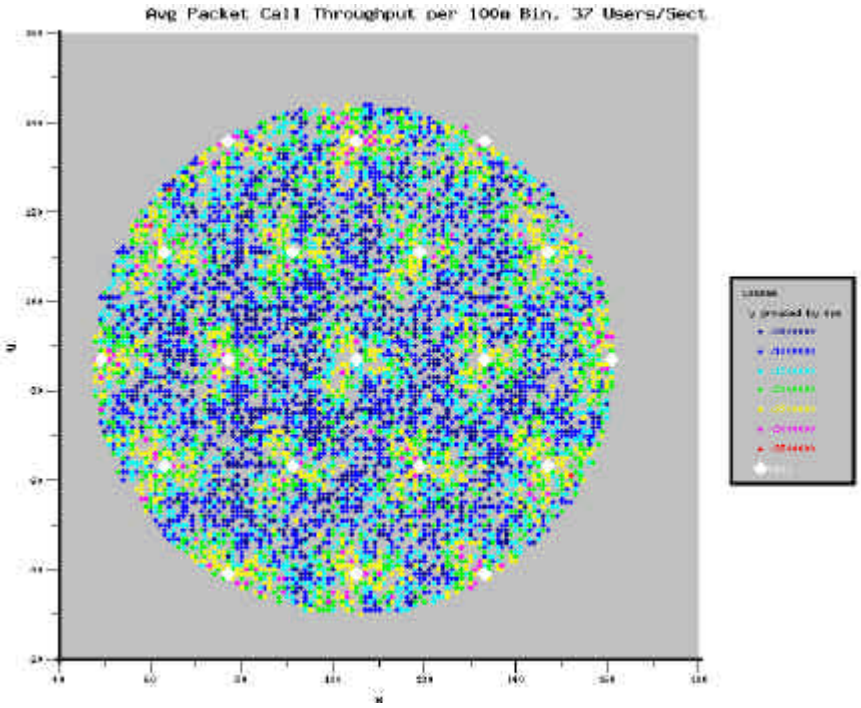

Figure B2. Avg Packet Call Throughput mesh plot for 37 users per sector. (MaxC/I)

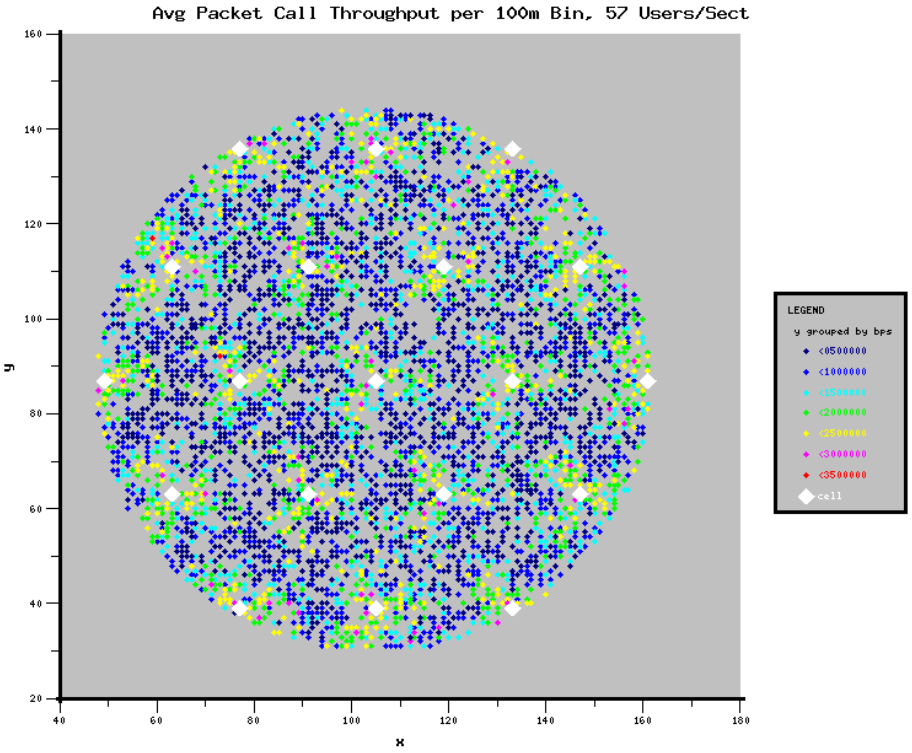

Figure B3. Avg Packet Call Throughput mesh plot for 57 users per sector. (MaxC/I)

