Agenda item:	AH24 : High Speed Downlink Packet Data Access
Source:	Lucent Technologies
Title:	Responses to comments/questions on throughput simulations for MIMO
Document for:	Discussion

1. INTRODUCTION

Responses to [1] titled "Comments/Questions on Throughput Simulations for MIMO" are given in this contribution. The comments and questions raised in [1] are given in italics. Responses are based on an email posted to the 3GPP WG1 reflector on February 1, 2001.

2. RESPONSES

<u>Traffic Model:</u>

There is no traffic model. All users have an infinite amount of data to send. These results are not directly comparable to other HSDPA results that use the web traffic model specified in the HSDPA TR. The web traffic model should be incorporated for proper comparisons.

We address these issues in [2].

<u>Diversity Mode Comparisons:</u>

Closed loop transmit diversity (two transmitting elements) is a supported diversity method in Release '99 and it is supported for the downlink shared channel (DSCH). It should be included as a reference for diversity mode comparisons. Further, the throughput results should be compared to baseline HSDPA results of the TR.

While closed loop transmit diversity is supported in Release '99, the HSDPA archtecture requires additional feedback bits for rate and/or channel information. Taken together, these feedback bits may be excessive. Hence this closed loop technique should not be required as a reference unless it can be shown that it can operate under the HSDPA feedback signaling specification. In contributions [2] and [6], we propose a closed loop selection transmit diversity technique which requires fewer feedback bits. The antenna selection bits are integrated with the channel quality indicator bits. This mode is used for providing lower data rates for non-MIMO transmission.

<u>Simulation Parameters:</u>

The simulations used an idealized antenna pattern, with no use of a backlobe. Also, no site-to-site correlation was modeled. These assumptions result in an optimistic (high) C/I distribution.

We address these issues in [2].

<u>Packet Call Delay:</u>

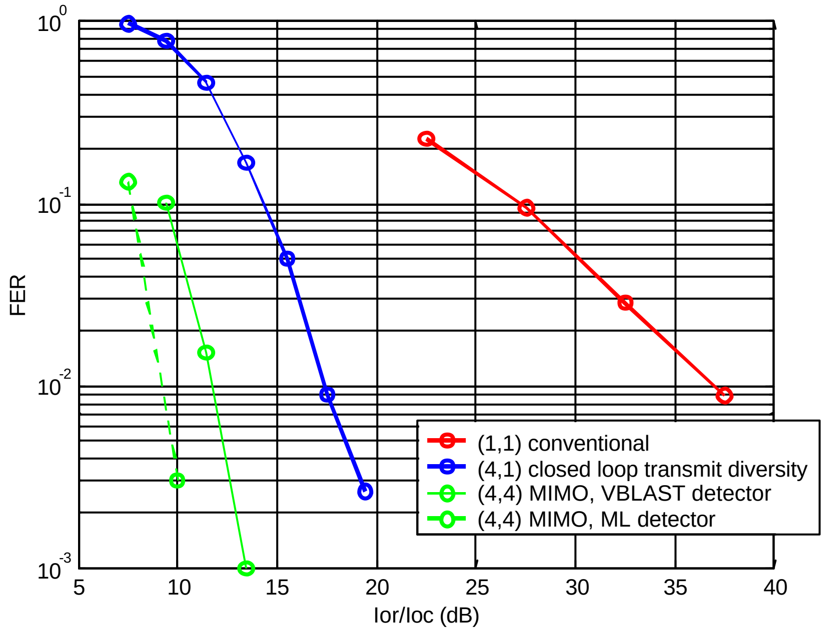
Multi-user diversity obtained by judicious scheduling is proposed. This technique will have an adverse effect on packet call delay. Packet call delay statistics should be reported to allow a proper evaluation of the performance of multi-user diversity. Since all packet traffic will not be delay tolerant, it is important to evaluate multi-user diversity performance under a mix of packet traffic types. In addition, feedback delay (both ARQ and modulation and coding select) was not included in the simulation. Since multi-user diversity relies on time scheduling, feedback delay may have an adverse effect and should be properly modeled.

All H-ARQ schemes have delays associated with them. It comes from two areas: feedback delays and the number of H-ARQ retransmissions. Multi-user optimized schemes have very similar delays; the only difference is the time between retransmissions (upon receiving a NACK) is variable. Feedback delays are of the order of a few milliseconds and the average number of retransmissions is about two. Thus the overall delays are expected to be modest. However the overall gain due to multi-user scheduling is substantial. In [2], we account for the effects of feedback delay.

Multi-Antenna Reference for Comparisons:

Closed loop transmit diversity with four transmitting elements is under study in WG1. This mode should be incorporated as a reference point for MIMO performance comparisons.

