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Mobile WiMAX MIMO Performance Analysis: Downlink and Uplink

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Contents

- Introduction
- Mobile WiMAX PHY Description
- MIMO Wideband Channel Model
- MIMO Scenarios Description
- Simulation Performance Analysis
- Conclusions

Summary

- A fully compliant MIMO 802.16e Mobile WiMAX is implemented for both Downlink (DL) and Uplink (UL).
- A detailed study of the throughput benefits of MIMO when applied to mobile WiMAX is presented.
- Throughput results of SISO and MIMO are presented for both the DL and UL
- The switching point between two MIMO schemes are determined (Transmit diversity and Spatial multiplexing)

Introduction

- The first WiMAX systems were based on the IEEE 802.16-2004 standard, for fixed broadband wireless applications via the installation of Customer Premises Equipment (CPE)
- In Dec 2005 the IEEE completed the 802.16e – 2005 (Mobile WiMAX) which added mobility supported features.
- Limited system bandwidth and growing broadband service demand resulted in the application of MIMO in Mobile WiMAX

Mobile WiMAX PHY

- Mobile WiMAX builds on the principles of Scalable OFDMA (SOFDMA)
- SOFDMA supports a wide range of bandwidths (1.25, 5, 10, and 20 MHz) by varying the FFT size from 128 to 512, 1024 and 2048.
- FFT size increases when the operating bandwidth increases and maintains a fixed subcarrier spacing of 10.94 kHz, which ensures a fixed OFDMA symbol duration. Therefore the impact of bandwidth scaling is minimized to the upper layers.

Mobile WiMAX PHY Parameters

OFDMA PHY Parameters

Parameters	Values			
FFT size	128	512	1024	2048
Channel bandwidth (MHz)	1.25	5	10	20
Subcarrier frequency spacing (kHz)	10.94			
Useful symbol period (μ s)	91.4			
Guard time	1/32, 1/16, 1/8, 1/4			

