Performance Analysis of MIMO-OFDM Systems using Indoor Wideband MIMO Channel Measurement Data

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- Purpose
- Propagation Measurement
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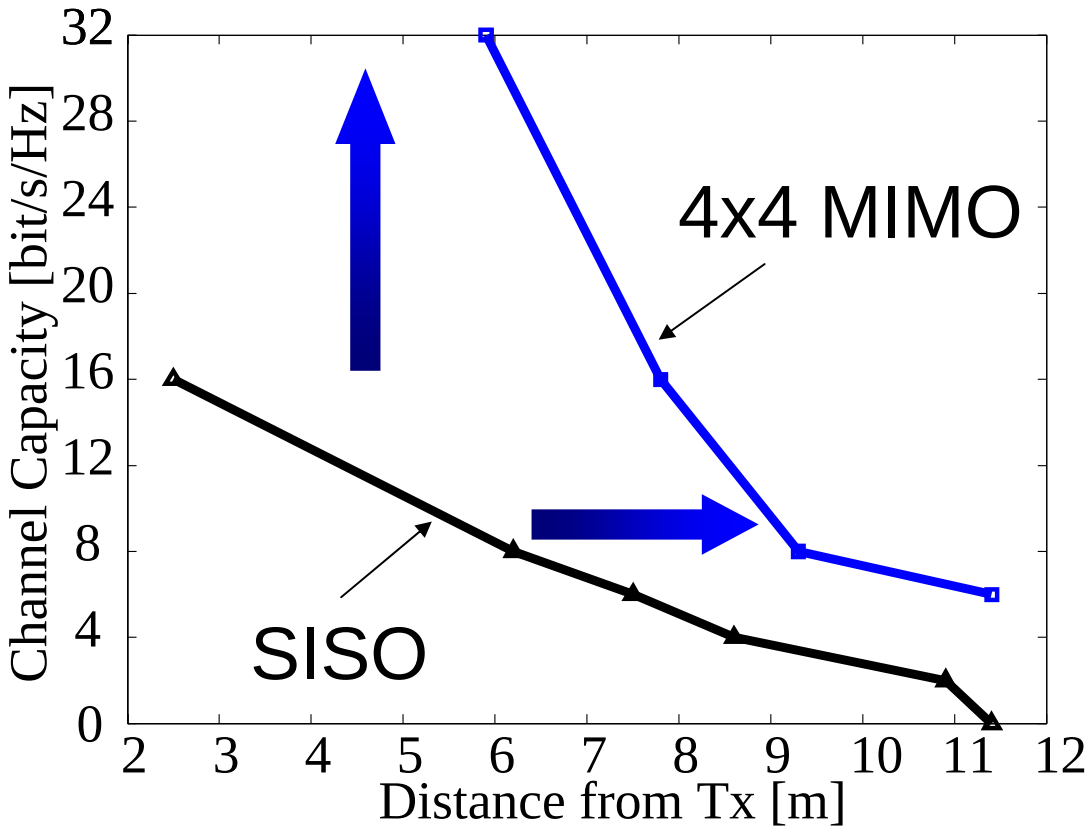
- Analysis Results
- Conclusion

Background

MIMO-OFDM Channel Capacity Measurement in Residential Environment

Measurement Environment



Benefit of MIMO

- **Increase channel capacity**
- **Area coverage expansion**
- **Performance improvement**

Source：D. N. Dung et al, ``Measurements on area coverage of 5GHz band MIMO-OFDM system in residential home environment,” The 16th PIMRC, Sep. 2005.

