Agenda item:	AH24 : High Speed Downlink Packet Data Access
Source:	Lucent Technologies
Title:	Further Discussion on UE Complexity for MIMO architectures
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1. INTRODUCTION

In previous contributions [1][2], link level results for high speed downlink packet access (HSDPA) demonstrated the gains of multi-input/multi-output (MIMO) transmission and detection techniques compared to conventional single antenna techniques. Contributions [3] and [4] have addressed the complexity of the UE for MIMO architectures while contribution [7] addressed the complexity of the Node B. In this contribution, we further address the complexity at the UE for MIMO architectures over those requirements for conventional HSDPA transmission with a single antenna. Specifically, we discuss cost/complexity for a MIMO UE under two specific scenarios: a) implementation using standard technologies available today and b) implementation using recently announced homodyne technology.

2. ASSUMPTIONS

To obtain an order of magnitude (OoM) estimate of the incremental cost of a 4x4 MIMO capable UE, we have discussed the cost structure of the UE with multiple UE vendors. As these are naturally highly proprietary, we cannot present any detailed cost numbers nor identify them by name. We have found consistency across the estimates from different sources and the data presented here is based on a composite (roughly an average) of all the cost structure data.

We evaluate the OoM for two specific MIMO-capable systems. MIMO-1 provides HSPDA at a peak rate of 14.4 Mb/sec and MIMO-2 provides HSPDA at a peak rate of 21.6 Mb/sec. Specific modulation/coding parameters for these configurations are given in [1], [2].

A table showing coding rates and data constellations for a representative set of data rates is shown in Table 1. For the scenarios considered here, MIMO-1 would be capable of providing all the data rates in Table 1 except for the highest rate of 21.6 Mb/sec. The MIMO-2 scenario adds the 21.6 Mb/sec data rate to those covered with MIMO-1.

Estimates of baseband complexity were previously presented in [11]. By considering the impact on the ASIC/signal processing as well as memory needs, our study estimates an increase of a factor of 1.5 for MIMO-1 and a factor of 2.5 for MIMO-2. These estimates for baseband complexity are independent of the RF implementations discussed in the next two sections.

3. BASELINE

For a baseline, single antenna UE, we have collected the following OoM estimates as a percentage of total UE cost (see Table 1). The baseband signal processing is primarily ASIC and memory. Signal processing at baseband or signaling for other activities, such as call processing, are included in the “Other” category. RF includes all components from the antenna down to baseband. The "Other" category includes numerous fixed costs such as circuit boards, battery, display, etc. Incremental battery costs have been included in the RF column.

# of trans-mitters	Tx tech-nique	Code rate	Modu-lation	Data rate per substream	# sub-streams	Total data rate
1	Conv.	¾	64QAM	540Kbps	20	10.8Mbps
2	MIMO	¾	8PSK	270Kbps	40	10.8Mbps
2	MIMO	¾	16QAM	360Kbps	40	14.4Mbps
4	MIMO	~½	QPSK	135Kbps	80	10.8Mbps
4	MIMO	¾	QPSK	180Kbps	80	14.4Mbps
4	MIMO	¾	8PSK	270Kbps	80	21.6Mbps

Table 1. Transmission architectures

Function	% of total cost (baseline)
Baseband processing	35%
RF	15%
Other	50%
Total	100%

Table 2. Order of Magnitude (OoM) Cost Structure for Baseline UE

4. ESTIMATES FOR CONVENTIONAL IMPLEMENTATION

Table 3 assumes a conventional RF structure at the UE with a worst-case assumption that the entire RF chain would need to be replicated four times to support a (4,4) MIMO HSPDA channel. Again, note that the only difference between the MIMO-1 and MIMO-2 modes is that MIMO-2 also supports the highest data rate of 21.6 Mb/sec.

As indicated by Table 3, even a worst case assumption of a four-fold replication of the RF hardware results in substantially less than a four-fold increase in total cost. To supply 14.4 Mb/sec to a data user, the cost of the UE would increase by approximately 60% over a baseline UE. To support the highest data rate of 21.6 Mb/sec, the total cost is estimated to be increased by a factor of only two over the baseline case.

Function	% of total cost (baseline)	MIMO-1	% of total cost (MIMO-1)	MIMO-2	% of total cost (MIMO-2)
Baseband Processing	35%	X 1.5	52%	X 2.5	87.5%
RF	15%	X 4	60%	X 4	60%
Other	50%		50%		50%
Total	100%		162%		197%

Table 3. Order of Magnitude (OoM) Cost Structure for conventional RF (4,4) MIMO

5. ESTIMATES FOR HOMODYNE IMPLEMENTATION

MIMO UEs require multiple RF-to-baseband conversion chains. A conventional RF-to-baseband chain first converts the RF signal to an intermediate frequency (IF) prior to converting to baseband. A new technology -- known as direct conversion, homodyne radio, or zero IF -- converts the RF signal directly to baseband, eliminating the need for IF circuitry and expensive surface acoustic wave (SAW) filters. Recently, several companies have announced direct conversion radio chips for GSM and/or wideband CDMA systems [8], [9], [10]. According to [10], the parts count and area of a CDMA direct conversion chip is reduced approximately 50 percent compared to conventional RF to baseband chains. In MIMO receivers, these chip architectures would significantly reduce the cost of the RF component. For homodyne implementation, we therefore will assume a 50% reduction in our OoM estimates of the RF section. Table 4 estimates the cost of a homodyne-based UE supporting (4,4) MIMO.

Function	% of total cost (baseline)	MIMO-1	% of total cost (MIMO-1)	MIMO-2	% of total cost (MIMO-2)
Baseband Processing	35%	X 1.5	52%	X 2.5	87.5%
RF	15%	X 2	30%	X 2	30%
Other	50%		50%		50%
Total	100%		132%		167%

Table 4. Order of Magnitude (OoM) Cost Structure for homodyne RF (4,4) MIMO

As indicated by Table 4, if we assume that technological advances, such as homodyne receivers, could be brought to bear in the next 3-5 years, the conventional assumption of a four-fold replication of the RF hardware could be reduced by perhaps as much as one half. To supply 14.4 Mb/sec to a data user, the cost of the UE would be increased by only 30%

over today's baseline UE. To support the highest data rate of 21.6 Mb/sec, the total cost is estimated to be increased by a factor of only 2/3 over the baseline case.

6. CONCLUSIONS

An order of magnitude study of the cost of providing (4,4) MIMO capability in a UE has been presented, based upon the inputs from a number of UE vendors. Using relative proportions of cost across the UE, we have estimated the incremental costs of providing HSPDA and found them to be substantially less than a linear increase with the number of antennas. Even using worst case assumptions whereby the RF costs are linear with the number of antennas, we estimate that the cost to provide the highest data rate of 21.6 Mb/sec is only a factor of two more than a baseline UE with only one antennas. If we allow for advanced RF implementations in the future, such as homodyne receivers, we see a potential to further reduce the cost.

7. REFERENCES

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