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Mobile WiMAX: Downlink Performance Analysis with Adaptive MIMO Switching

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Introduction

- Mobile WiMAX supports a number of MIMO techniques. These include space time block coding (STBC), spatial multiplexing (SM) and eigen-beamforming (EBF)
- This paper investigates the MIMO Mobile WiMAX downlink performance in terms of PER, throughput, and operating range
- Adaptive MIMO Switching (AMS) is used to determine the most appropriate MIMO technique based on range, throughput, and PER
- Performance results are presented for both spatially uncorrelated and correlated channels

Mobile WiMAX Description (1)

- Mobile WiMAX builds on the principles of Scalable OFDMA
- 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

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

OFDMA PHY Parameters

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Mobile WiMAX PHY Description (2)

- Channel bandwidth: 5 MHz (FFT size 512)
- Distributed subcarrier allocation (PUSC)
- There are 3 users, each allocated one third of the total bandwidth
- Channel coding: Convolution code 1/2, 2/3 and 3/4 rate
- Modulation: QPSK, 16QAM, 64QAM
- Channel: 3GPP Spatial Channel Model
- MIMO schemes: 2 x 2 Space Time Block Coding (STBC), Spatial Multiplexing (SM), and eigen-beamforming (EBF)

MIMO Implementation

- Open-loop techniques do not require Channel State Information (CSI) at the Tx:
  1. *MxN* Space Time Block Coding (STBC) – standard technique used to improve robustness
  2. *MxN* Spatial Multiplexing (SM) – standard technique used to increase throughput (requires equaliser at RX)
- Closed-loop techniques use CSI at the Tx to create min(*M*,*N*) independent parallel 'eigen-channels':
  3. *MxN* Dominant eigen-beamforming (SVD DE) – uses 'dominant eigen-channel' to improve robustness
  4. *MxN* SM eigen-beamforming (SVD SM) – uses all 'eigen-channels' to increase throughput

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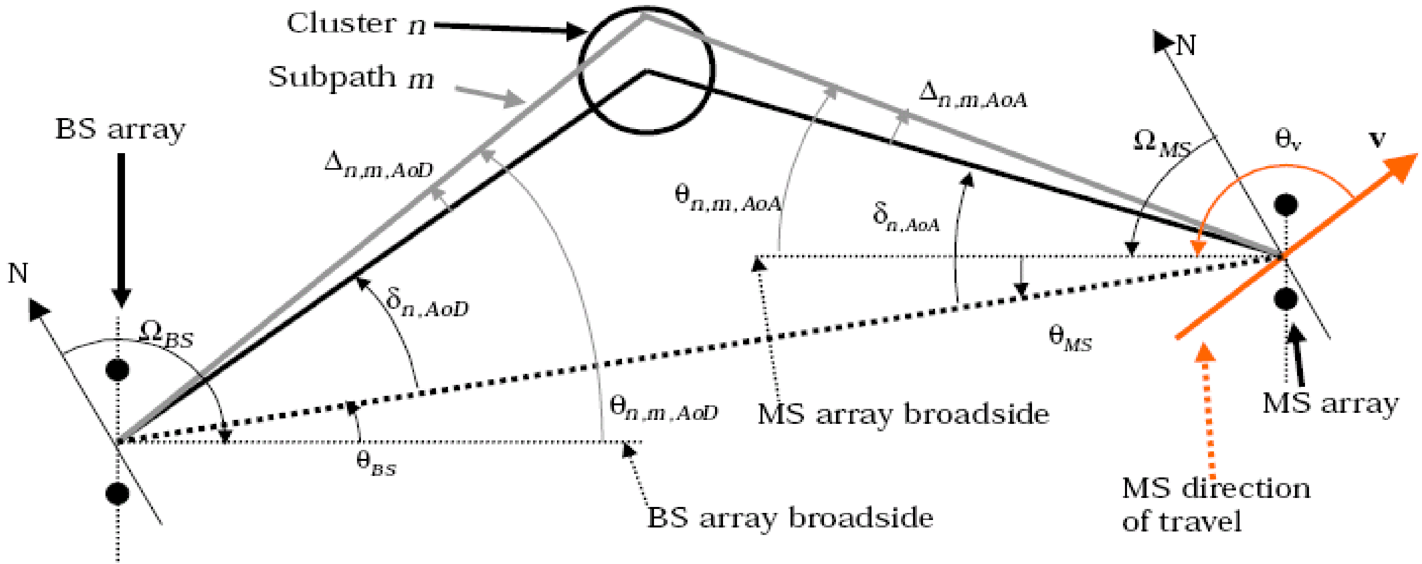
MIMO Wideband Channel Model: 3GPP Spatial Channel Model (SCM)