Purpose

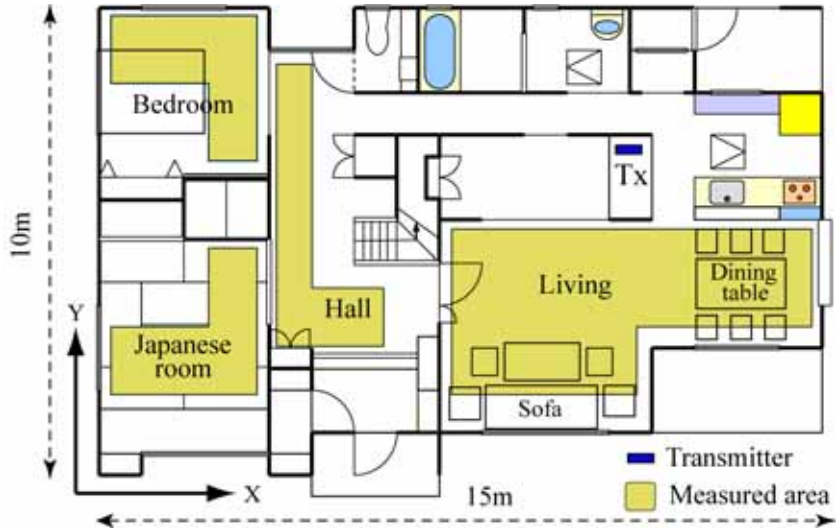
MIMO Scheme

- **Linear Detection**
  - **MMSE: Minimum Mean Square Error**
- **Non-linear Detection**
  - **VBLAST: Vertical Bell Labs Layered Space-Time**
  - **QRM-MLD: Maximum Likelihood Detection based on QR Decomposition and M-algorithm**
- **Beam-forming**
  - **SVD-MIMO: Singular Value Decomposition based MIMO**

Measurement data are used to

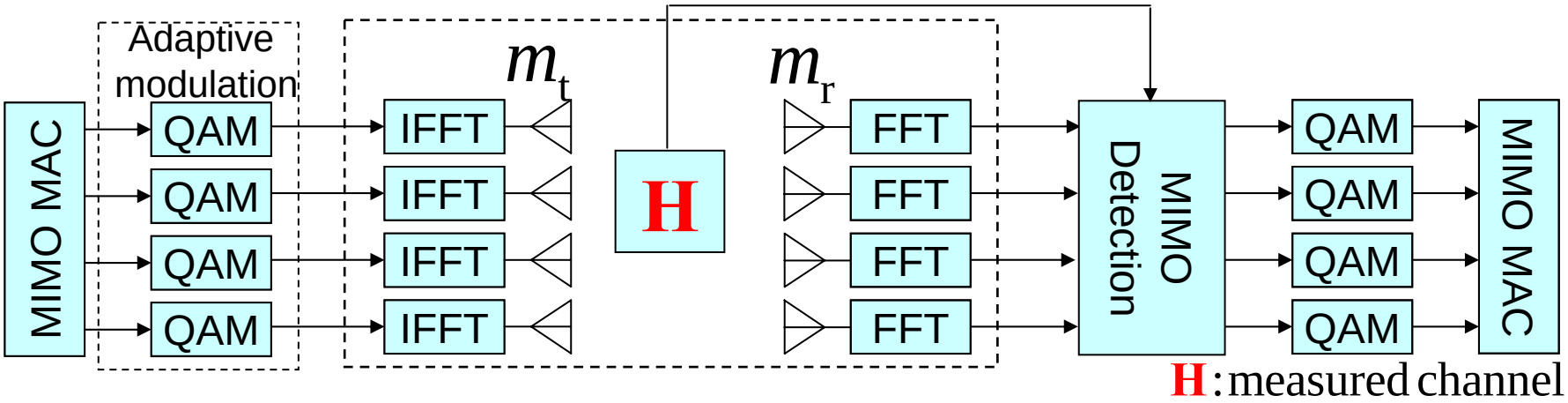
- **Verify performance improvement in residential environment as the benefit of MIMO**
- **Compare performance of different MIMO schemes**

MIMO Propagation Measurement



MIMO Configuration	4(Tx) x 4(Rx)
Antenna Configuration	ULA spacing half a wavelength
Central Frequency	5.06 GHz
Bandwidth	20 MHz
Signal	IEEE802.11a modified standard
Spatial Sample	50,993 (2cm step)

Analysis Method (Unknown CSI at Tx)



