Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Multi-user MIMO using non-orthogonal superposition in uplink**
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Re:	SDD Session 56 Cleanup; in response to the TGm Call for Contributions and Comments 802.16m-08/033 for Session 57
Abstract	SDD text proposal for MU-MIMO using non-orthogonal superposition in uplink
Purpose	Consider for inclusion into the SDD
Notice	
Release	
Patent Policy	

Multi-User MIMO Using Non-orthogonal Superposition in UL

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1. Motivation

From the two-user uplink rate region it can be seen that significant throughput gains can be achieved by non-orthogonal superposition.

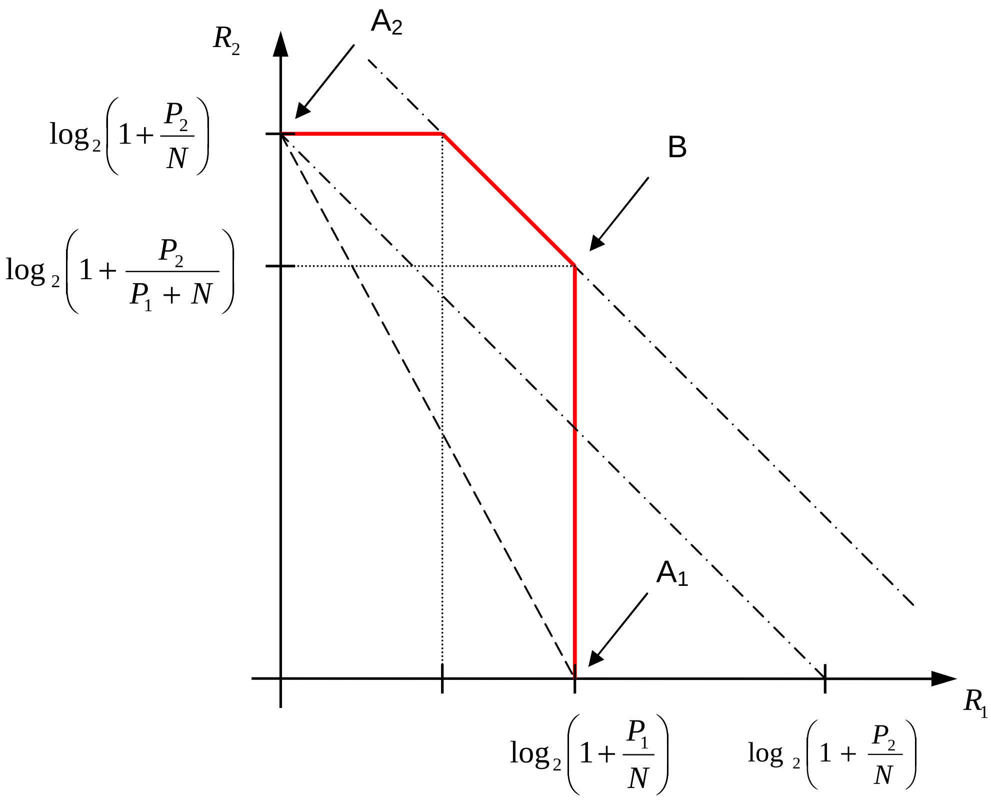

Figure 1: Two user achievable rate region in uplink

Figure 1 shows the achievable rates (normalized to bandwidth) of user 1 and user 2. In the points A_1 and A_2, only one user is transmitting at a time. In point B both users are transmitting at the same time on the same frequency resource (and, in the case of multiple antennas, in the same spatial direction) and the sum rate is significantly higher. This point can be reached in practical implementations by using successive interference cancellation (SIC) at the receiver.

2. Principles

- Signals from different users are not orthogonal; neither in time or frequency nor in the space or code domain
- Receive signal is a weighted sum of the signals from different users
- Signals can be separated by multi-user detection, especially successive interference cancellation (SIC)
- Typically the signals for different users have significantly different power levels
- No instantaneous CSI required at transmitter (only statistics like e.g. a mean path loss)
- Can be used with single or multiple antennas

3. Practical Implementation

- o Superimposed signals can be coded and modulated using conventional modulation and coding schemes
- o Simple e.g. two-user SIC receiver in the BS is sufficient
- o Standard support required e.g. for control signaling, power control and HARQ

4. Simulation Results

4.1. Link Level

Configuration:

- o UL PUSC
- o MMSE channel estimation
- o MMSE equalizer
- o Coding: CTC
- o Pilots:
  - o With superposition: 4 pilots;
  - o Without superposition: 2 orth. Pilot patterns with 3dB boosting
- o Channel: Pedestrian B, 3km/h and AWGN

Figure 2 and Figure 3 show that the performance of the interference cancellation using standard algorithms is good enough to achieve the expected performance gains on system level even in realistic fading channels.