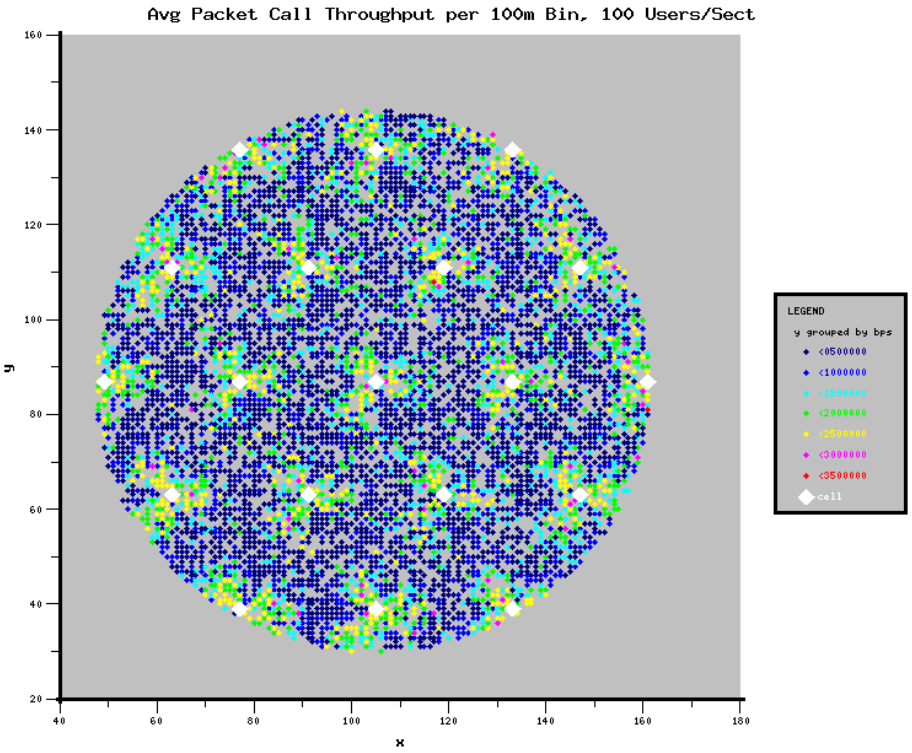

Figure B4. Avg Packet Call Throughput mesh plot for 100 users per sector. (MaxC/I)