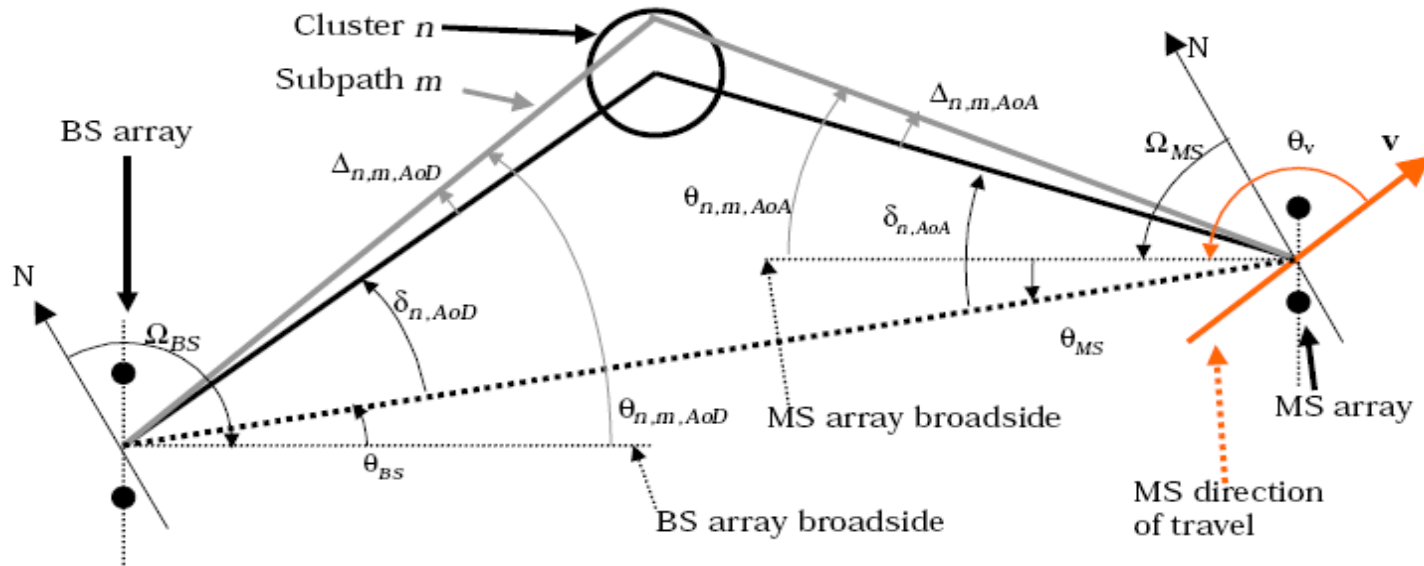
Mobile WiMAX PHY

Key simulation parameters

- Channel bandwidth: 5 MHz (FFT size 512)
- Subcarrier permutation mechanism: PUSC for both DL and UL, subcarriers are distributed throughout the spectrum, 24 subcarriers in a subchannel.
- Number of subchannels allocated to each user: 5 for DL and 4 for UL (this will affect the throughput)
- Channel coding: Convolution code 1/2, 2/3, 3/4
- Modulation: QPSK, 16QAM, 64QAM
- MIMO scheme: 2 x 2 Transmit diversity and spatial multiplexing
- MIMO channel: 3GPP Spatial Channel Model

MIMO Wideband Channel Model

3GPP Spatial channel model



The received signal at the MS consists of **6** time-delayed multipath replicas of the transmitted signal. Each path consists of **20** subpaths.

MIMO Wideband Channel Model

3GPP Spatial channel model

- Urban micro tap delay line (TDL) with 6 non-uniform delay taps
- MS velocity of 40 km/h
- Antenna element separation of half wavelength

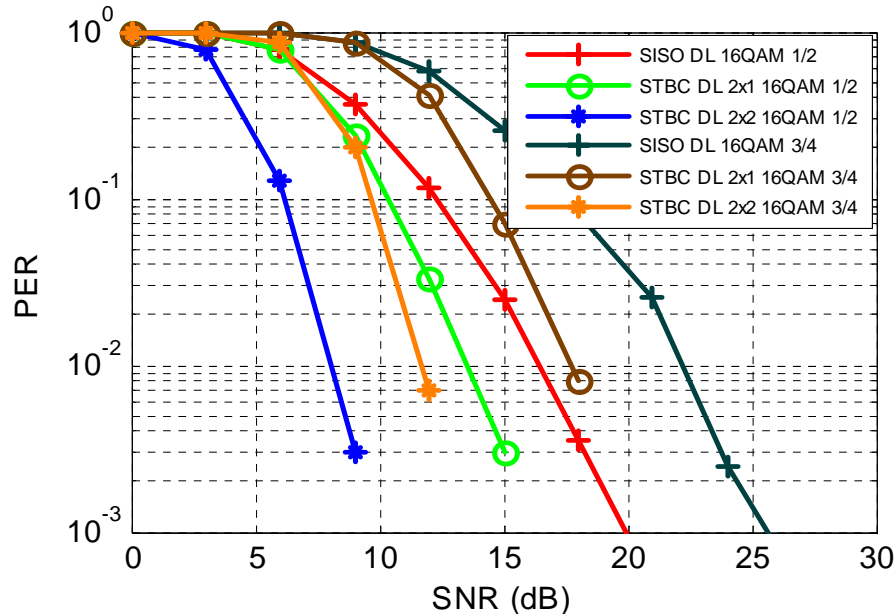
	Tap 1	Tap 2	Tap 3	Tap 4	Tap 5	Tap 6
Delay (ns)	0	210	470	760	845	910
Power (dB)	0	-1.8	-1.5	-7.2	-10	-13
K factor	0	0	0	0	0	0
Delay spread	279 ns					