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

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MIMO Wideband Channel Model: Channel assumptions

- Urban micro tap delay line (TDL) with 6 non-uniform delay taps
- MS velocity of 40 km/h
- Omni antenna elements separation at half a 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					

MIMO wideband channel model parameters

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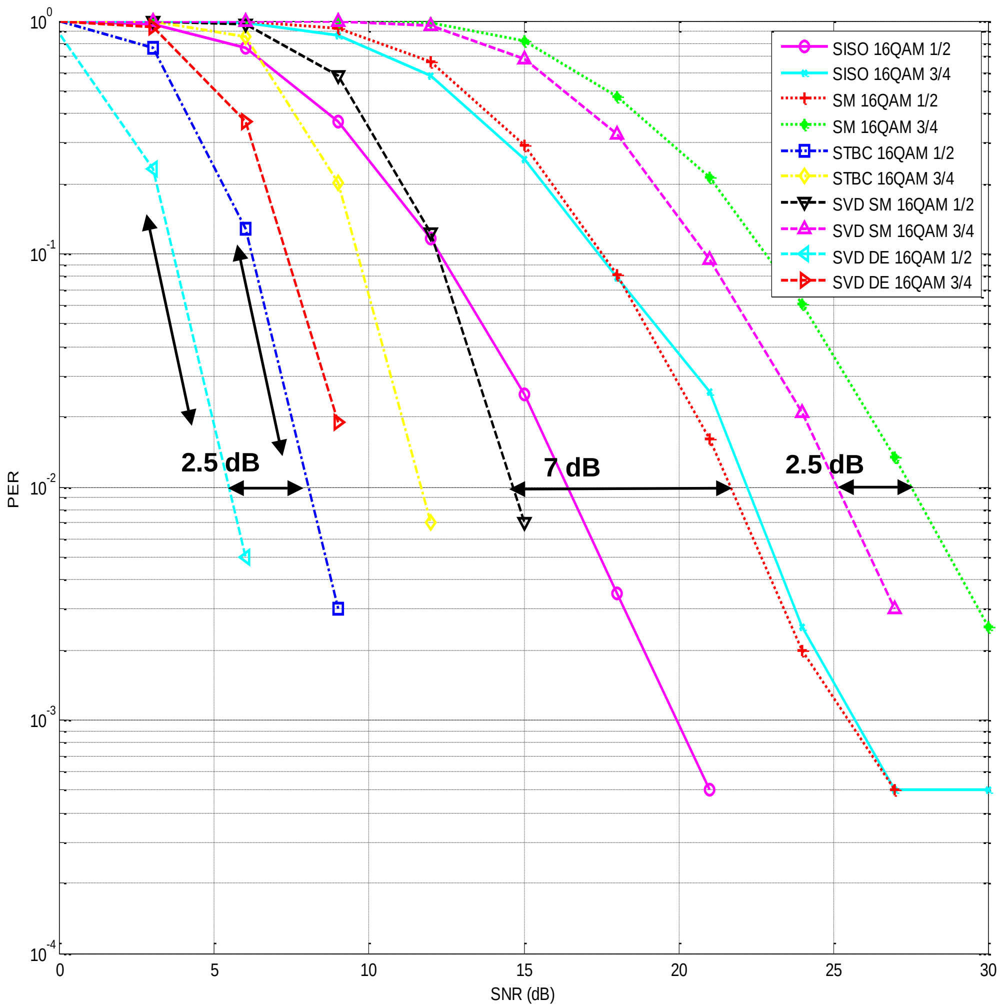
Simulation Performance Analysis

