Agenda item:	**AdHoc #24 HSDPA**
Source:	**Motorola**
Title:	**Integrated Voice and HSDPA Data system performance**
Document for:	**Discussion/Information**

Summary:

Sector data throughput of an integrated voice and High Speed Downlink Packet Access (HSDPA) system is investigated using the analytical-simulation approach described in [1]. The approach is to integrate the data throughput characteristic (Thruput(x)) in **equation 1** below obtained from link level simulations [2]) for a given channel condition with the achievable carrier to interference ratio (C/I (x)) obtained from system simulation for the coverage area of several representative sectors of the voice & data system.

$$AveSectorThruput \; ? \; \int_{?20}^{20} Thruput(x) \; ? \; P(x) \; ? \; dx \qquad \textbf{Equation 1}$$

The predicted sector throughput is therefore calculated from a combination of link level and system simulations. **Figure 1** shows the throughput in bps versus the ratio of energy per chip over other cell interference (Ec/Ioc) at the mobile receiver. We now use Ec/Ioc instead of C/I. Both Hybrid ARQ and transmit diversity (STTD) are enabled. Each curve plotted is in fact a composite of several link simulations for 64QAM R=3/4, 16QAM R=1/2 & R=3/4, and QPSK, using Turbo coding (see [2]). Hybrid ARQ in these simulations uses max-ratio combining of successive attempts (Chase combining). All curves have been simulated at 3kph one-ray Raleigh fading channel model at a carrier frequency of 2GHz. Link adaptation switches between the modulation and coding levels to maximize the throughput for given Ec/Ioc value. As an exa mple **Figure 2** shows the composite and constituent curves for link adaptation with hybrid ARQ.

