Agenda item:

Source: Lucent Technologies

Title: Preliminary link level results for HSDPA using multiple antennas

Document for: Discussion

1. INTRODUCTION

A previous contribution [1] highlighted the techniques and benefits of using multiple antennas for High Speed Downlink Packet Access (HSDPA), orginally proposed by Motorola in [2]. Using multiple antennas with space-time transmission and detection techniques, one can exploit the spatial dimension and increase the spectral efficiency of the channel significantly compared to conventional single antenna links.

In this contribution, we present some prelinimary link level results demonstrating the gains of space-time transmission and detection techniques. In particular, we show the following results:

- Space-time techniques can achieve a given data rate and frame-error rate with lower required Eb/N0 and smaller data constellations than single antenna links.
- Space-time techniques can achieve higher maximum data rates than single antenna links.

2. TRANSMISSION TECHNIQUES

Conventional transmitter. The conventional transmitter for the downlink shared channel is shown in Figure 1. The turbo encoder, rate matching, variable modulator, channel gain, and multi-code demultiplexer can be adaptively adjusted to match the desired data rate. Specifically, the coding rates of the turbo encoder can be set to ½ or ¾, and the variable modulator can use QPSK, 8PSK, 16QAM, or 64QAM data constellations. The demultiplexer splits the input into N lower rate substreams which are spread using N Walsh covering sequences.

Space-time transmit diversity (STTD). Second order diversity can be achieved for each demultiplexed substream using space-time transmit diversity [3] as shown in Figure 2. This is the technique used for open loop diversity in UMTS. Each STTD block takes two consecutive data symbols $s^{(j)}, s^{(j+1)}$ at the input. During interval j, the top output is $s^{(j)}$ and the bottom output is $-\left(s^{(j+1)}\right)^*$ where * denotes the complex conjugate. During interval $j+1$, the top output is $s^{(j+1)}$ and the bottom output is $\left(s^{(j)}\right)^*$. The top output from STTD block n ($n = 1 \ldots N$) is spread using Walsh codes W_n. The N spread signals from the top outputs are summed, scrambled using a PN sequence, and transmitted from antenna 1. The bottom outputs are similarly processed and transmitted from antenna 2. By normalizing the channel gains appropriately, the STTD technique provides second order diversity without using extra bandwidth or power resources compared to a single antenna system.

Code re-use. In contrast to STTD which provides transmit diversity gains but not spectral efficiency gains, code re-use increases the spectral efficiency but provides no transmit diversity. Spectral efficiency is increased by using each spreading code to modulate M separate data substreams. The code re-use transmitter, as shown in Figure 4, uses a multicode demultiplexer to split the input signal into MN substreams, where N is the number of spreading codes and M is the number of transmit antennas. For the mth transmit antenna (m = 1 … M), N consecutive substreams (m-1)N+1 through mN (m = 1 … M) are respectively spread using codes W_1 through W_N. These are summed, scrambled with the PN code and transmitted from the mth antenna. The M substreams which share the same spreading code must be resolved spatially at the receiver using multiple antennas. In general, the number of receive antennas must be at least M.

By reducing the transmit power of each antenna by a factor of M, the total transmit power is the same as for the conventional single antenna system. Also, since only N spreading codes are used, the code resources are also the same. Therefore for a given channel coding rate and constellation size, code re-use with M antennas increases the spectral efficiency by a factor of M over a conventional transmitter without using additional power or code resources. In addition, code re-use requires smaller constellations than conventional transmission to achieve the same data rate.