Appendix C

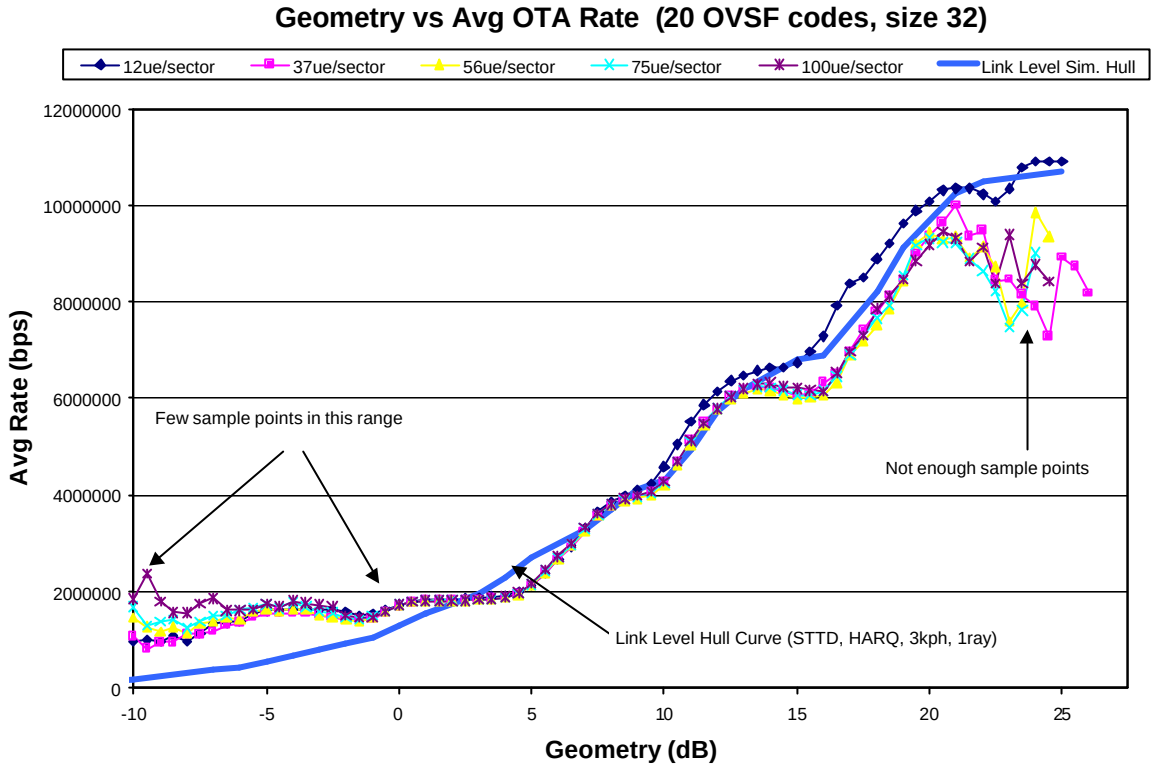

Figure B.1 Geometry vs Average OTA Rate for different Loads with 20% Overhead.

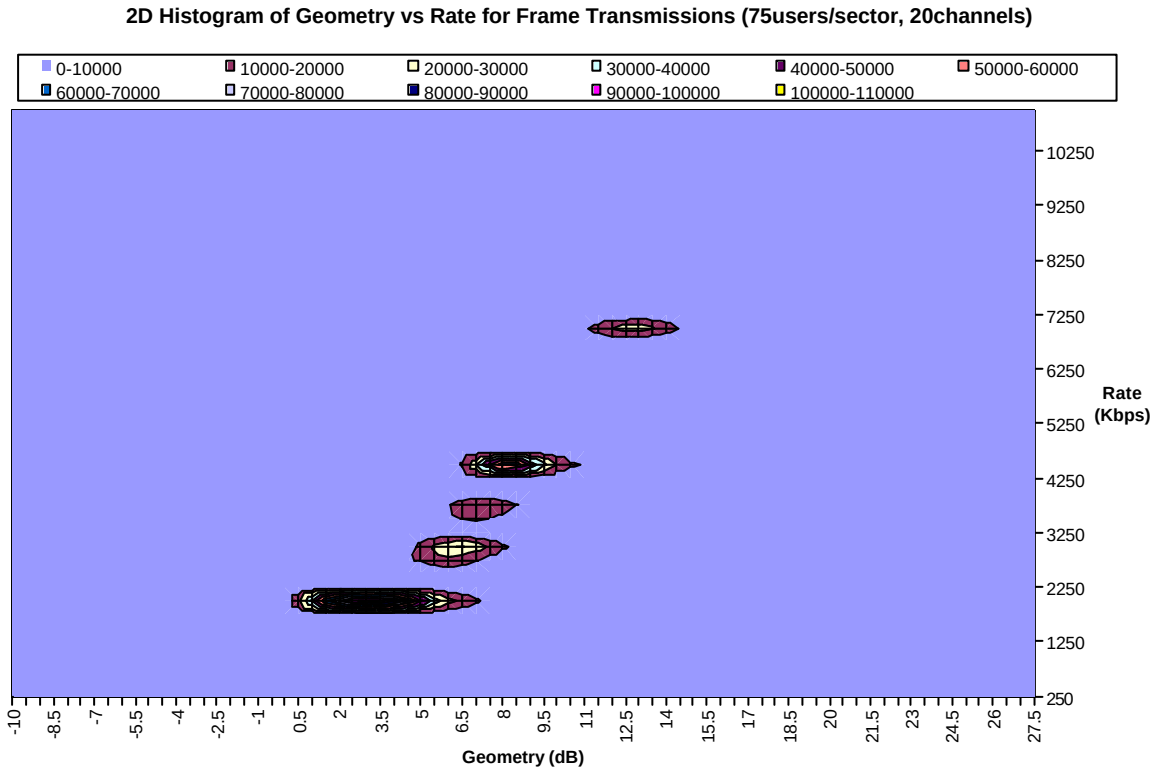

Figure B.2 2D Histogram of Geometry vs Average OTA Rate for 75 users/sector with 20% Overhead.