Simulation Condition

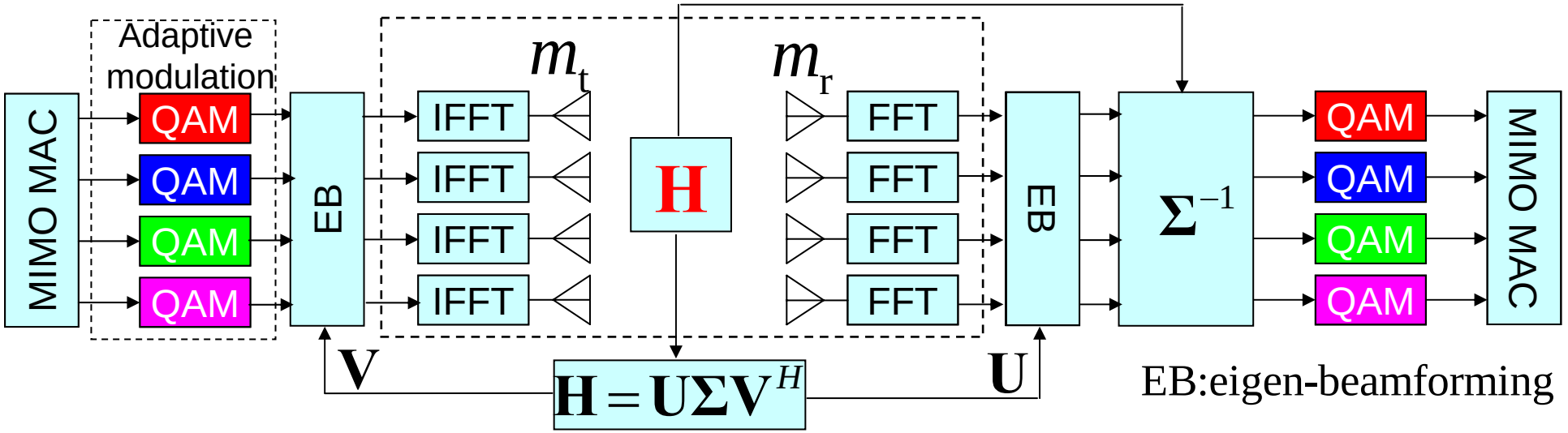
- Simulation in frequency domain
- Perfect synchronization
- Perfect channel estimation (CE)
- Quasi-static channel variation
- Equal power allocation

Throughput Calculation

$$T = m_t \max_l [l(1 - PER)]$$

l : modulation level

Analysis Method (Known CSI at Tx)



Simulation Condition

- Simulation in frequency domain
- Perfect synchronization
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Throughput Calculation

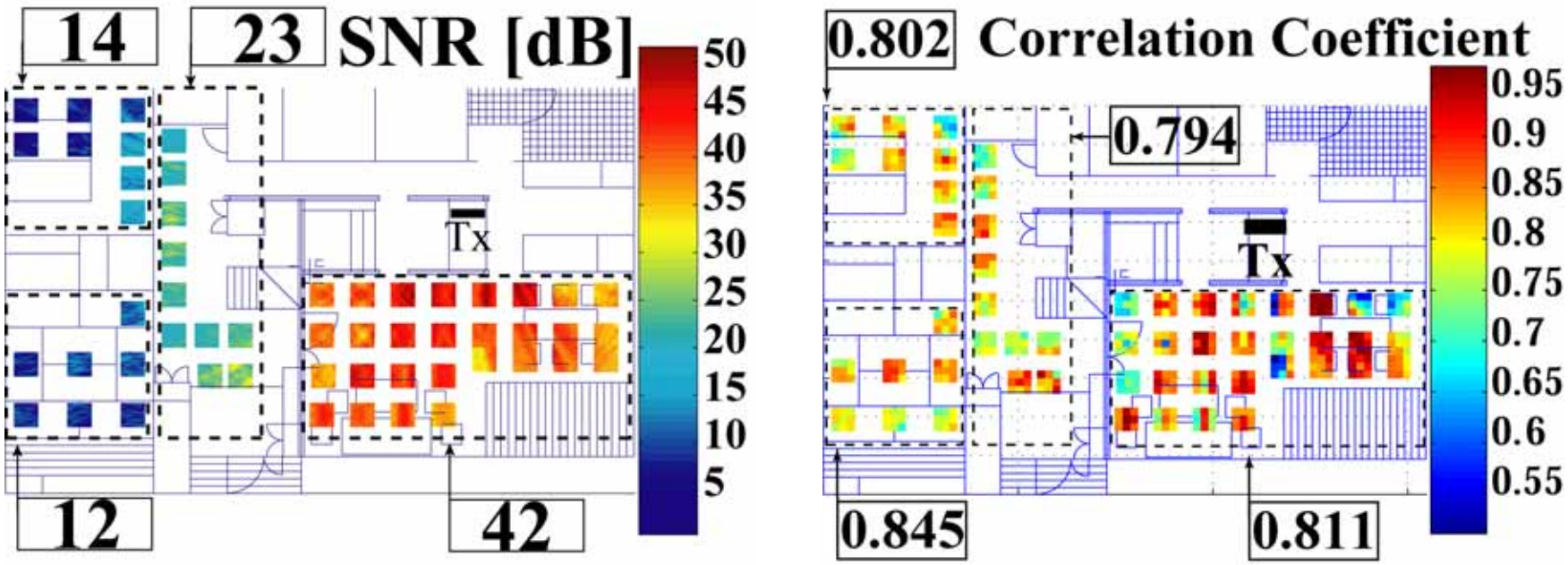
$$T = \sum_i \max_{l_i} [l_i (1 - PER)]$$

