Mobile WiMAX: MIMO Performance Analysis from a Quality of Service (QoS) Viewpoint

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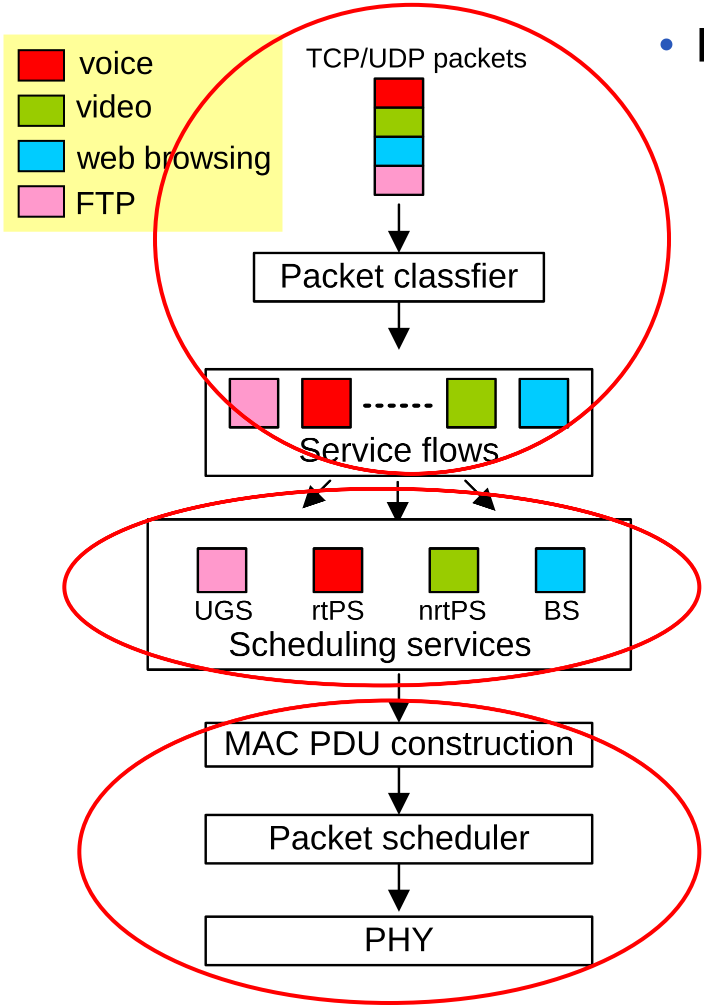
Introduction and Objectives

- Mobile WiMAX supports a wide range of applications with different QoS requirements
- TCP-based applications (e.g., web browsing) can tolerate a relatively high PHY PER due to the use of Automatic-Repeat-reQuest (ARQ) to resend lost packets
- In contrast, UDP-based applications (e.g., real-time video) can not afford the latency induced by ARQ and thus require a very low PER
- This paper analyses how the *difference* in required PHY PER results in *differences* in the achievable throughput and operating range for a mobile WiMAX system

Mobile WiMAX Description: Medium Access Control (MAC) layer



- In the mobile WiMAX MAC:
  - Higher layer packets from a range of applications (i.e. voice, video and web browsing) are classified into unique service flows
  - Each service flow is associated with a unique set of QoS parameters: latency, throughput, max ARQ etc.
  - Service flows are mapped to different scheduling services: Unsolicited Grant Service (UGS), real-time Polling Service (rtPS), non real-time Polling Service (nrtPS) and Best Effort (BE)
  - Each MS can support multiple applications over multiple logical connections, each with different QoS