SIMULATION PERFORMANCE ANALYSIS

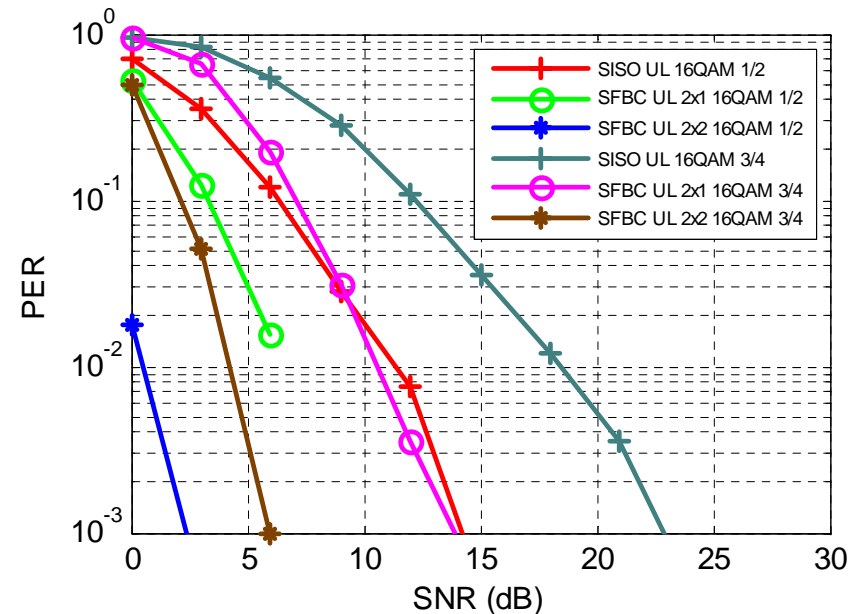
- SISO and MIMO PER and throughput performance are presented with the following assumptions:
 - The BS transmits data simultaneously to 3 MS, with each sharing a common OFDMA symbol. Each user access the subchannels allocated to him.
 - 3 MSs sharing an OFDMA symbol on the UL
 - Perfect channel estimation and synchronization at the receiver
 - For SM, MMSE receiver is used to remove the inter-stream interference on a per sub-carrier basis

SIMULATION PERFORMANCE ANALYSIS

MIMO PER analysis – 16QAM 1/2 and 3/4



DL PER SISO vs STBC comparison



UL PER SISO vs SFBC comparison

- PER is enhanced by 2 x 1 and 2 x 2 STBC DL and SFBC UL
- At the same PER of 10^{-2} , UL PER has a gain about 7.5dB compared to DL. This is called subchannelization gain since the same transmit power is spread over a smaller subset of subcarriers on the UL

Mobile WiMAX PHY Description

MIMO Throughput analysis

The link throughput for each user is calculated from the PER:

$$R = D(1 - \text{PER})$$

where D represents the peak transmission rate calculated as below:

$$D = N_D N_b R_{FEC} R_{STC} / T_s$$

N_D : number of assigned subcarrier to each user

N_b : bits per subcarrier (depend on modulation scheme: 2, 4, 6)

R_{FEC} : FEC coding rate (1/2, 2/3, 3/4)

R_{STC} : Space-time coding rate (1 for transmit diversity, 2 for SM)

T_s : OFDMA symbol duration

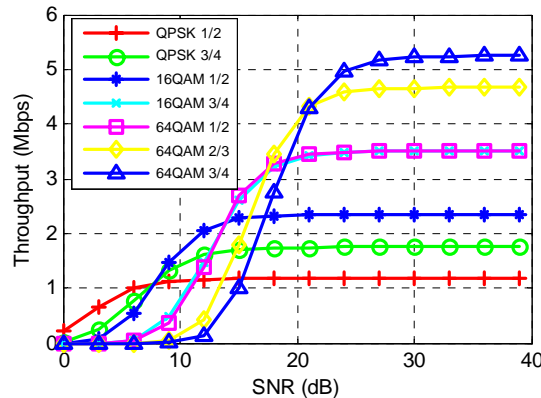
Mobile WiMAX PHY Description

MIMO Throughput analysis

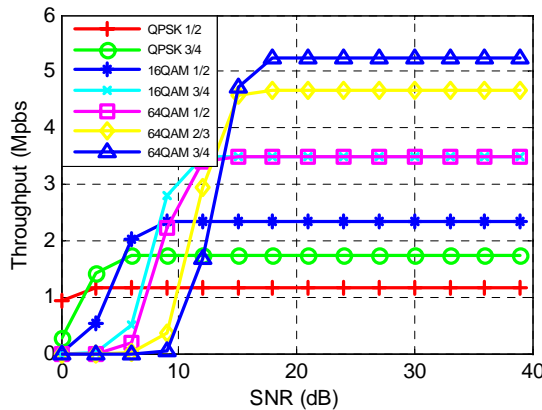
Mode (Link-Speed)	No. of coded bits per subchannel DL/UL	No. of data bits per subchannel DL/UL	STBC 2x2 DL/UL bit rate/user (Mbps)	SM 2x2 DL/UL bit rate/user (Mbps)
QPSK 1/2	48/32	24/16	1.17/0.62	2.34/1.24
QPSK 3/4	48/32	36/24	1.75/0.93	3.5/1.86
16 QAM 1/2	96/64	48/32	2.33/1.24	4.66/2.49
16 QAM 3/4	96/64	72/48	3.50/1.87	7/3.73
64 QAM 1/2	144/96	72/48	3.50/1.87	7/3.73
64 QAM 2/3	144/96	96/64	4.66/2.49	9.33/4.98
64 QAM 3/4	144/96	108/72	5.25/2.80	10.50/5.60

