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Re:	Comment on SDD IEEE 802.16m-08/003r9 – Section 11.8 and 11.12
Abstract	This contribution proposes antenna selection support to be included in DL and UL MIMO section.
Purpose	To be discussed and adopted by TGm for use in the IEEE 802.16m SDD
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CR for SDD Text on DL and UL MIMO: Antenna Selection for IEEE802.16m

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1 Introduction

Antenna selection (AS) is a technique in which only a subset of available antenna elements is used for the transmission/reception of data. The subset can change according to channel conditions and interference situation.

- AS technique *reduces hardware complexity*, as the number of RF chains for upconversion/ downconversion can be smaller. Indeed, the number of RF chains only needs to equal the number of *used* antenna elements, not the number of *available* antenna elements.
- AS *retains most of the benefits of large antenna arrays*: the diversity order is determined by the number of *available* antenna elements.

For these reasons, AS is now widely used for MIMO-based high-speed wireless systems (e.g., 3GPP LTE, IEEE 802.11n, etc.).

In this contribution, we propose amendment text to support AS at the AMS in IEEE802.16m. Note that since the baseline configuration at the AMS uses 2 receive antennas and 1 transmit antenna, it is reasonable to have a smaller number of transmit RF chains (limiting the number of power amplifiers), but the receive *antenna elements* can serve as transmit antenna elements without extra effort. Thus, using a 1-out-of-2 transmit antenna selection is a logical step to take.

2 AMS Antenna Selection

In this section, we provide several examples of how AMS antenna selection can be performed.

- **(Case 1) *1* out of *2* selection, frequency-flat**
  In a frequency-flat fading environment, if an AMS has 2 antenna elements and 1 RF chain, it is intuitively clear that the AMS should select the antenna element with the better SINR.
  - **DL AMS antenna selection:** Since the AMS has only 1 RF chain, it has to measure the DL channel quality in a time-multiplexed manner, i.e., the AMS first has to measure at one antenna element, and then, after some time, at the other. Then it decides which antenna element is better, and uses it for the remainder of the reception time. As long as the channel stays constant during this whole process, there is no loss in optimality.
  - **UL AMS antenna selection:** If the channel is reciprocal, the same antenna subset chosen in DL AMS antenna selection can be used for uplink transmission. If the channel is not reciprocal, then the AMS should send out uplink training signals (e.g., pilots), and then ABS needs to feed back

in the downlink control signaling which antenna should be used for the transmission. Due to the delay of such a feedback scheme, it is most beneficial when the users are (quasi)-stationary.

- **(Case 2) *L* out of *N* selection, frequency-flat**
  If an AMS has N antenna elements and L RF chains, the selection of the best antenna subset is not straightforward anymore, since the SINR is not the most relevant criterion. Rather, the capacity of the link should be maximized. Both brute-force approach and more efficient algorithms can be used. Note that the selection of the subset is a matter of implementation and does not have to be standardized.

  The protocol and signaling process are similar to that described in (Case 1).

- **(Case 3) Frequency-selective, selection without joint scheduling**
  In frequency-selective environment, assume that frequency scheduling (i.e., which subcarriers are to be used) has already been done. Different antenna subset can be optimal at different frequencies. However, since each RF antenna element can only be connected to one antenna element at a time, it is desirable to choose the antenna subset that is optimum in a "frequency-integrated" manner. The selection of the optimum antenna subset is again implementation-dependent.

  Note that the same protocol and signaling process described in (Case 1) would apply.

- **(Case 4) Frequency-selective, joint selection and scheduling**
  In this case, the scheduling and antenna selection decision need to be done jointly at the ABS. By providing multiple antenna subsets to choose from, the scheduler now has a larger ensemble (all subchannels on the antenna subsets) to assign the data streams to. Note the restriction that all assigned data streams have to be on one antenna subset. Optimum assignment in this enlarged ensemble naturally gives higher multi-user diversity gain, enables interference reduction, etc. Again, the algorithm by which the ABS does the optimum scheduling is outside the scope of the standard.

  The joint selection and scheduling requires more extensive training. The ABS has to be aware of the transfer function to each of the antenna subsets *for the whole system bandwidth*. For the uplink, this implies that channel sounding signals covering the whole bandwidth have to be sent from each possible subset, or – more efficiently – from each antenna element. For the downlink in the nonreciprocal case, the AMS needs to obtain CSI (channel state information) for the whole bandwidth from the preambles, and feed back this information to the ABS.

3 Performance Evaluation

Figure 1 demonstrates how AMS antenna selection can improve the performance at link level of a MIMO system. As shown in Figure 1, AMS antenna selection outperforms the non-AS case in terms of BER, in both correlated and uncorrelated channel models. Antenna selection in correlated channel even outperforms the non-AS case in uncorrelated channel at high SNR, since AS gives a larger diversity gain.