Mobile WiMAX Description: Physical (PHY) Layer

- 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

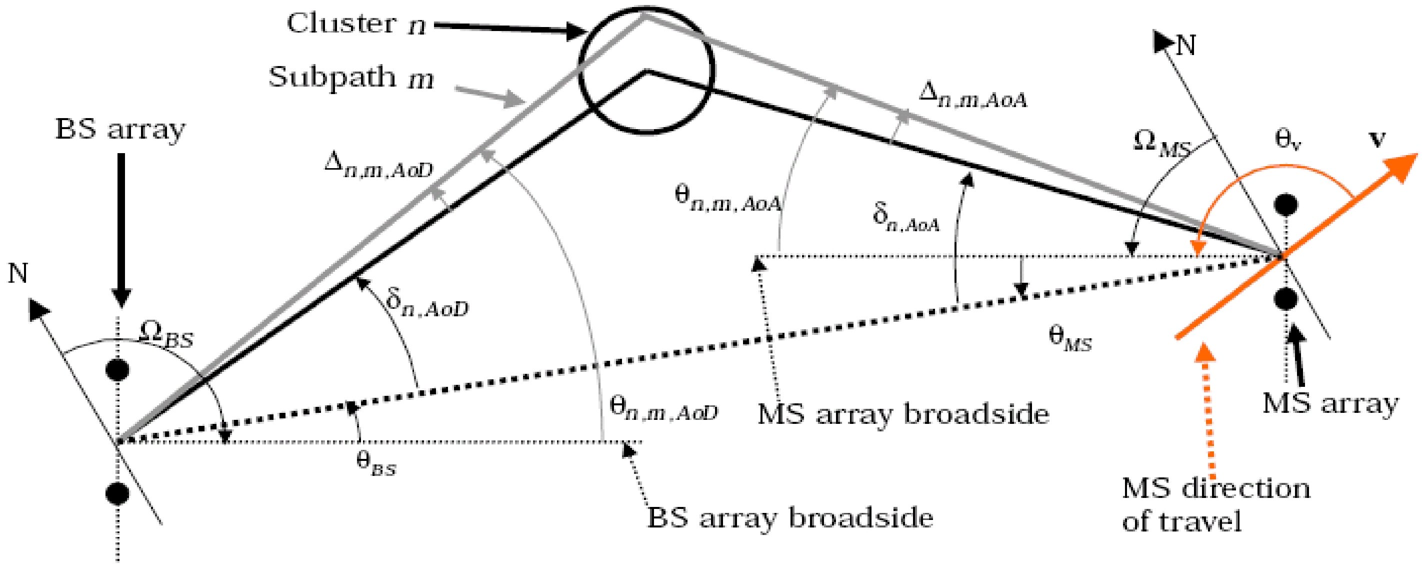
Mobile WiMAX PHY Description
Key simulation parameters

- 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 scheme: 2 x 2 Space Time Block Coding (STBC), Spatial Multiplexing (SM), and Eigen Beamforming

Considered MIMO Techniques

- Open-loop MIMO
  - Space-Time Block Coding: Alamouti scheme
  - Spatial Multiplexing: 2 x 2 SM with MMSE reception
- Closed-loop MIMO – Eigen Beamforming
  - Eigen beamforming uses Singular Value Decomposition (SVD) to transform a MIMO channel into *N* equivalent SISO Eigen-channels
  - Diversity can be achieved by transmitting data over the strongest Eigen-channel: Dominant Eigen beamforming (SVD DE)
  - Spatial multiplexing can be achieved by transmitting data over parallel Eigen-channels: SVD SM