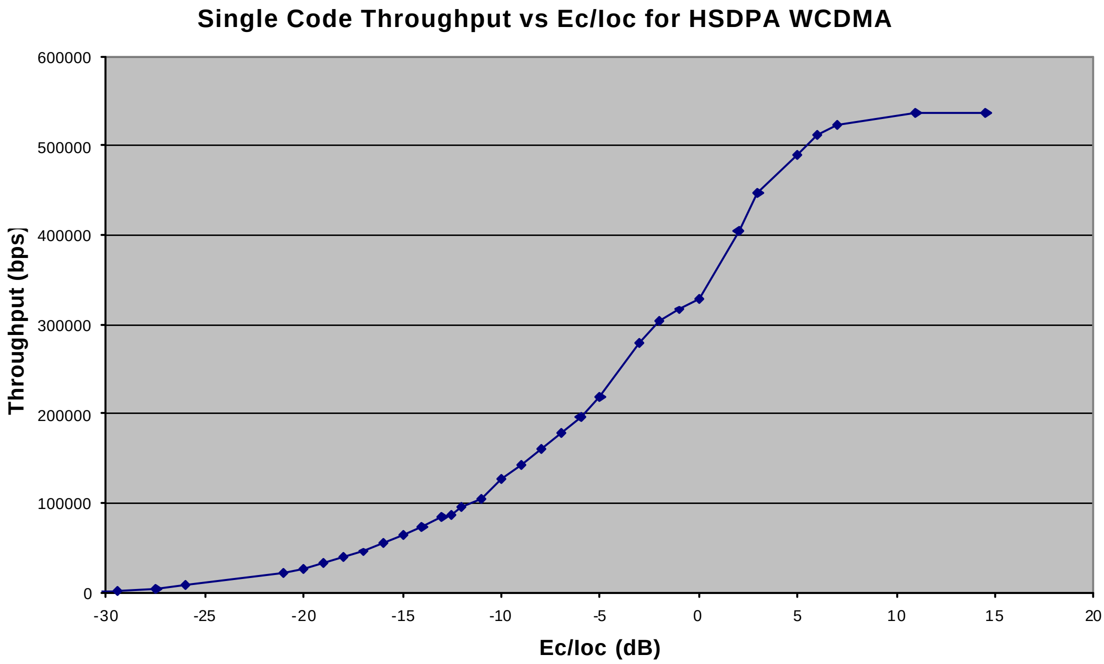

Figure 1. HSDPA Throughput Hull Curve vs Ec/Ioc for 3kph and flat fading

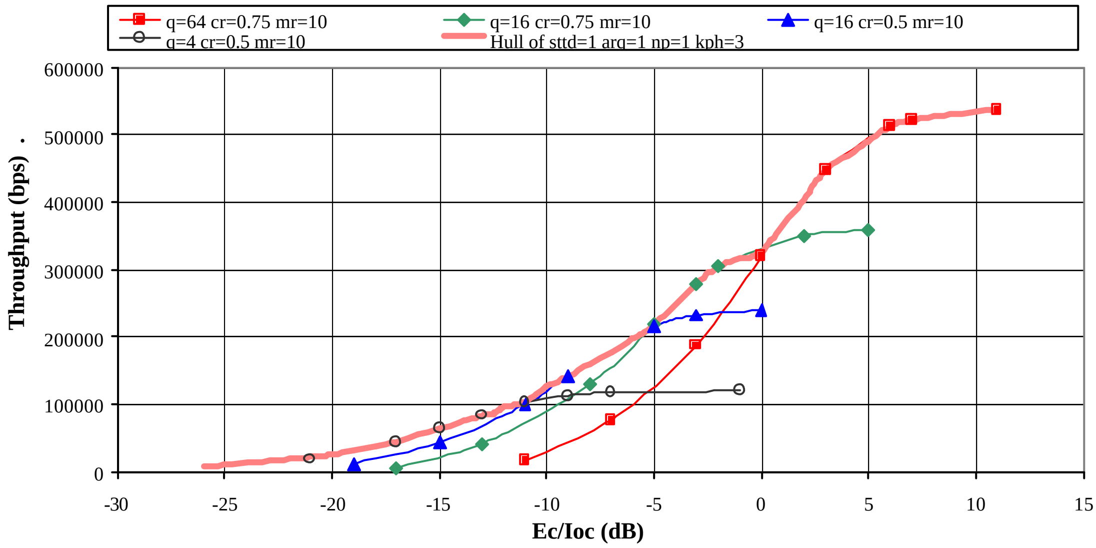

Figure 2. Composite and constituent curves for Hybrid ARQ and STTD

The area probability for a given Ec/Ioc has been calculated from a system simulation of two hexagonal rings comprising 19 3-sector cells with log-normal standard deviation of 8.0dB and a 50% site to site correlation. A full set of radio (Eb/Nt vs FER) curves is used for modeling the 12.2kbit/s voice users. These curves account for 1,2, or 3rays with imbalances from 0 to 12 dB and speeds from 0 to 120kph and geometries (^Ior/Ioc) ranging from –6 to +12dB. The system is assumed to be 100% loaded resulting in the base transceivers having a constant 100% linear power amp (LPA) load of 17 Watts. By always transmitting with constant power (17 Watts in this case (see **Figure 6**)) the voice users will not see abrupt changes in interference levels as the available power margin is allocated to data. Of the LPA load, up to 70% of the power can be allocated to the data channel constructed from up to 20 (or 28) multicodes with spreading factor 32 depending on the voice users (12.2kbit/s) loading. The other 30% of the LPA load is allocated to overhead channels (such as pilot (CPICH), paging (PICH), synchronization (SCH), etc.) and dedicated control channels. The Ec/Ioc area distribution is based on the inner ring sectors and center cell sectors in order to exclude system edge effects (see **Figure 5**).

The sector data throughput for "equal average power" scheduler may be calculated by integrating the throughput from the link simulations against the area pdf for Ec/Ioc derived from the system simulation (see **Equations 2** below). The Ec/Ioc is determined from the available power margin left over after power is allocated to overhead channels (such as pilot (CPICH), paging (PICH), synchronization (SCH)), dedicated control channels, and voice user channels. The number of size 32 OVSF codes, and hence the peak rate that can be allocated, depends on the code tree left over after the overhead and voice channels have been allocated their codes. The equal average power scheduler assigns equal base station power to all users throughout the coverage area achieving the maximum possible throughput for each location. For HSDPA, equal average power scheduling would be achieved by cycling through all users in the coverage area, assigning one 3.33 ms frame with up to 20 (or 28) size 32 OVSF codes and up to 70% of the LPA power while using the optimum modulation and coding level. Over time, each user would receive an equal number of frames and therefore an equal average power allocation from the serving BTS. However, the average data received per user would be biased by the user's location. Users closer to the base site would receive more data then those toward the cell edge.