SIMULATION PERFORMANCE ANALYSIS

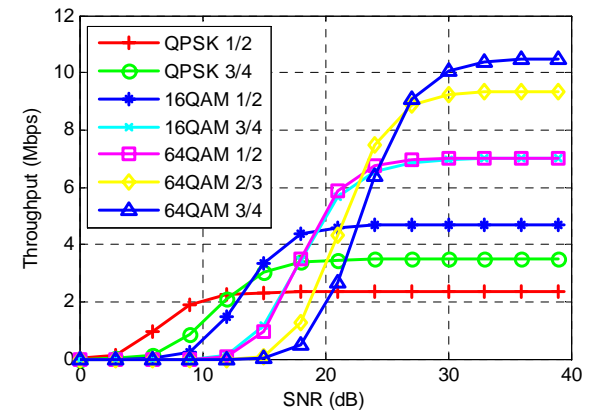
MIMO Throughput analysis (DL)



SISO DL Throughput



STBC 2x2 DL Throughput

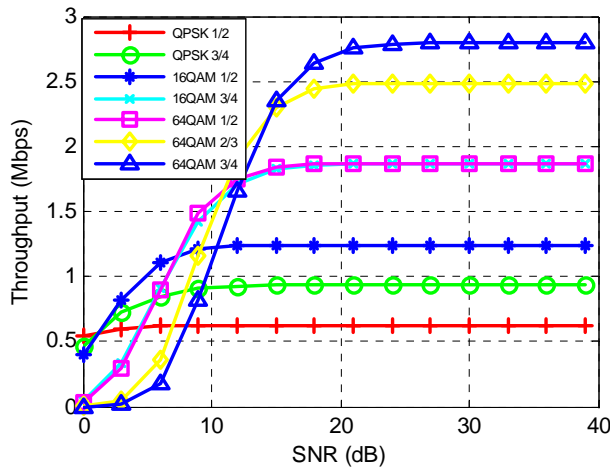


SM 2x2 DL Throughput

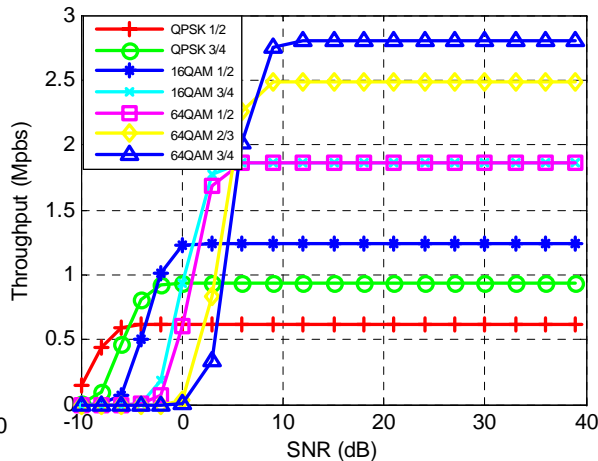
- STBC offers a significant performance gain of 3–9 dB over SISO for the same achieved throughput, depend on the selected link-speed
- SM 2x2 mode doubles the peak error-free throughput of every link-speed

SIMULATION PERFORMANCE ANALYSIS

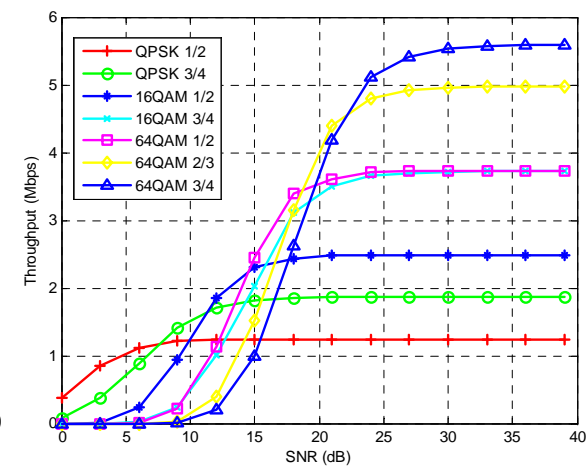
MIMO Throughput analysis (UL)