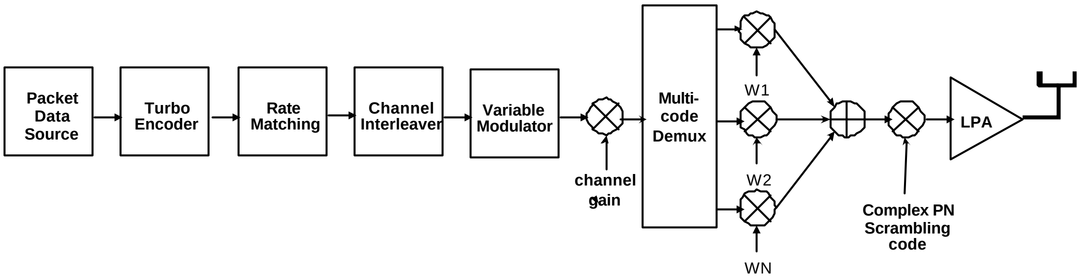

Figure 1. Conventional transmitter

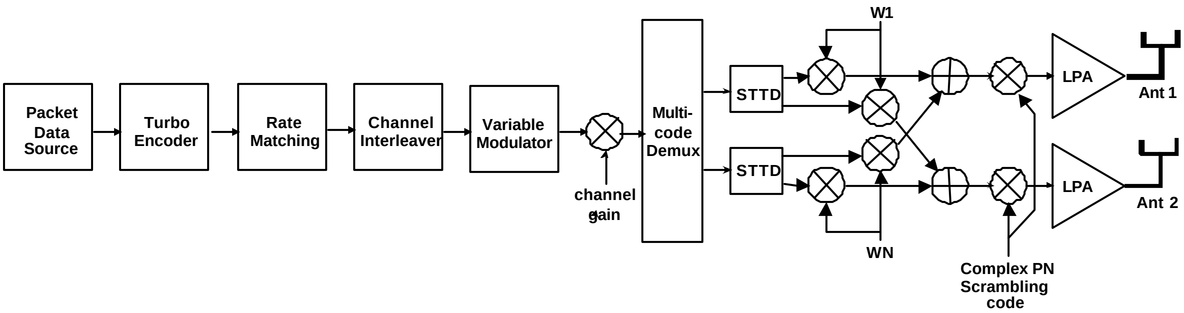

Figure 2. STTD transmitter with 2 antennas

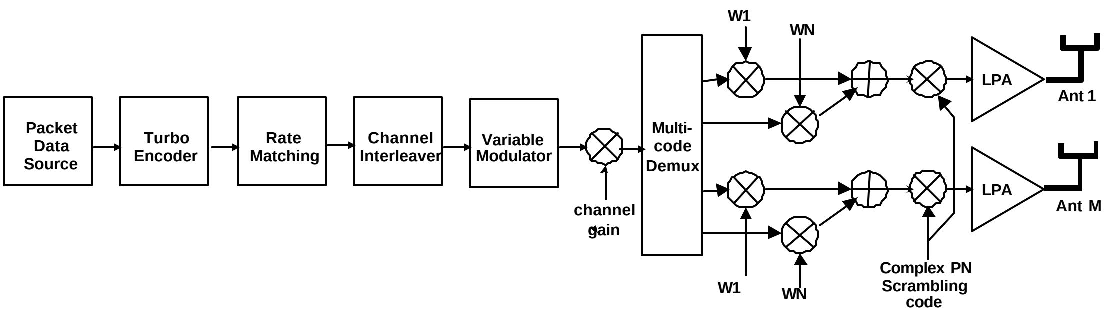

Figure 3. Code re-use transmitter with M antennas

3. CHANNEL MODEL

The simulations are performed over a flat fading channel generated using Jakes's model for 3km/h. For systems with multiple antennas, the channels are assumed to be independent among each transmit/receiver pair. The channel coefficients are assumed to be known at the receiver.

4. SIMULATION RESULTS

We perform link level simulations and measure the frame error rate versus Eb/N0 for a variety of system architectures. We first compare the systems for a fixed data rate and show that, compared to the conventional transmitter, multiple antenna architectures can achieve the same frame error rate at much lower Eb/N0. Next, we show how for a similar Eb/N0, the multiple antenna architectures can achieve higher data rates. We use turbo codes of rates ½ and ¾, and we assume that the pilot uses 20% of the downlink power.

4.1 Fixed data rate

We fix the spectral efficiency at 4.5 information bits per coded symbol. Then at a chipping rate of 3.84 Mchips/sec, a spreading factor of 32 chips per symbol, and using $N = 20$ codes, the data rate is 10.8Mbps. We consider the following system architectures for M transmit antennas and P receive antennas:

(M, P)	Tx technique	Code rate	Modulation	Data rate
(1,1)	Conventional	¾	64QAM	10.8Mbps
(2,1)	STTD	¾	64QAM	10.8Mbps
(2,2)	Code re-use (CR)	¾	8PSK	10.8Mbps
(4,4)	Code re-use (CR)	½ (8/9 puncturing)	QPSK	10.8Mbps

Table 1. System architectures for achieving 10.8 Mbps

Note that the code rates and data constellation sizes (and puncturing) are chosen to give 4.5 bits per symbol. Figure 4 shows the performance of the various architectures. Compared to the conventional and STTD systems, multiple antennas with code re-use provide significant performance gains. There is about a 5dB gain between the (2,2) code re-use sytem and the (2,1) STTD system. Using (4,4) code re-use, 10.8 Mbps can be achieved using only QPSK constellations, and there is a further gain of about 6dB.