EQUATIONs 2 (note the power margin could be up to 80% in the sytem simulation. Therefore, in the equations the computed Ec/Ioc is reduced by 0.6 dB to limit the maximum available power for HSDPA data to 70%)

$$\frac{E_c}{I_{or}} ? \frac{P_{margin}}{P_{margin} ? P_{voice} ? P_{ovhd}} ? \frac{P_{margin}}{P_{cell}(j)} \quad \text{for cell } j \text{ at time } t$$

$$\frac{E_c}{I_{oc}} ? 10\log_{10}\left(\frac{E_c}{I_{or}} ?? \Big/ (I_{on} ? ?)\right) \qquad I_{on} ? P_{cell}(j)T(j,k) \Big/ \sum_{i?1}^{Ncells} P_{cell}(i)T(i,k)$$

$P_{cell}(j)$ - total power in Watts for cell j (always 17 Watts)

$T(i,k)$ - transmission gain from cell i to probe mobile at location k

? ? fraction of total available power recovered (FRP)

I_{on} ? best serving cell to total power ratio for location k

$$Thrupt ? N_{multi?codes} ?Thruput\_Hull\_Curve\left(\frac{E_c}{I_{oc}} ? N_{multi?codes\_dB} ? 0.6\right)$$

Conclusion:

Figure 3 below presents sector throughput of the equal average power scheduler for increasing voice loading and for different (FRP) fractions of total recovered power due to delay spread. For FRP=0.98 and 20 codes the achieved Data only Throughput is about 2.5Mbit/s which then drops almost linearly (see also **Figure 4**) as voice erlangs per sector increases. For a voice user (12.2kbit/s) load of about 35 erlangs/sector the Data 'equal power' sector throughput is still about 1Mbit/s.

An FRP of 0.98 results in about a 10% loss in throughput relative to an FRP=1.0 while a FRP of 0.92 results in about a 35% loss.

High data sector throughput is maintained by simply allocating the available power margin to data users. This approach is effective as long as the delay from measuring C/I and scheduling for a given user is small. Also the less slots (power control updates) a HSDPA frame encompasses the less margin needs to be set aside for voice users to guarantee them a minimum performance level during a scheduled burst. Alternatively, the power control rate for voice users could be reduced to 500Hz to minimize the power margin needed for voice users over a data frame interval such as 3.33ms.

The draw backs of the kind of simulation-analysis presented are that the effects of voice activity and fast FPC are not adequately modeled and such effects may degrade C/I estimation and hence degrade data throughput. Effects of voice activity and fast FPC will be addressed in later analysis and future quasi-static system simulations. The reverse link will also be modeled.

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.