SISO UL Throughput



SFBC 2x2 UL Throughput

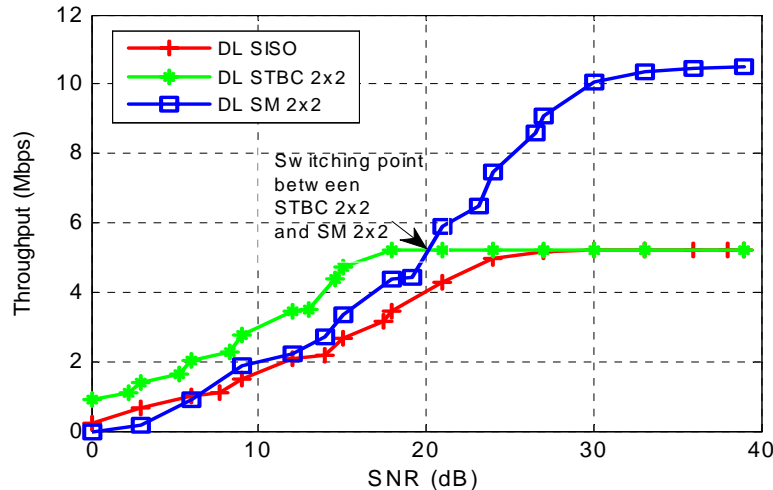


SM 2x2 UL Throughput

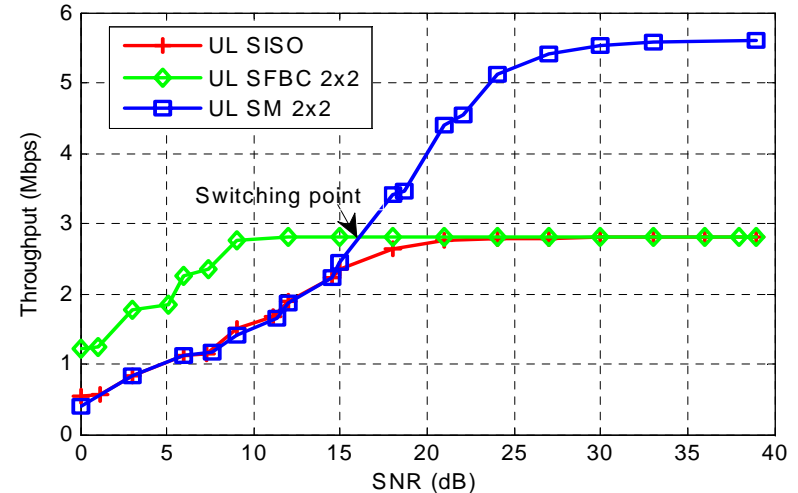
- We observe the same trend as in the DL case, SFBC offers the same throughput with much lower SNR, and SM double the peak throughput of every link-speed

SIMULATION PERFORMANCE ANALYSIS

MIMO Throughput analysis



Throughput Envelope vs SNR for
DL SISO, 2x2 STBC and 2x2 SM



Throughput Envelope vs SNR for
UL SISO, 2x2 SFBC and 2x2 SM

- The envelope was generated using adaptive modulation and coding (AMC) to increase and/or decrease the link-speed to maximise the throughput for any value of SNR
- STBC produces the best performance at low to medium values of SNR, at high SNR the increased error-free data rate makes SM the best choice
- Mobile WiMAX supports Adaptive MIMO Switching (AMS) to select the best MIMO scheme
- The switching point between DL STBC and SM is 20 dB, and UL SFBC and SM is 16 dB

Conclusion

- A detailed study of the throughput benefits of MIMO when applied to mobile WiMAX was presented for both UL and DL. In both cases, at lower values of SNR STBC (DL) and SFBC (UL) are preferred. However, at high SNR AMS should be used to switch to SM.
- The switching point for DL MIMO is 20 dB, and for UL MIMO is 16 dB
- Future work should take into account the spatial correlation because it will move the switching point.

THANK YOU