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

MIMO Wideband Channel Model: Channel assumptions

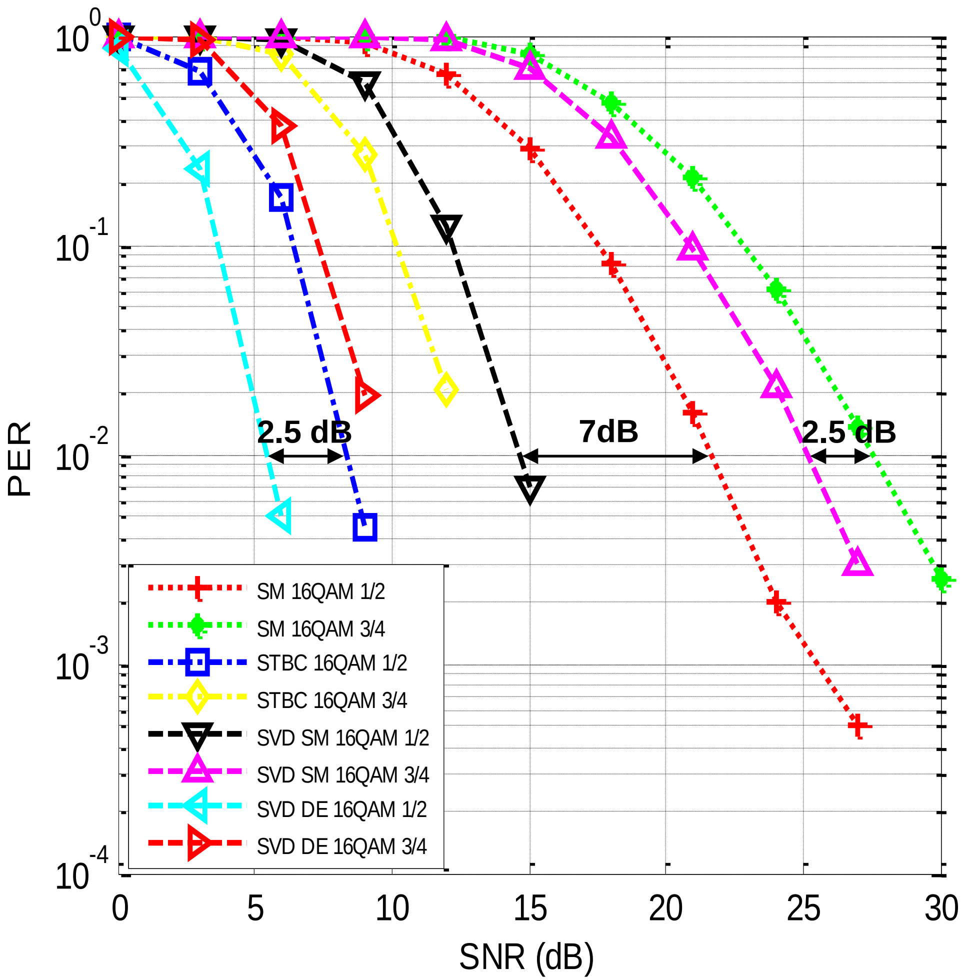
- Urban micro tap delay line (TDL) with 6 non-uniform delay taps
- MS velocity of 40 km/h
- Omni antenna elements separation at half a wavelength

	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					

Simulation Performance Analysis

- The paper analyses:
  - PER for different MIMO schemes
  - Achievable throughput for TCP and UDP-based applications
  - Achievable operating range for TCP and UDP-based applications
  - SNR thresholds used in the AMC scheme for TCP and UPD-based applications

Simulation Performance Analysis: PER versus SNR for different MIMO techniques



- SVD SM offers a large improvement compared with SM
- For 16QAM 1/2 and 3/4 rate, at 10^{-2} PER, the gain is 7dB and 2.5 dB, respectively. Note there is little diversity gain for the 3/4 code rate
- SVD DE outperforms STBC. For 16QAM 1/2, at 10^{-2} PER, there is an array gain of 2.5 dB. No diversity gain is achieved when compared with STBC