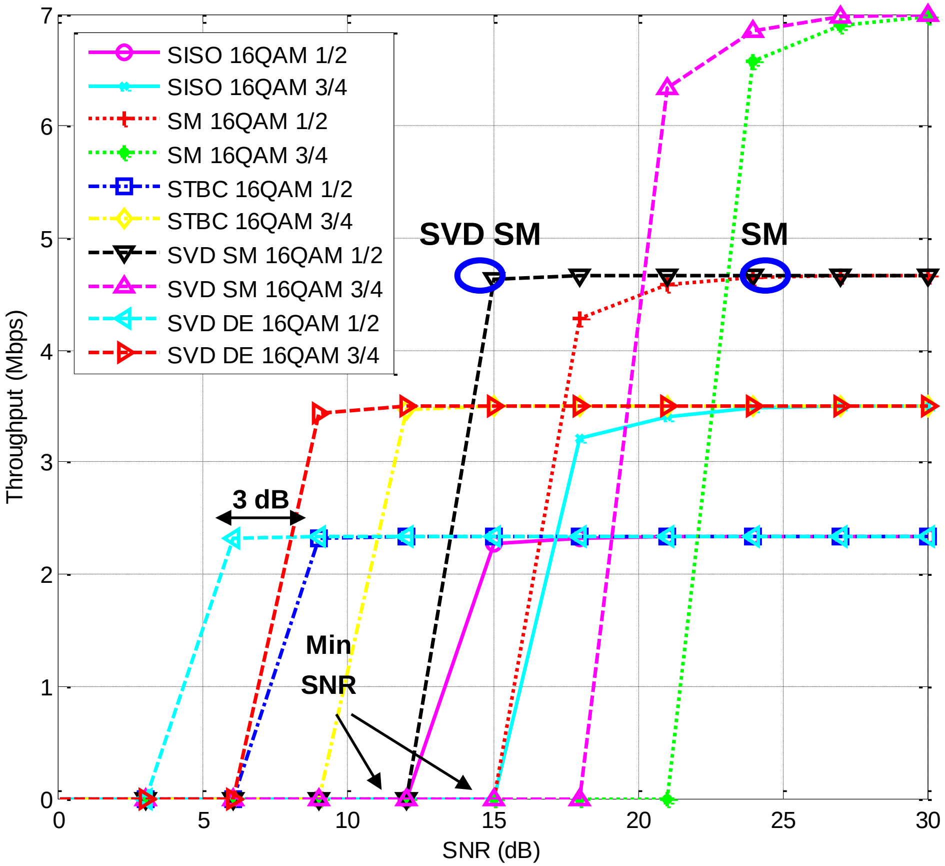
- Our paper analyses (for both high and low spatial correlation):
  - PER vs. SNR for different MIMO schemes
  - Throughput vs. SNR for different MIMO schemes
  - Throughput vs. operating range for different MIMO schemes (using WI with P_T=43dBm and G_T=15dBi)
  - The Adaptive MIMO Switching (AMS) algorithm decision points (i.e. SNR and BS-MS distance thresholds)

PER vs. SNR for various MIMO schemes (low ρ)



- SVD SM outperforms open-loop SM, at 10^{-2} PER:
  - For 16QAM ½ the gain is 7dB
  - For 16QAM ¾, the gain is only 2.5dB (much less diversity gain than ½ rate)
- SVD DE outperforms STBC, at 10^{-2} PER:
  - For 16QAM ½ there is an array gain of 2.5 dB
  - Both schemes achieve a diversity order of 4

Tput vs. SNR for different MIMO schemes (low ρ)



- Throughput is calculated based on a 10% PER threshold
- For 16QAM ½, SVD DE requires 3dB less than STBC for same Tput
- For 16QAM ½ SVD SM requires 3dB less SNR to operate compared to open-loop SM
- For 16QAM ½, SVD SM can double the SISO Tput at 15dB SNR
- Open-loop SM requires 25dB SNR to achieve this