l : modulation level

Simulation Parameters

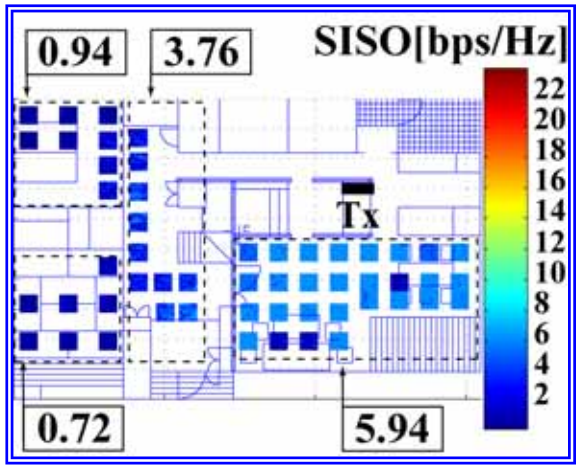
Total Transmit Power	0 dBm
Noise power	-92 dBm (NF = 7dB)
System Configuration	SISO-OFDM 4x4 MIMO-OFDM
OFDM Configuration	IEEE 802.11a standard
MIMO Scheme	MMSE, VBLAST (MMSE) QRM-MLD, SVD-MIMO
Modulation Scheme (Adaptive Modulation)	BPSK, QPSK 16QAM, 64QAM
Packet Length	60 bytes
Spatial Sample	50,993