The arguments we present above for closed loop transmit diversity with two elements apply here. Nevertheless, let us compare the link level performance of closed loop transmit diversity with MIMO. Let (M,P) denote a system with M transmit antennas and P receive antennas. The figure below shows the FER versus Ior/Ioc at 10.8 Mbps for the following systems: 1) the conventional (1,1) system, 2) the (4,1) system with closed loop transmit diversity, 3) the (4,4) MIMO system with VBLAST detection, and 4) the (4,4) MIMO system with maximum likelihood detection. The coding and modulation formats are given in [3], except for the (4,1) system which employs the scheme of the (1,1) system (i.e., rate ¾ coding and 64 QAM modulation). The simulations are for Rayleigh fading channels with uncorrelated spatial fading and known channel estimates. Furthermore, the transmit diversity system assumes perfect unquantized channel feedback to the transmitter. The performance difference between the transmit diversity technique and the MIMO techniques is at least 5dB.



MIMO Transmission:

On page 4, a metric is defined based on the log-det. It is not clear why this is a proper method or metric. Please expand on this approach. What log-det threshold values were used to select the MIMO data rates? Page 4 specifies 0.1% FER as the criterion. What is this FER level based upon? H-ARQ was not modeled. What will be its impact on MIMO performance? Was MMSE receiver with SIC used in the link level simulations described on page 4 to generate the FER Vs log-det curve in Figure 2? Is it possible to provide a basic block diagram of the receiver used in the simulations?

The log-det metric was introduced in contribution [3,4] as a metric for rate determination at the UE. In conventional single antenna systems, the desired data rate is determined by a C/I measurement at the UE. In multiple antenna systems, the C/I alone is not sufficient to determine the rate, since the rate is also dependent on the channel coefficients. For a given C/I and given data rate, the frame error rate (FER) performance depends on the correlation between the columns of the channel matrix H. The log-det metric is simply one feasible metric for mapping the C/I and channel coefficients to a supportable rate. As stated in the contribution, there may be alternative metrics.

With regard to the threshold values, these are chosen from the link level simulation results as shown in slide 12 of [4]. This slide shows the FER versus the log-det metric for 3 MIMO data rates, and it shows that the log-det metric provides a reliable estimate of the FER. The intention was to arbitrarily set the FER target at 0.2% (not 0.1%) to provide a conservative estimate on the achievable capacity; under this assumption for example, those users with channels which had a log-det metric between 8.5 and 10 were assumed to request a data rate of 10.8 Mbps and achieve a rate of (1-0.002)*10.8Mbps. For a given data rate, the threshold values is supposed to correspond to the log-det value below which the FER is 0.002 or higher. These thresholds were chosen as 8.5, 10and 15 for rates of 10.8, 14.4, and 21.6 Mbps, respectively.

The complete baseband receiver architecture consists of a despreader, a spatial combiner, a MIMO detector, a multiplexer, and a turbo decoder. Details of the receiver architecture are given in [7]; however, we give a summary here. For a system with M transmitters and P receive antennas using N codes (for example $N = 20$ if the spreading factor is 32), there are a total of MN transmitted substreams. Each receive antenna is followed by a bank of N despreaders matched to these N codes. For each of the MN substreams, the P components from the appropriate despreader outputs are combined using spatial channel estimates and maximal ratio combining. The MIMO detector which follows is either a maximum likelihood detector or V-BLAST detector [5] which is a linear MMSE transformation followed by ordered successive interference cancellation. The maximum likelihood detector can be derived from the sufficient statistic outputs of the spatial combiner. Following the MIMO detector, the MN substreams are multiplexed into a single high data rate stream, demapped to bits, deinterleaved, and decoded. A maximum likelihood detector was used to generate the FER versus log-det curve.

3. REFERENCES

[1] Motorola. Comments/Questions on Throughput Simulations for MIMO. TSG_R WG1 document TSGR1#18(01)0043, 15th-18th January 2001, Boston, USA.

[2] Lucent. Throughput simulations for MIMO enhancements to HSDPA. TSG_R WG1 document TSGR1#19(01)0304, 27th February – 2nd March 2001, Las Vegas, USA.

[3] Lucent. Throughput simulations for MIMO and transmit diversity enhancements to HSDPA. TSG_R WG1 document TSGR1#17(00)1388, 21-24th, November 2000, Stockholm, Sweden.

[4] Lucent. Throughput simulations for MIMO and transmit diversity enhancements to HSDPA. TSG_R WG1 document TSGR1#17(00)1407, 21-24th, November 2000, Stockholm, Sweden.

[5] P. Wolniansky et. al., “V-BLAST: An architecture for achieving very high data rates over the rich-scattering wireless channel,” in *Proc. ISSSE-98*, Pisa, Italy.

[6] Lucent. MIMO system integration and signaling in HSDPA. TSG_R WG1 document TSGR1#19(01)0305, 27th February – 2nd March 2001, Las Vegas, USA.

[7] Lucent. MIMO physical layer description. TSG_R WG1 document TSGR1#19(01)0306, 27th February – 2nd March 2001, Las Vegas, USA.