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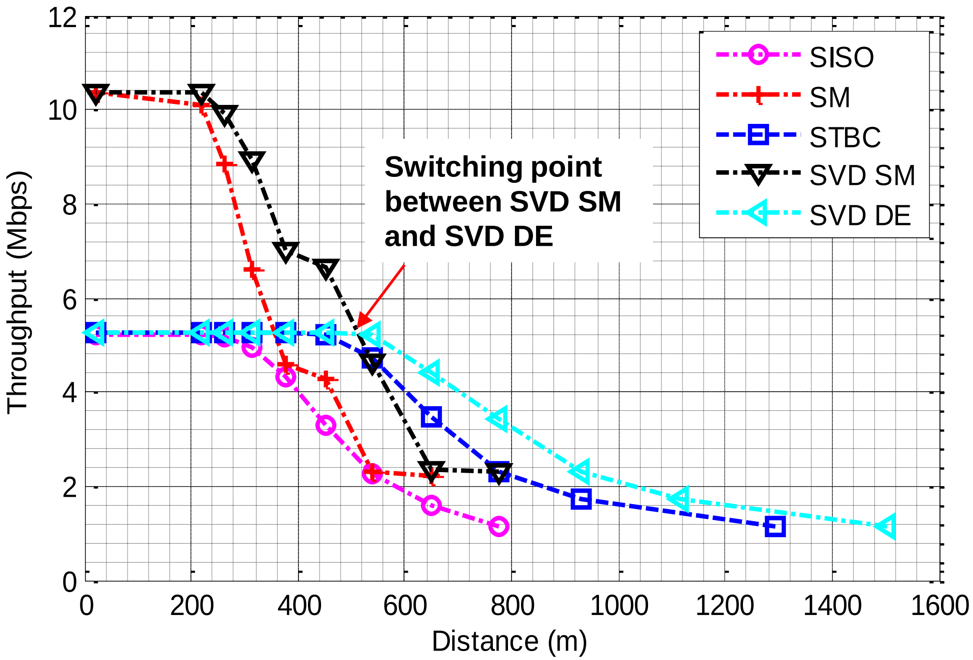
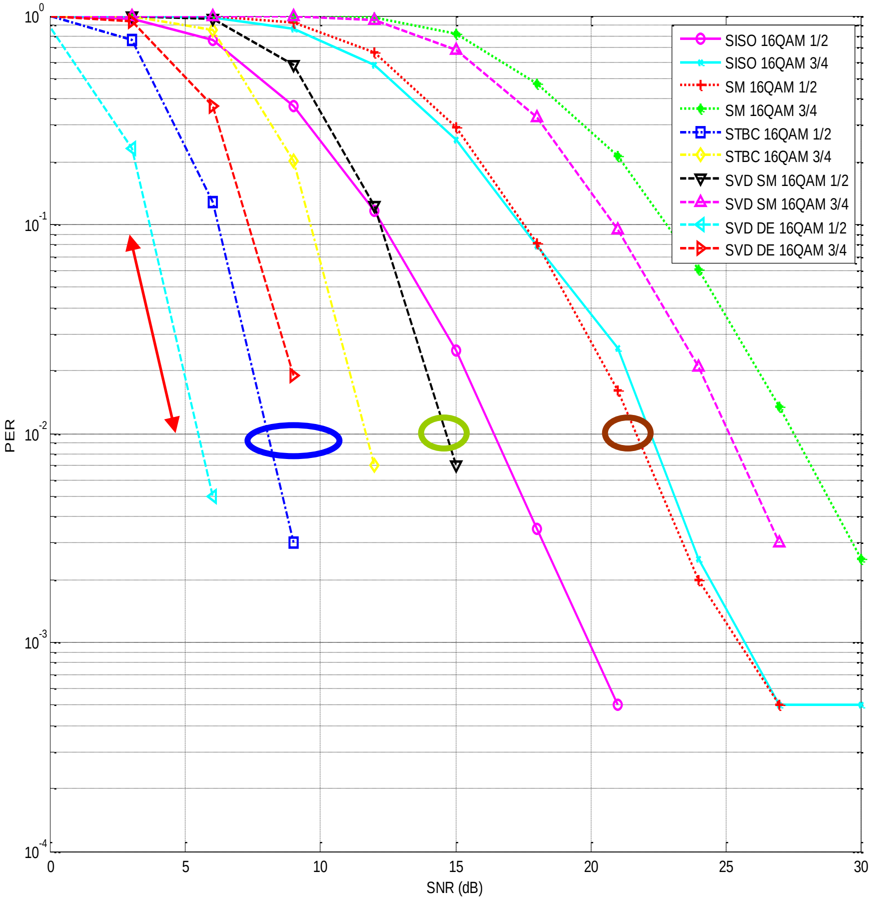
Tput vs. distance, low channel correlation (ρ)