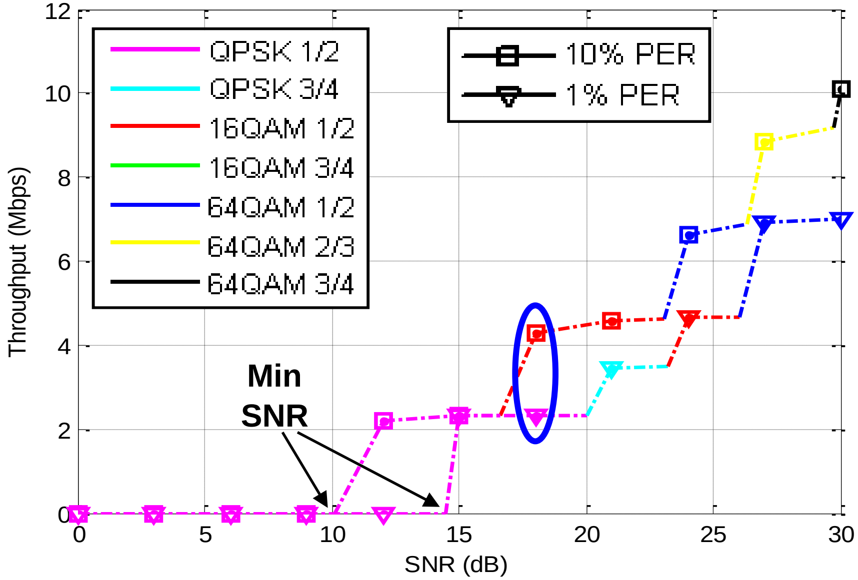
Simulation Performance Analysis: Throughput and operating range analysis

- Different PER thresholds are used to determine the achievable throughputs and operating range for TCP and UDP applications
- 10% PER is considered the highest acceptable for TCP applications (web browsing and FTP); any PER in excess of this value is assumed too severe to maintain a practical data link
- For UDP applications (real time voice and video) a PER threshold of 1% is assumed

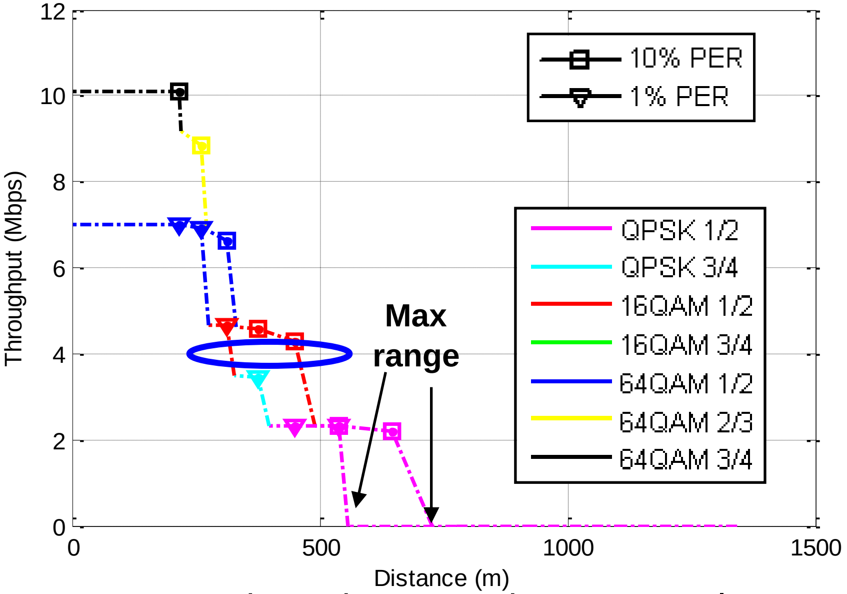
voice, video } 1% PER (UDP)

web browsing, FTP } 10% PER (TCP)

Simulation Performance Analysis:
Throughput and operating range analysis – SM 2x2