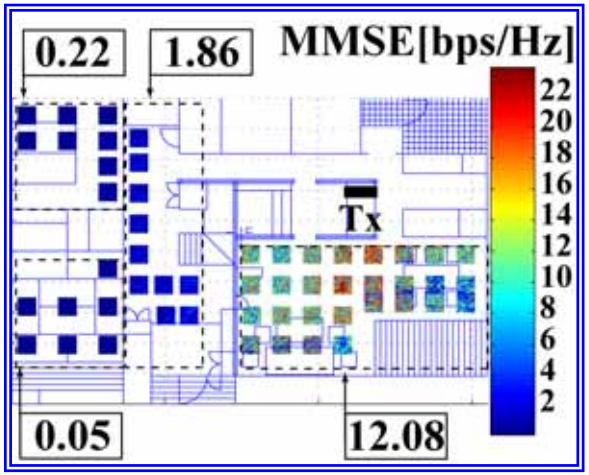
SNR & Spatial Correlation Distribution

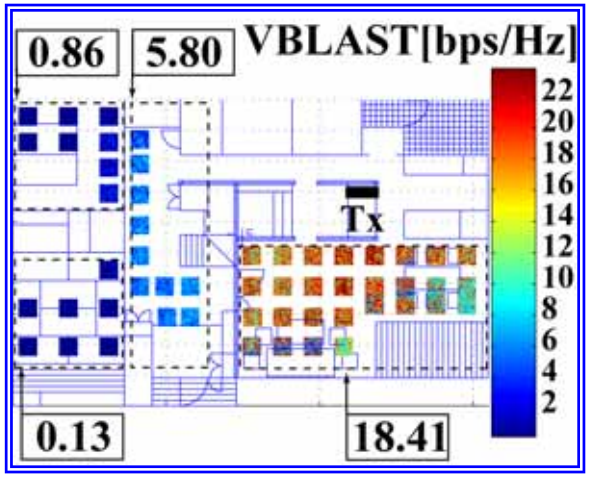


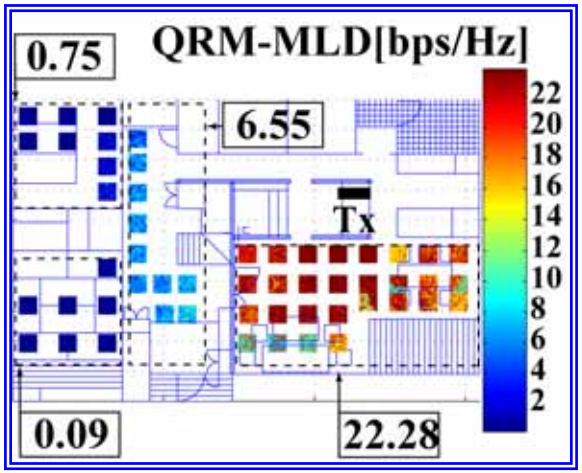
- SNR decreases as far from the Tx
  - Free space path loss
  - Shadowing
  - Penetration loss
- Spatial correlation is high even in NLOS environment
  - Wooden house is not a richly scattering environment