Appendix D

Throughput Statistic Definition

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).

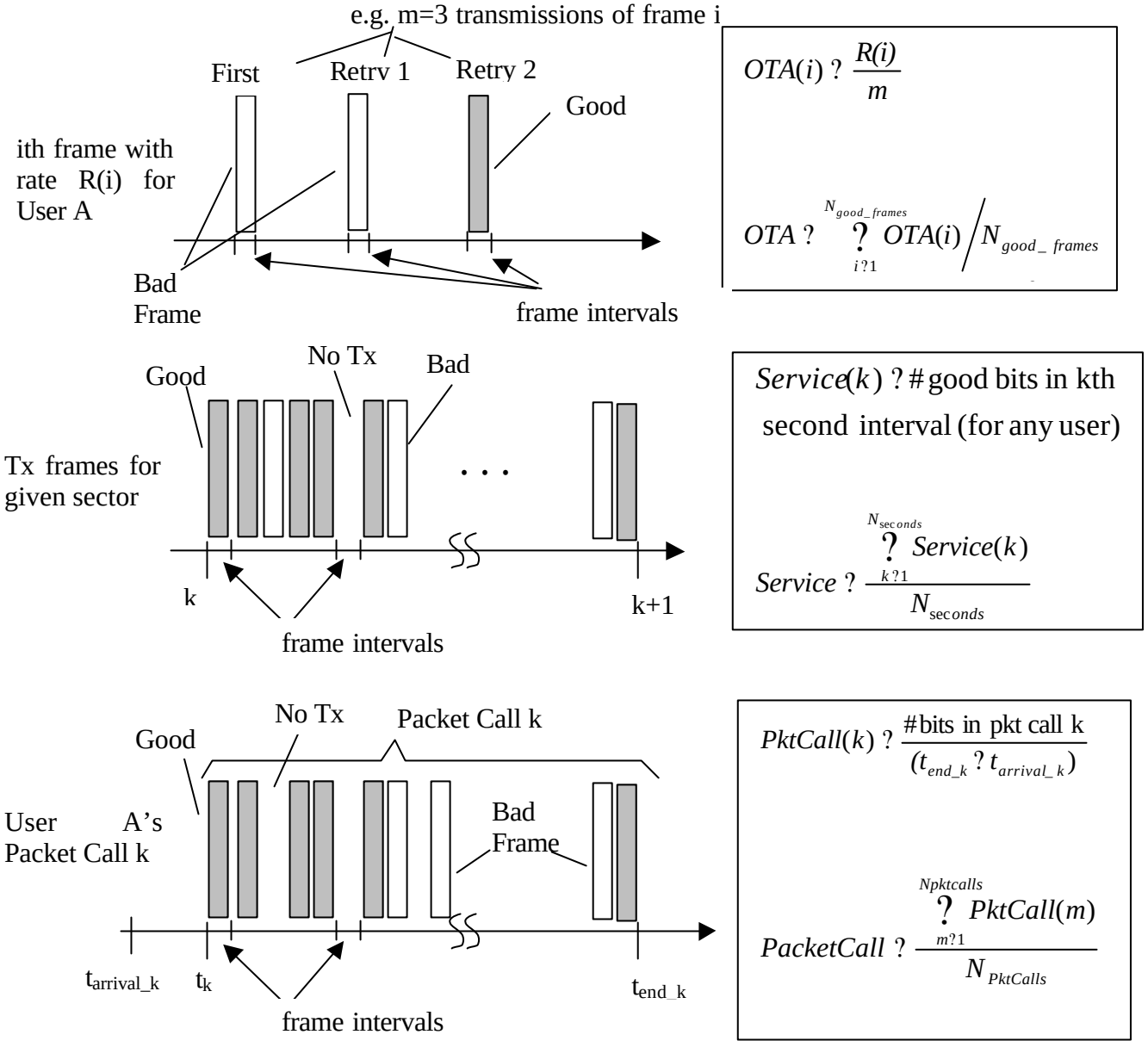

Figure C1. Throughput Statistic Description for System Simulations.