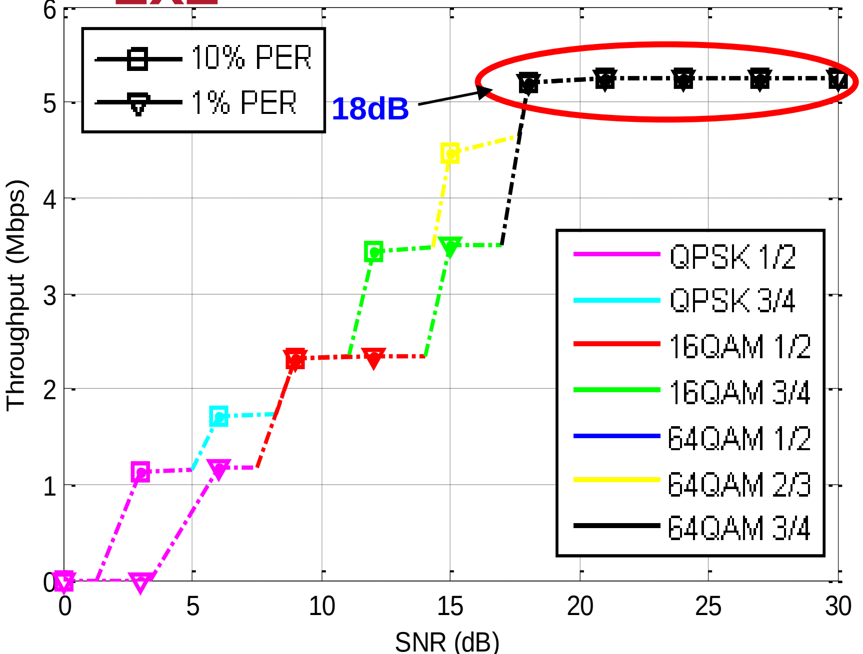
SM 2x2 Throughput vs. SNR envelope



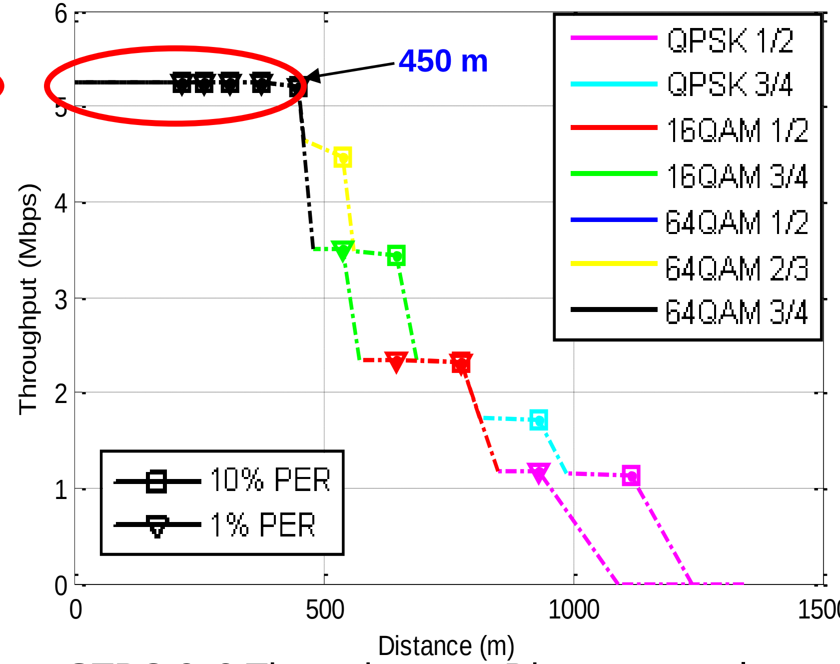
SM 2x2 Throughput vs. Distance envelope

- AMC used to adjust the link-speed depending on received SNR and threshold PER
- Compared with the 1% PER case, the 10% case:
  - achieves: - a higher throughput - a higher operating range
  - requires lower minimum SNR to operate
  - achieves a higher maximum achievable range

Simulation Performance Analysis: Throughput and operating range analysis – STBC 2x2