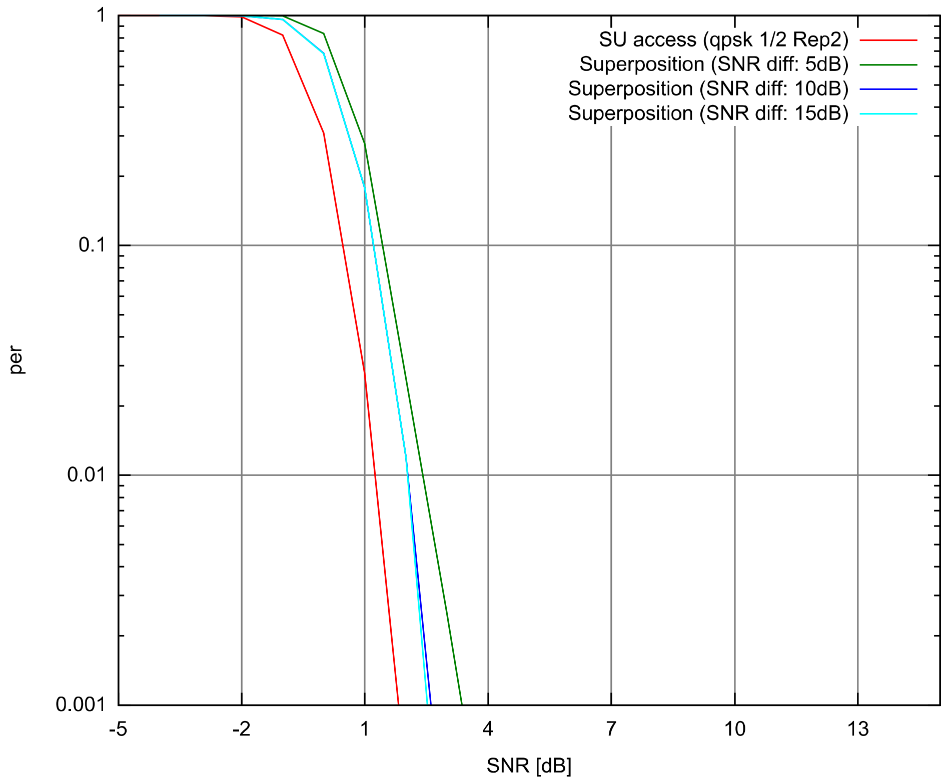

Figure 2: Packet error rate (per) vs. SNR with and without superposition in an AWGN channel

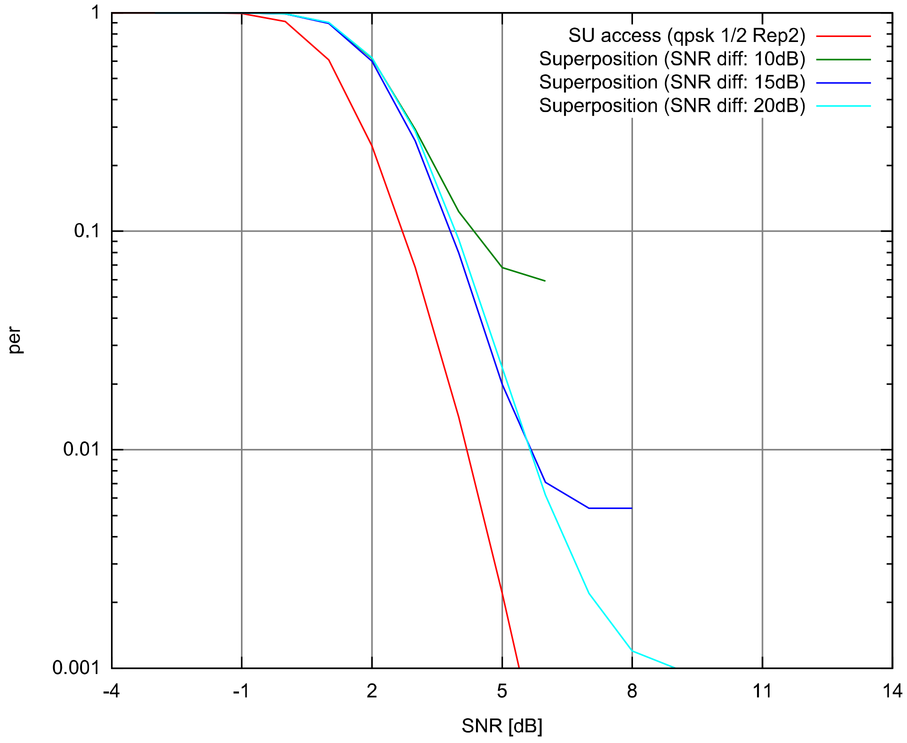

Figure 3: Packet error rate (per) vs. SNR with and without superposition in a frequency selective channel (Ped B 3 km/h)