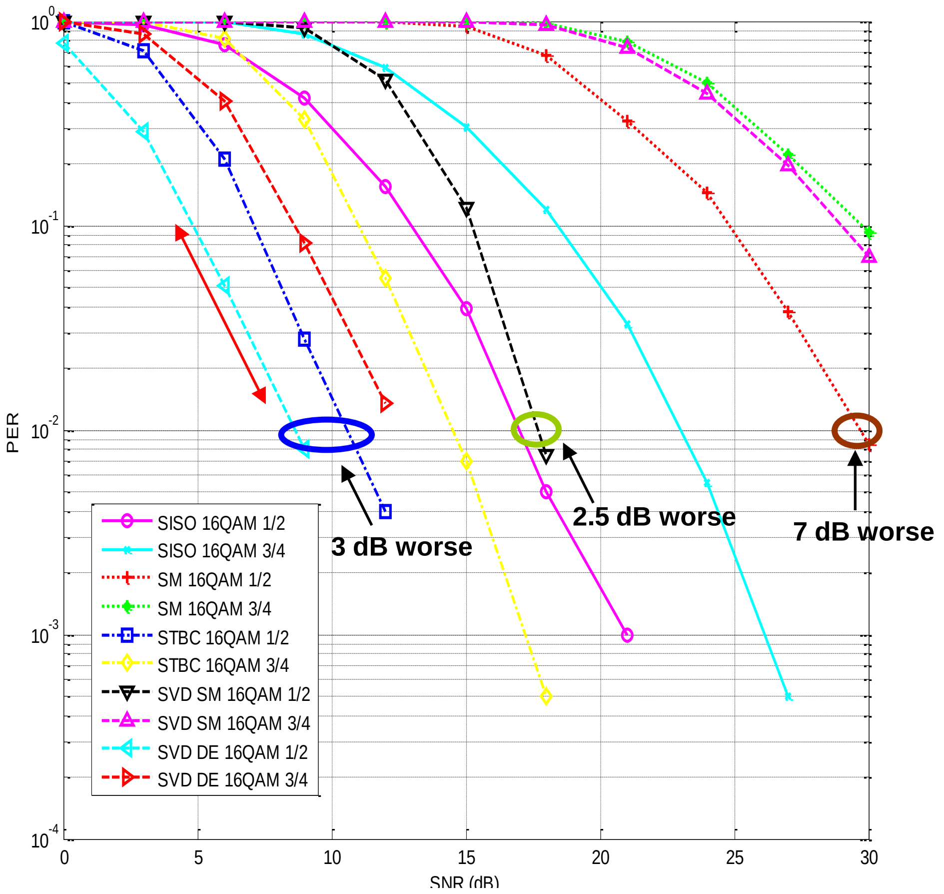


- Individual envelopes generated using Adaptive Modulation and Coding
- Adaptive MIMO Switching is used to select the optimal MIMO mode
- SVD SM is optimum < 520 m, SVD DE is optimum > 520m
- Open-loop MIMO modes not selected (assumes ideal channel feedback)

PER vs. SNR for different correlations (ρ)