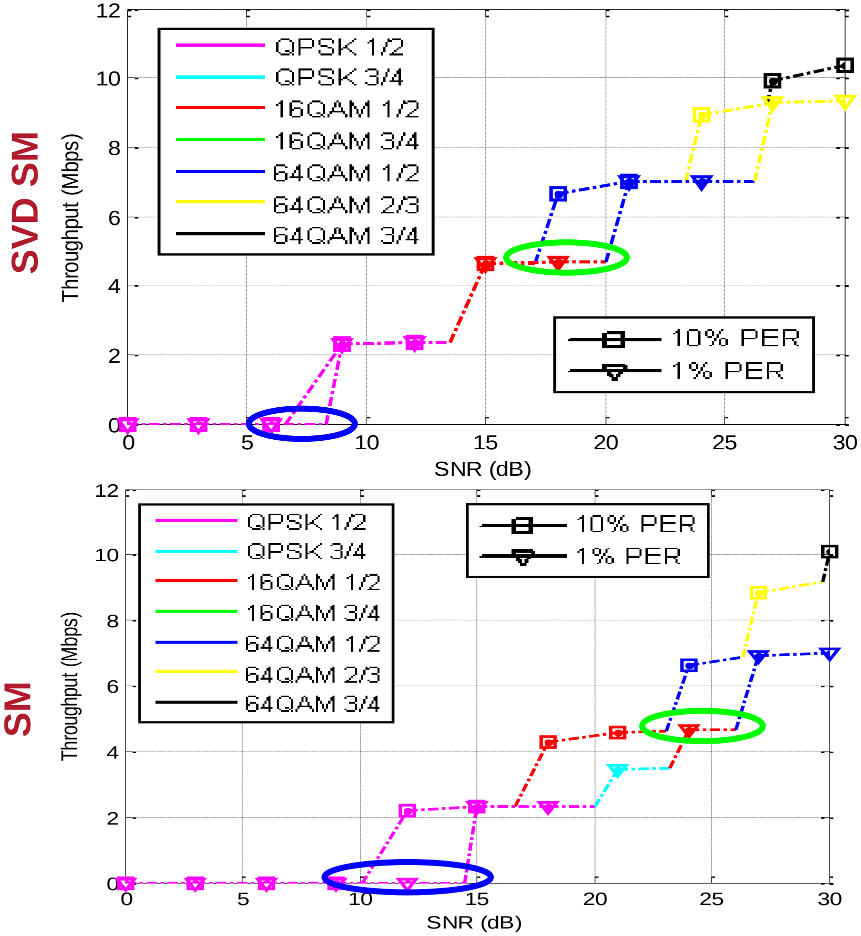
STBC 2x2 Throughput vs. SNR envelope



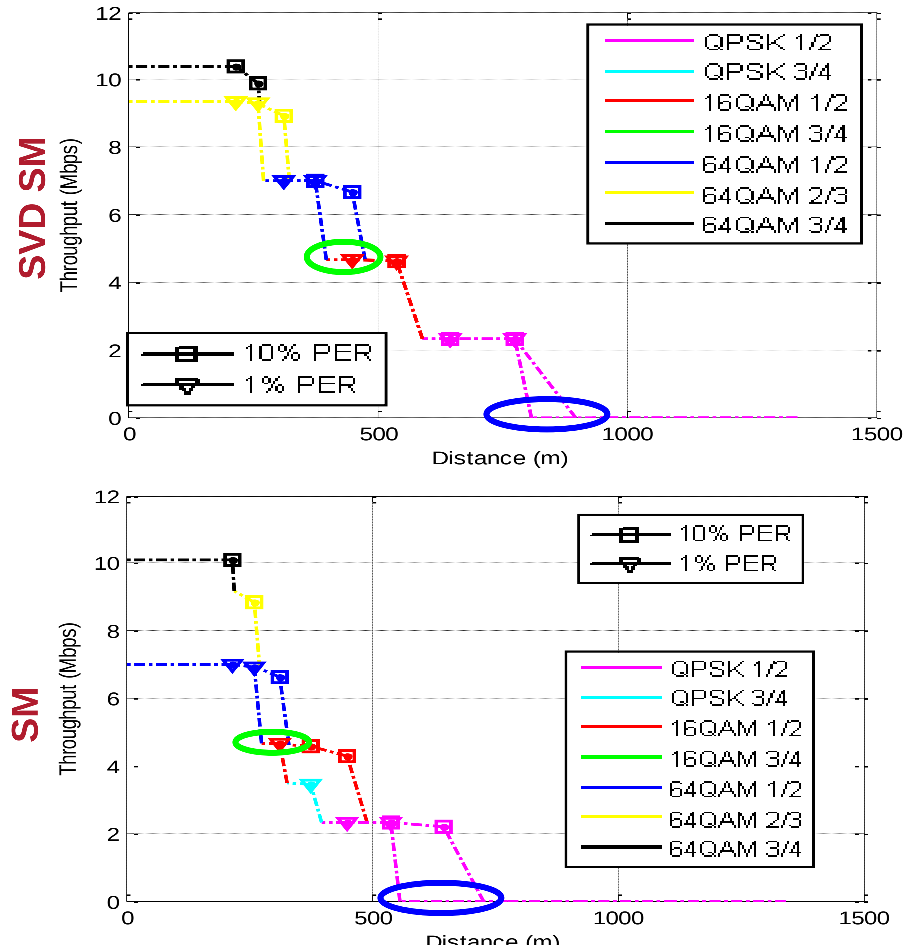
STBC 2x2 Throughput vs. Distance envelope