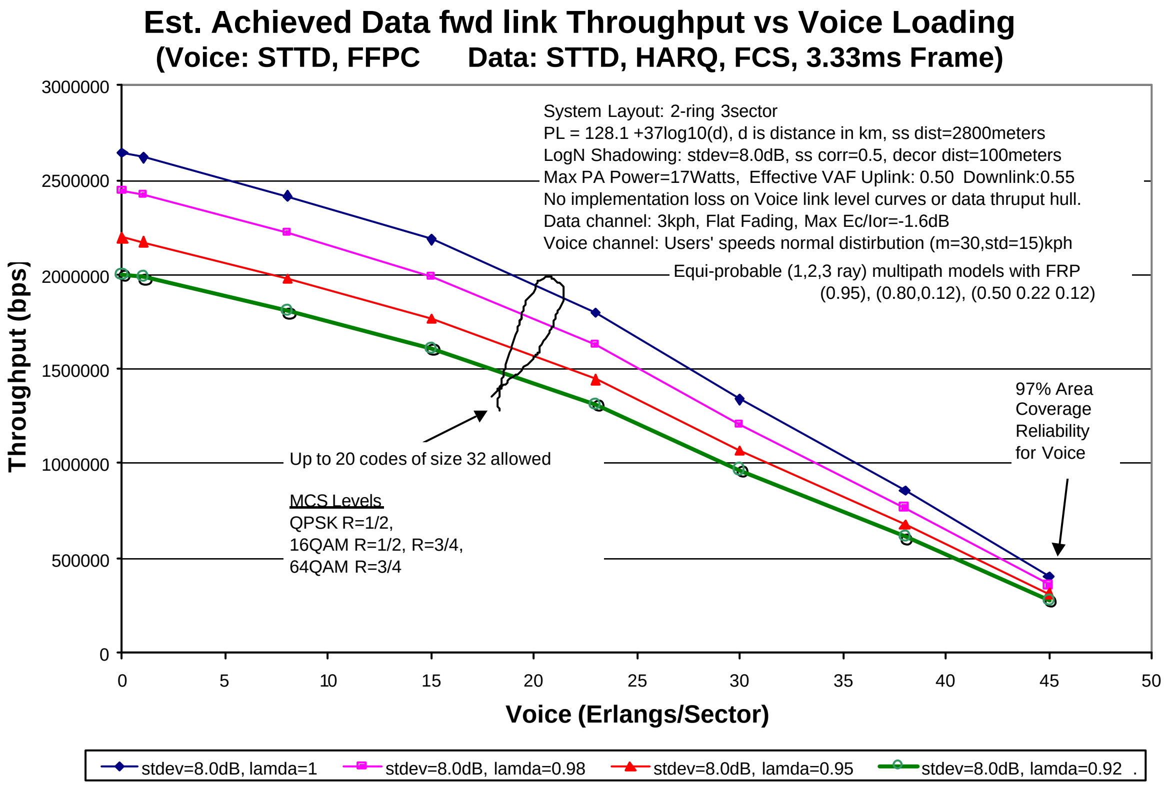

Figure 3. HSDPA Throughput vs Voice Loading for different FRP (lamda) where an Equal Average Data Scheduler is assumed.

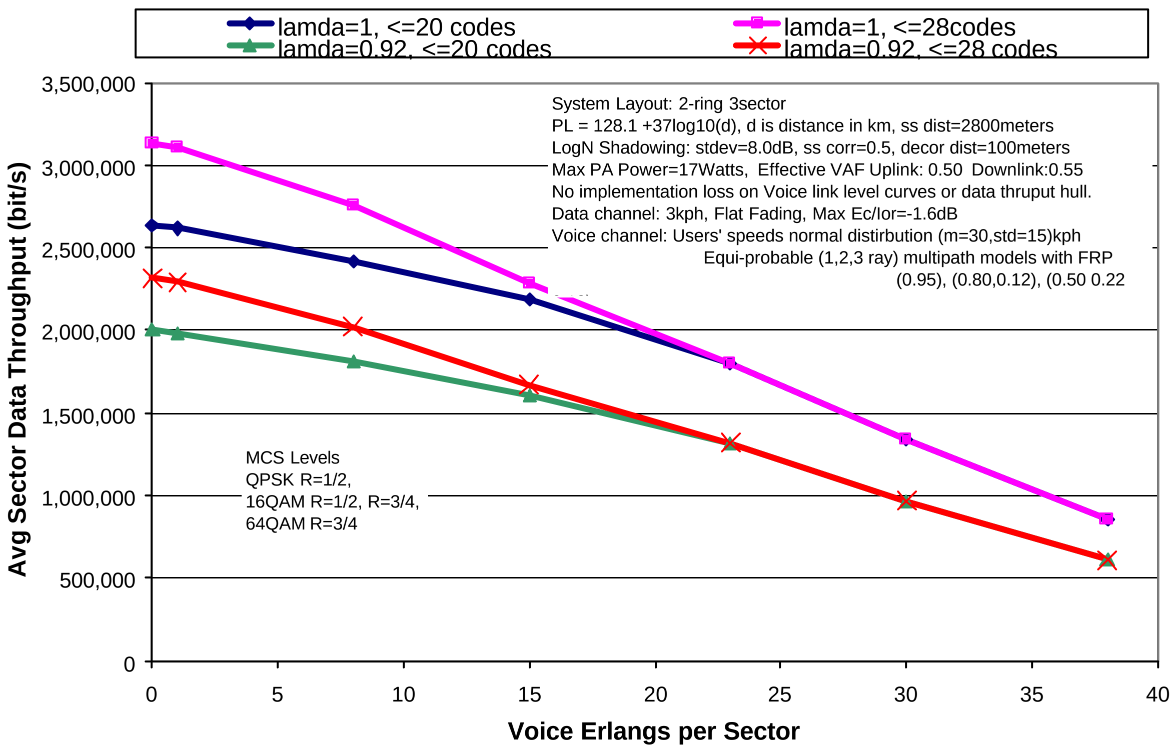

Figure 4. HSDPA Throughput vs. Voice Loading for different FRP (lamda) and for 20 and 28 OVSF codes where an Equal Average Data Scheduler is assumed.