4.2. System Level

Configuration:

- o Cell edge SNR (lowest in cell) = -1 dB
- o Log-distance path loss model with exponent 3.5
- o 30 "active" users in sector
- o MCS: from "QPSK 1/2 Rep 6" to "64 QAM 1/2"
- o Channel: Pedestrian B, 3 km/h
- o Spectral efficiency values take into account CP
- o User throughput values take into account CP and guard subcarriers

Figure 4 shows that the CCDF of the spectral efficiency on the time-frequency resources can be improved significantly by using non-orthogonal superposition. The average spectral efficiencies are:

- o Without superposition: 0.817 bps/Hz
- o With superposition using scheduling algorithm S3: 1.065 bps/Hz gain: 30 %
- o With superposition using scheduling algorithm S4: 1.579 bps/Hz gain: 93 %

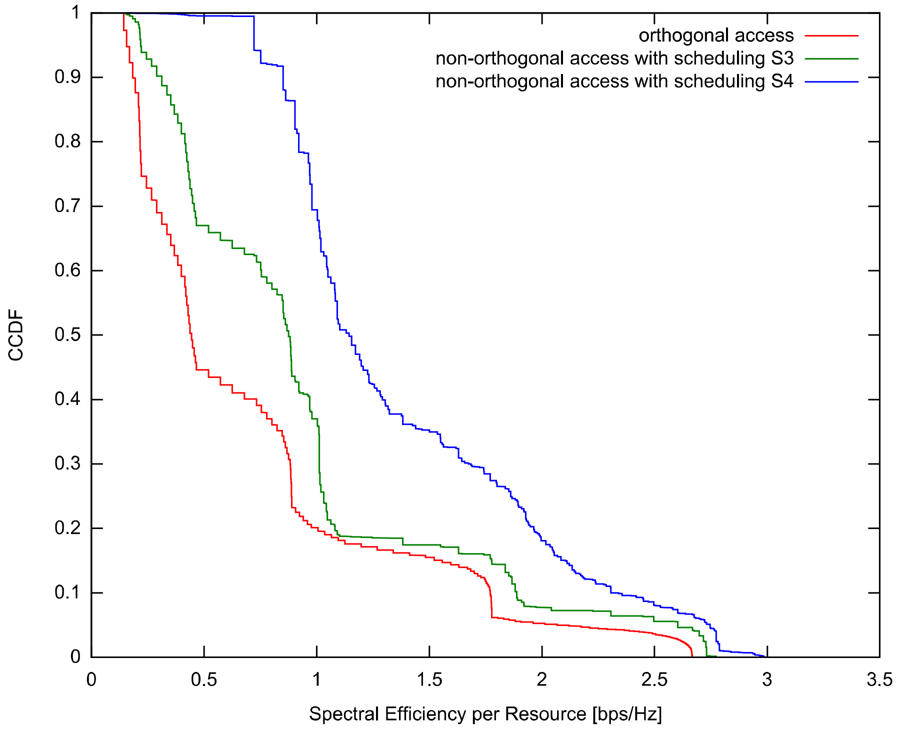

Figure 4: Spectral efficiency per resource (Ped B, 3 km/h)

From the above numbers and from Figure 5 and Figure 6 we can see that both the average throughput and the cell edge throughput can be improved by non-orthogonal superposition with appropriate scheduling.

The blue curve in Figure 6 shows that there may be a performance loss for some users due to superposition and interference cancellation with real channel estimation, if the same amount of resources as in the single-user case is assigned to them (scheduling algorithm S4). By assigning a higher fraction of the resources to those users (green curve, scheduling algorithm S3) this effect can be overcompensated, which results in a better performance even for the cell edge users and improved fairness among the users in the cell. The cell edge performance can be further improved by optimizing the scheduling algorithm. But of course it is limited by the physics of the channel.