- At SNR < 18dB or distance > 450m, we observe the same trend as in SM 2x2
- At SNR > 18dB, or distance < 450m, both PER thresholds achieve the same max throughput. The reason is that STBC allows both types of applications to run at the highest MCS mode (64QAM 3/4 rate) and still guarantee the PER threshold

Simulation Performance Analysis:
Throughput and operating range analysis – SVD SM

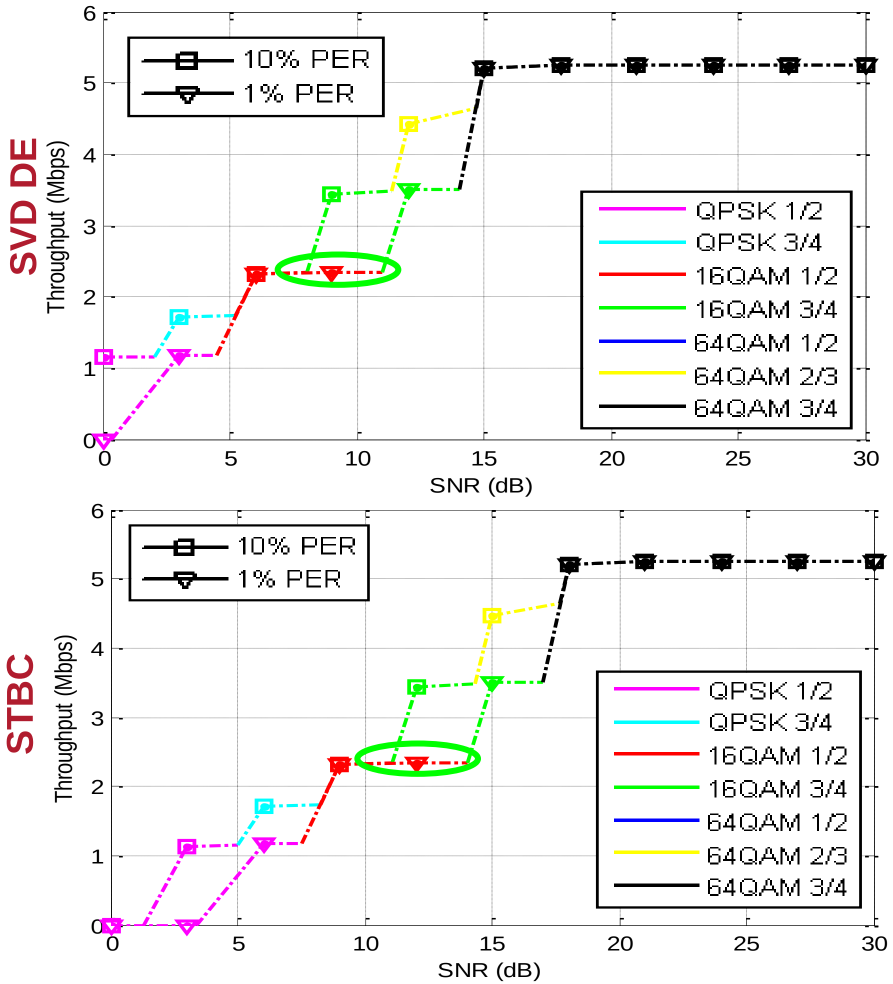


SM and SVD SM 2x2 Throughput vs. SNR envelope

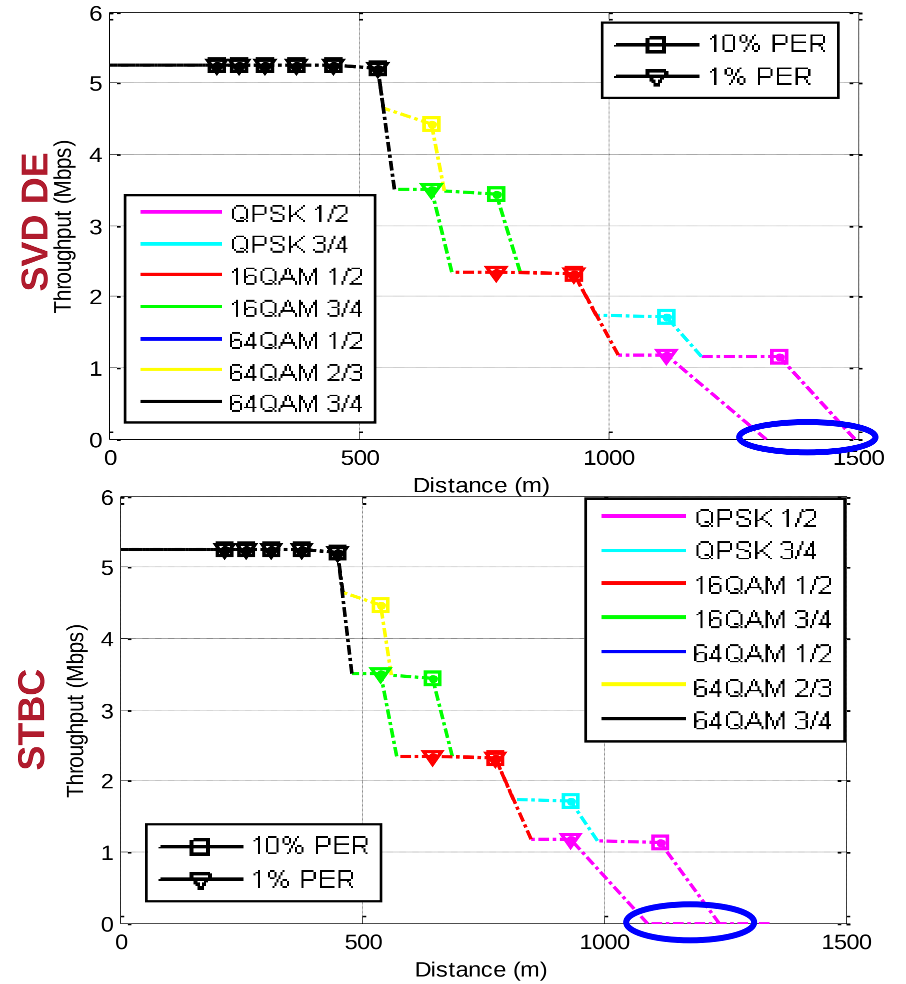


SM and SVD SM 2x2 Throughput vs. distance envelope

Simulation Performance Analysis: Throughput and operating range analysis – SVD DE



STBC and SVD DE 2x2 Throughput vs. SNR envelope



STBC and SVD DE 2x2 Throughput vs. distance envelope

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Conclusion

- A detailed study of the throughput and operating range of MIMO enabled mobile WiMAX was presented for two different PHY PER QoS thresholds
- The results show that TCP applications achieve a *higher* throughput and a *longer* operating range when compared with UDP applications. This means that voice and video applications will fail before web browsing and FTP applications
- UDP applications require *higher* SNR in order to switch to the *same* link speed as TCP applications. This demonstrates the importance of cross-layer interaction when determining the AMC switching points: the system needs to know the SNR from the PHY layer *and* the QoS from the higher layers in order to select the optimum link speed

THANK YOU

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