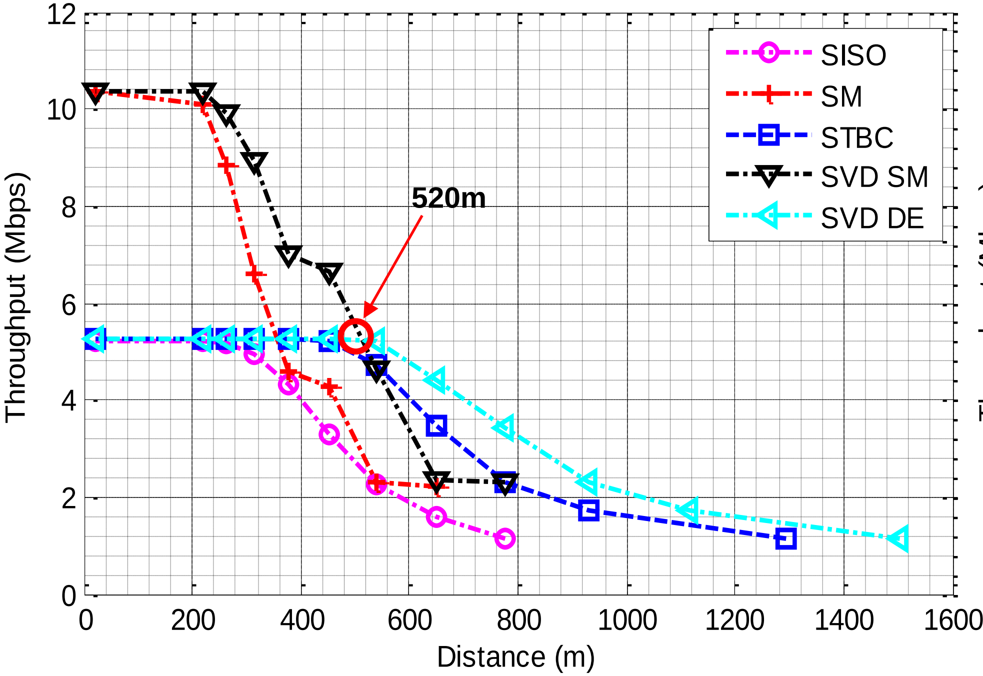


MIMO uncorrelated channel (ρ=0.16)

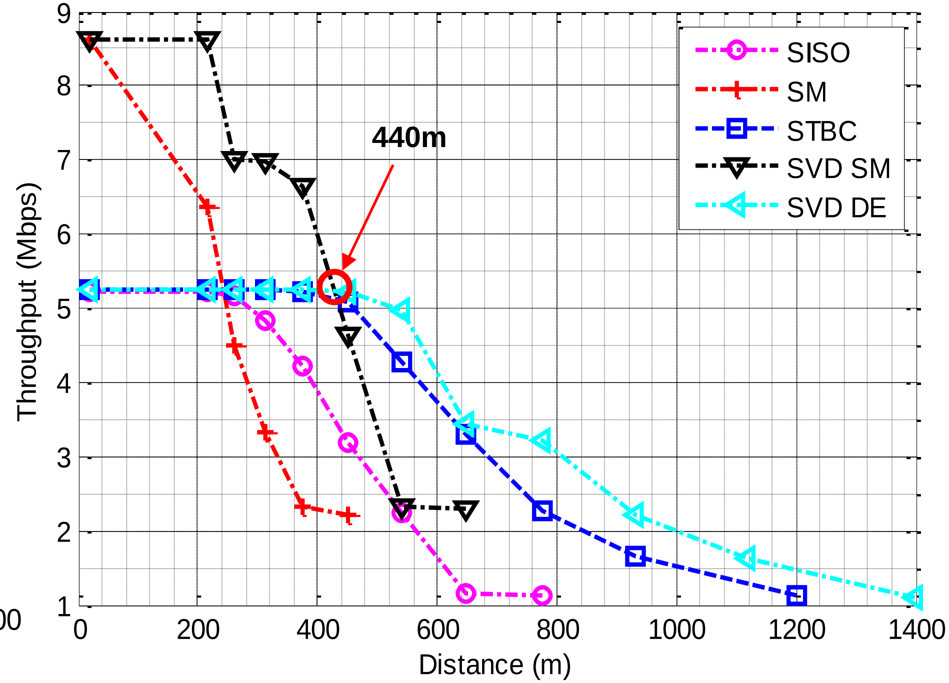


MIMO correlated channel (ρ=0.8)

Switching point comparison for different ρ



MIMO uncorrelated channel (ρ=0.16)



MIMO correlated channel (ρ=0.8)

- The switching point in the highly correlated MIMO channel is reduced from 520m to 440m

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Operating range comparison

MIMO Scheme	ρ=0.16		ρ=0.8	
	d_{max} (m)	*SNR (dB)*	d_{max} (m)	*SNR (dB)*
SISO	780	9	780	9
SM	640	12	450	18
STBC	1295	0.57	1201	1.82
SVD SM	780	9	650	12
SVD DE	1504	-1.89	1399	-0.71

Operating range comparison for different MIMO modes and correlations

- Both eigen-beamforming solutions improve the maximum range
- Relative to STBC, the range of SVD DE is improved by 210m (16%)

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Conclusions

- The PER, throughput and operating range of both open and closed-loop MIMO Mobile WiMAX scenarios was analysed for two levels of channel correlation

1. Simulations show that an ideal AMS algorithm will always choose the closed-loop techniques (perfect CSI) over the open-loop ones
   - At low SNR, SVD DE is the most robust MIMO mode
   - At high SNR, AMS should be used to switch to SVD SM to maximise throughput
2. The AMS switching point depends on channel correlation
3. In practise: feedback overhead, imperfect CSI, and delayed CSI will reduce the overall Tput making open-loop techniques preferable in certain circumstances

Any Questions?

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