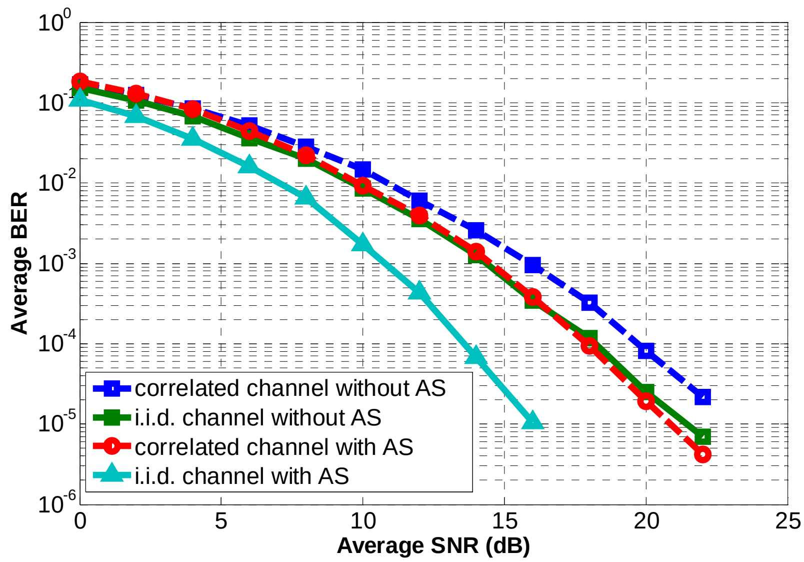

Figure 1: Average BER

Table 1: Parameters for link-level simulation used in Figure 1

Traffic	Downlink
Permutation	FUSC
Number of transmit antenna at AMS	2
Number of transmit RF chain at AMS	2
Number of receive antenna at AMS	4
Number of receive RF chain at AMS	2
Number of transmit antenna at ABS	4
Number of transmit RF chain at ABS	4
Number of receive antenna at ABS	4
Number of receive RF chain at ABS	4
Fading	Rayleigh
Path loss	3.7
Distance between AMS and ABS	500m

Figure 2 through Figure 5 provide system level performance results for antenna selection. The simulation is conducted in OPNET WiMAX model. Figure 2 plots the instantaneous throughput over time when the AMS and the ABS are 700 meters apart. As the channel gain for a particular propagation path varies with time, its associated SNR fluctuates accordingly. This results in the variation of throughput. When antenna selection is not applied, a fixed antenna element continuously transmits data. As shown in the figure, the instantaneous throughput varies over a wide range from 0 to 6 Mbps, with an average of 3 Mbps. When antenna selection is enabled at the AMS, the antenna element with the best channel gain (and highest SNR) is selected for UL data transmission. The resultant instantaneous throughput is much more stable and hovers around 6 Mbps. The AS mechanism with 4 antennas has double the throughput of a terminal with only a single antenna.

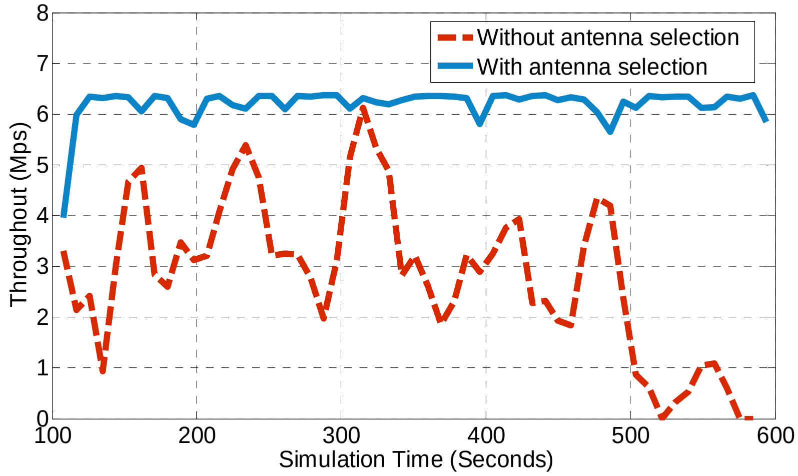

Figure 2: Instantaneous throughput with ARQ

Figure 3 and Figure 4 illustrate the cumulative distribution function (CDF) of the packet delays experienced by an ARQ-enabled AMS without and with antenna selection, respectively. The two figures clearly demonstrate that antenna selection can significantly lower system latency. This is because of the better channel gain achieved by antenna selection, which considerably reduces the number of retransmissions.