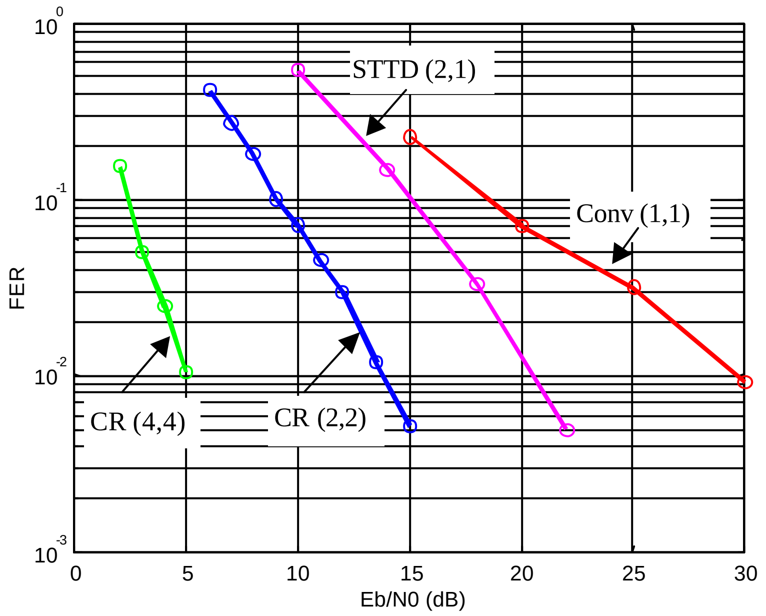

Figure 3. Flat fading channel performance for 10.8Mbps at 3km/hr

4.2 Increased maximum data rate

Using code re-use, the maximum data rate can increase to 14.4 or 21.6 Mbps using relatively small (8PSK or smaller) constellation sizes, as shown in Table 2. As seen in Figure 5, the required Eb/N0's for these rates are less than that for the conventional system operating at 10.8Mbps.

(*M*, *P*)	Tx technique	Code rate	Modulation	Data rate
(1,1)	Conventional	¾	64QAM	10.8Mbps
(2,1)	STTD	¾	64QAM	10.8Mbps
(4,4)	Code re-use (CR)	¾	QPSK	14.4Mbps
(4,4)	Code re-use (CR)	¾	8PSK	21.6Mbps

Table 2. System architectures for achieving up to 21.6 Mbps

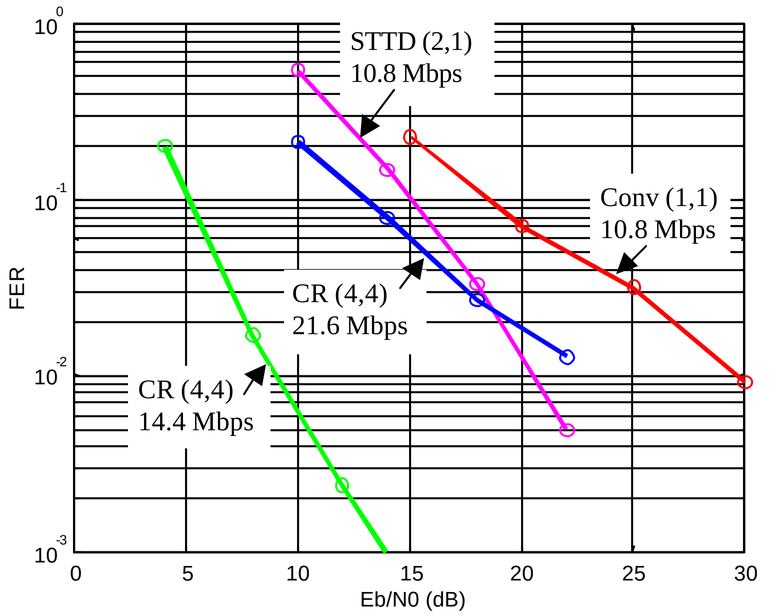

Figure 5. Flat fading channel performance for higher data rates at 3km/hr

4.3 Probability of achieving high data rate services

Using system level Eb/N0 measurements and the link level results above, one can estimate the probability with which a given data rate can be achieved. For the system level Eb/N0 measurements, the received Eb/N0 (with no spreading) is given by the ratio of the strongest received base station's signal to the sum of the interfering base signals. Independent shadow fading is assumed from each base, and the user location is varied uniformly over the center cell of a 3 ring system. The resulting cumulative distribution function of the received Eb/N0 is shown in Figure 6.