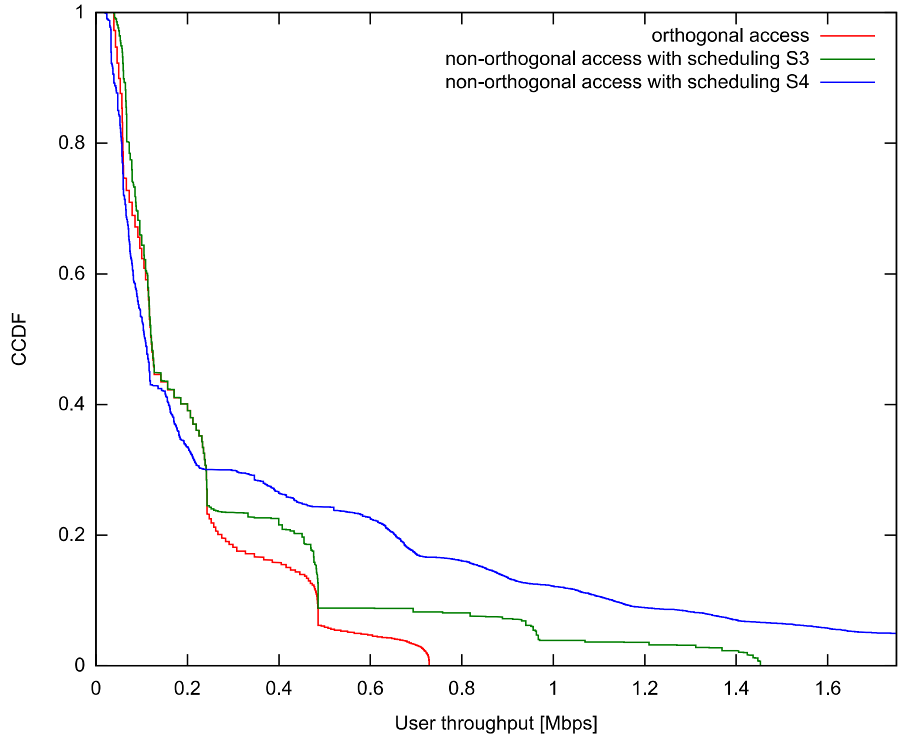

Figure 5: Throughput per user (Ped B, 3 km/h)

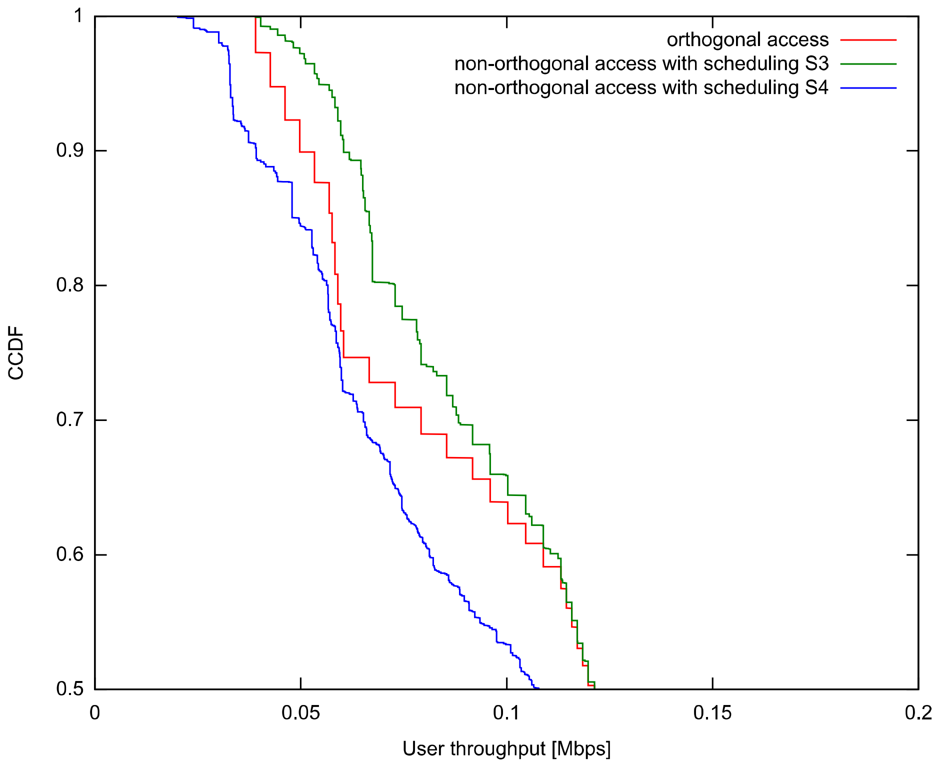

Figure 6: Detail of the throughput per user (Ped B, 3 km/h)