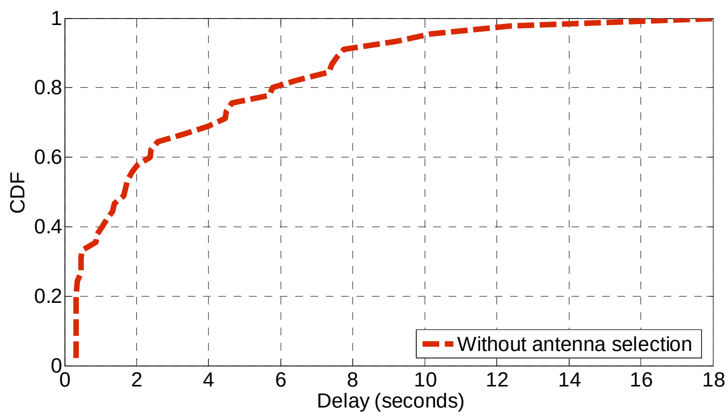

Figure 3: Delay CDF without antenna selection

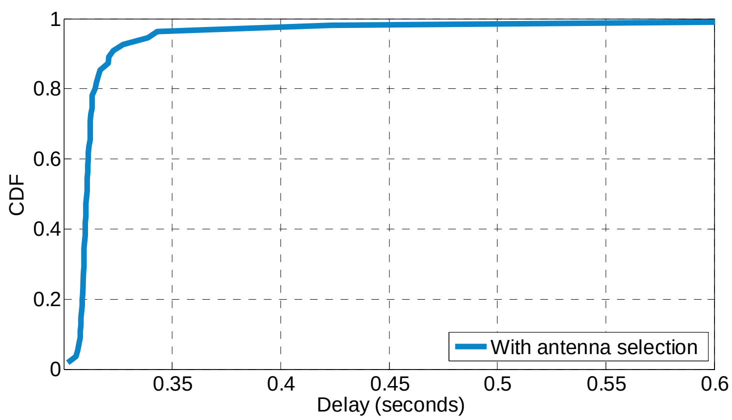

Figure 4: Delay CDF with antenna selection

In Figure 5, the average throughput is plotted as a function of the ABS to AMS distance. When compared with no-antenna selection, using antenna selection clearly increases the average throughput. In the figure, antenna selection, in fact, enhances the system throughput by as much as 100% in specific situations. At the same time, we also observe for small ABS-AMS distances, e.g., 500 meters or less, the throughputs with and without antenna selection are quite similar despite the difference between the corresponding SNR values. This saturation in throughput for high SNRs occurs because of the limitation on throughput imposed by the maximum modulation constellation size.

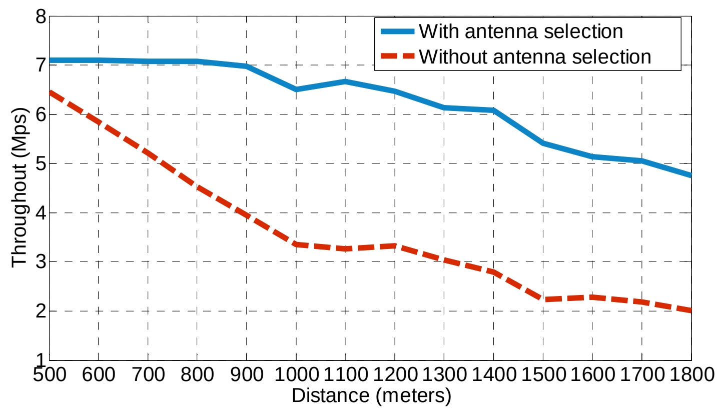

Figure 5: Throughput improvement enabled by antenna selection

Table 2: Parameters for system-level simulation used in Figure 2 through Figure 5

Coherence Time	50 milliseconds
Distance between AMS and ABS	500 ~1800m
AMS Transmit Power	50 mW
ABS Antenna Gain	15 dB
AMS Antenna Gain	-1 dB
Number of Antennas	4
Number of RF chains	1
Modulation & Coding Rate	64QAM, CC1/2
Scheduling Type	rtPS
OFDMA FFT Size	2048
Path Loss Model	Free Space
UL to DL Bandwidth Ratio	1/3
Permutation	PUSC
Traffic direction	UL
Frame duration	5ms
ARQ Mechanism	Go-Back-N (window size 512 blocks)

4 Proposed Text

[---Start of Text Proposal---]

11.8 DL MIMO Transmission Scheme

11.8.1.5 Signaling support for MIMO

[Insert section 11.8.1.5.3 as follows]

11.8.1.5.3 Signaling support for antenna selection
AMS and ABS can negotiate their support for downlink AMS antenna selection in access state.

If downlink AMS antenna selection is supported, AMS can notify ABS using uplink signaling after the AMS switches to a different antenna subset for downlink reception,.

11.12 UL MIMO Transmission Scheme

11.12.1.5. Signaling support for MIMO

[Insert following text at the end of section 11.12.1.5]

AMS and ABS can negotiate their support for uplink AMS antenna selection in access state. If uplink AMS antenna selection is supported, ABS can instruct AMS to use different antenna subset to transmit in different resource units for channel estimation purpose. ABS can further instruct AMS to switch to a specific antenna subset for uplink transmission.

[--End of Text Proposal--]

5 Reference

[1] Shkumbin Hamiti, "The Draft IEEE 802.16m System Description Document", IEEE 802.16m-08/003r8