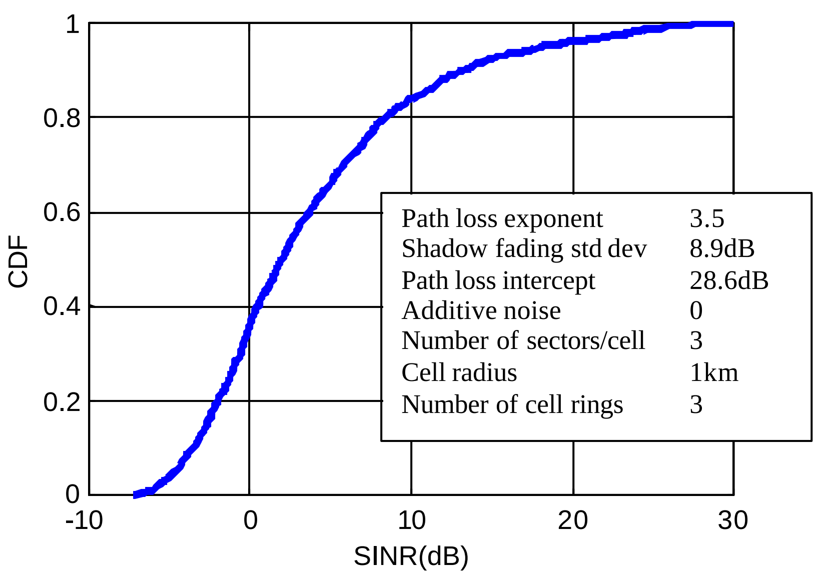

Figure 6. Cumulative distribution function of the received SINR

Using the link level results, we determine the required Eb/N0 at 10% FER to achieve a given data rate for the various system architectures. These values are listed in Table 3 along with the probability that this Eb/N0 requirement is met or exceeded. For example, the (1,1) conventional system at 10.8 Mbps requires an Eb/N0 of 18.5dB. From Figure 6, this Eb/N0 can be achieved only with probability 0.04. Using a (4,4) code re-use system, one can achieve at least 10.8 Mbps with probability 0.46. If the received Eb/N0 is between 5.0 and 13.0 dB (probability 0.33-0.10 = 0.23), a user can achieve 14.4 Mbps. Finally, if the Eb/N0 is above 13.0 dB, it can achieve 21.6 Mbps. The probability of doing so is comparable to that of a (2,1) STTD system achieving only 10.8 Mbps.

(M, P)	Tx technique	Code rate	Modulation	Data rate	Req. Eb/N0	Probability
(1,1)	Conventional	¾	64QAM	10.8 Mbps	18.5 dB	0.04
(2,1)	STTD	¾	64QAM	10.8 Mbps	15.0 dB	0.07
(2,2)	Code re-use	¾	8PSK	10.8 Mbps	9.2 dB	0.18
(4,4)	Code re-use	½	QPSK	10.8 Mbps	2.4 dB	0.46
(4,4)	Code re-use	¾	QPSK	14.4 Mbps	5.0 dB	0.33
(4,4)	Code re-use	¾	8PSK	21.6 Mbps	13.0 dB	0.10

Table 3. Probabilities for achieving high data rate services over random locations and shadowing

5. CONCLUSIONS

We have shown preleininary link level results for a multiple antenna architecture with code re-use. For flat fading channels with ideal channel estimation, the gains over conventional single antenna and STTD systems are significant. For future simulation studies, we hope to investigate the effects of noisy channel estimation and scheduling.

6. REFERENCES

[1] Lucent. Enhancements for HSDPA Using Multiple Antennas. TSG_R WG1 document TSGR1#15(00)1096, 22-26th, August 2000, Berlin, Germany.

[2] Motorola. Work item description sheet for High Speed Downlink Packet Access. TSG-R document, TSGR#7(00)0032, 13-15th, March, 2000, Madrid, Spain, 3 pp.

[3] S. M. Alamouti, A simple transmit diversity technique for wireless communications. *IEEE Trans. on Select Areas in Communications*, vol.16, p.1451-58, 1998