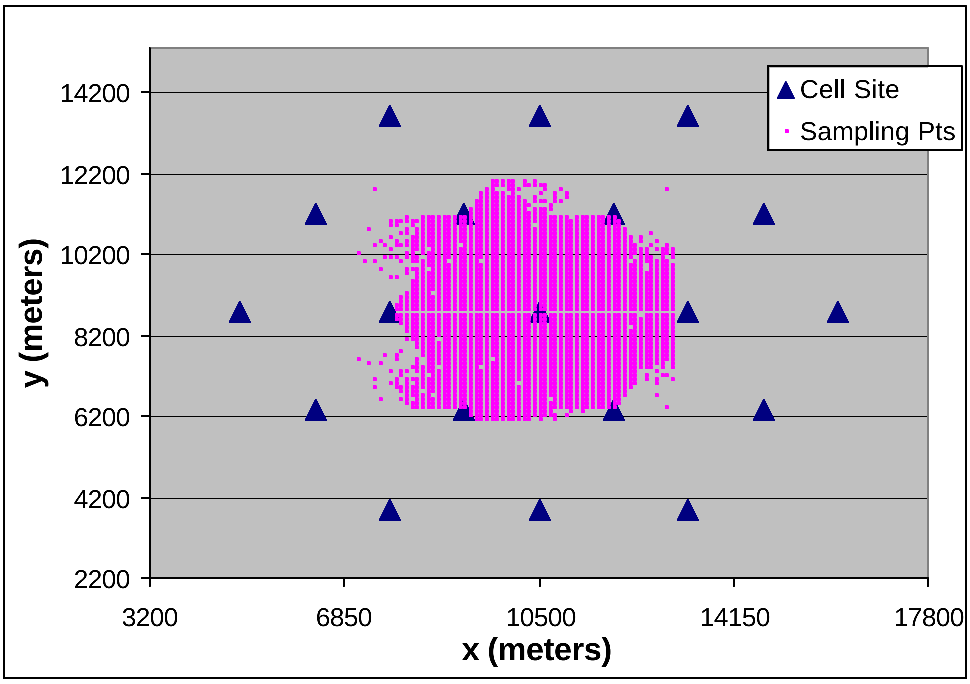

Figure 5. System used for Voice and Data HSDPA Simulation. C/I (Ec/Ioc) sampling points corresponding to coverage area of inner ring sectors and center cell sectors.

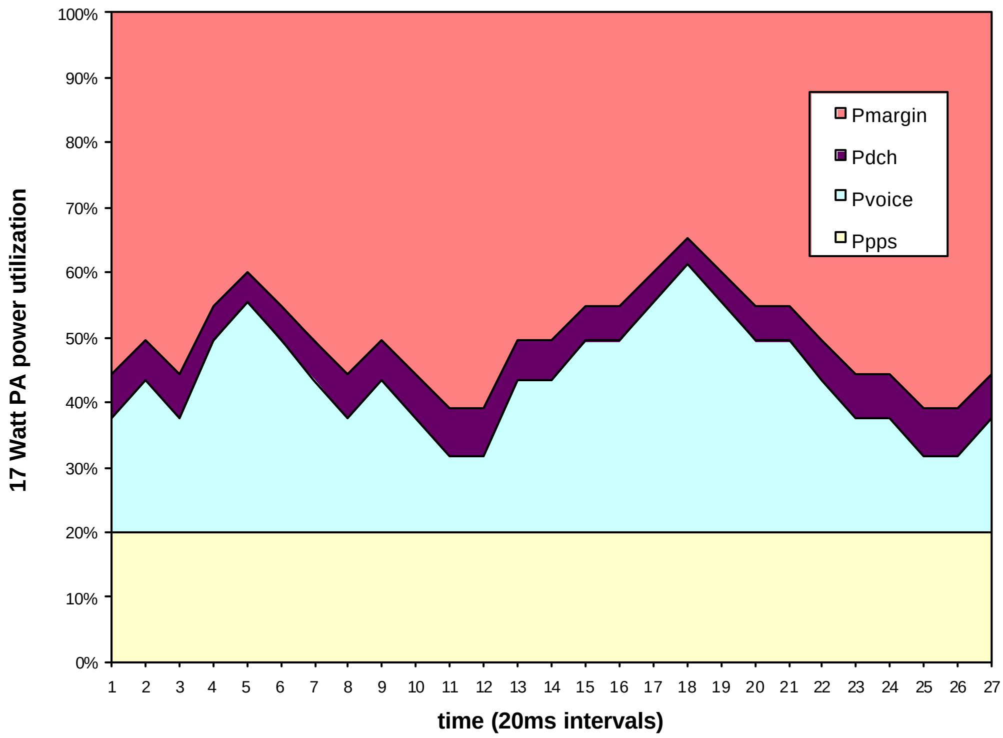

Figure 6. Percentage utilization of 17 Watt PA for a given sector in the system. Note at all times 17 Watts is transmitted for each sector.