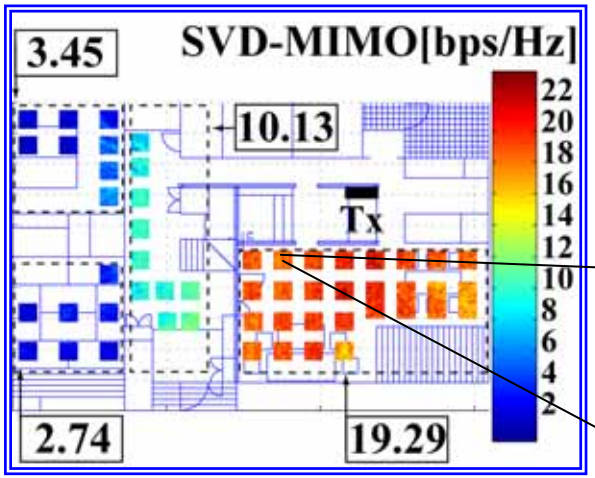
Throughput Distribution





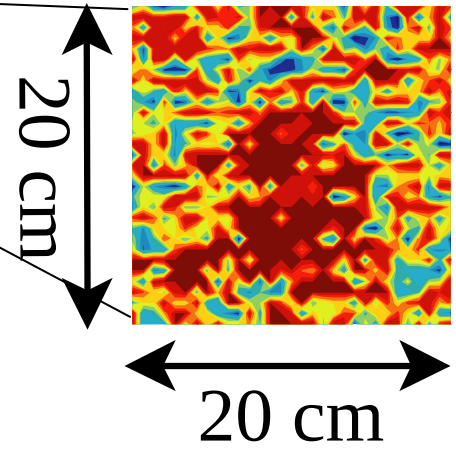




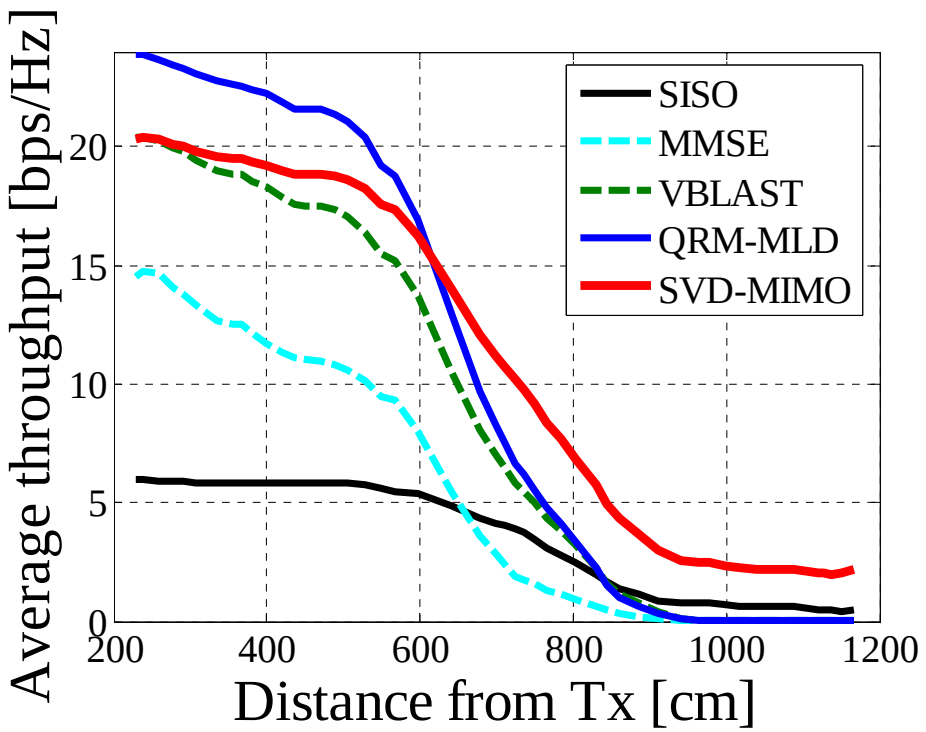


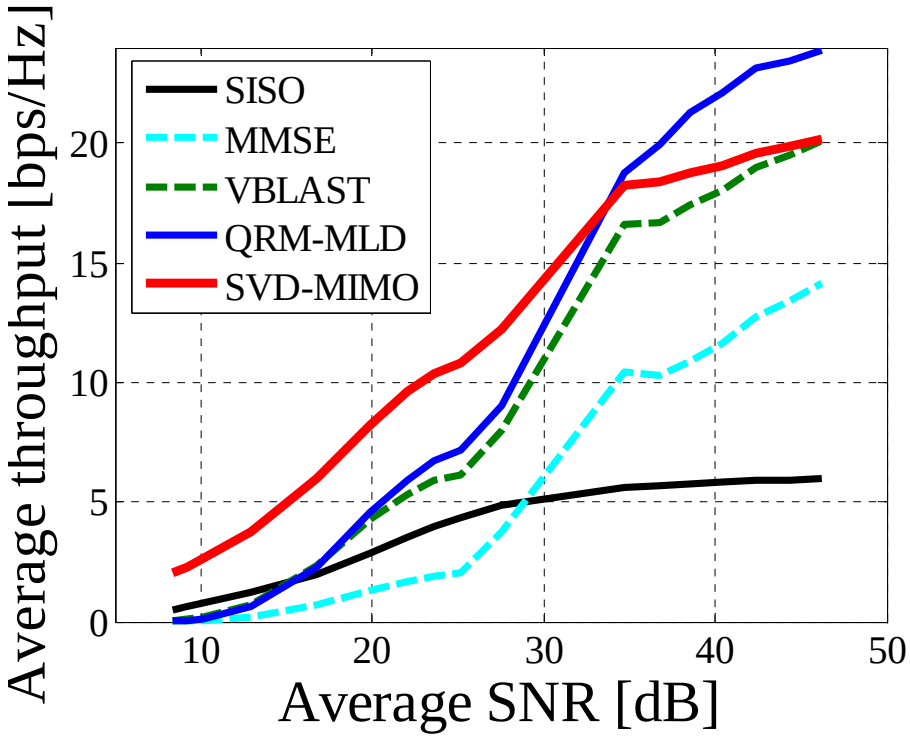
$$T_\mu = \mathcal{E}[T_{inst}]$$

$$\Pr(T_{inst} \le T_0) = 0.01$$



Average Throughput Performance





- Scheme which does not require CSI at Tx:
  - Throughput performance improvement of MIMO with high SNR
  - QRM-MLD shows best performance
  - Performance degradation of MMSE to SISO in low SNR area
- If CSI is available at Tx, SVD-MIMO is superior to the other schemes

Effect of Spatial Correlation

Exponential Spatial Correlation Model

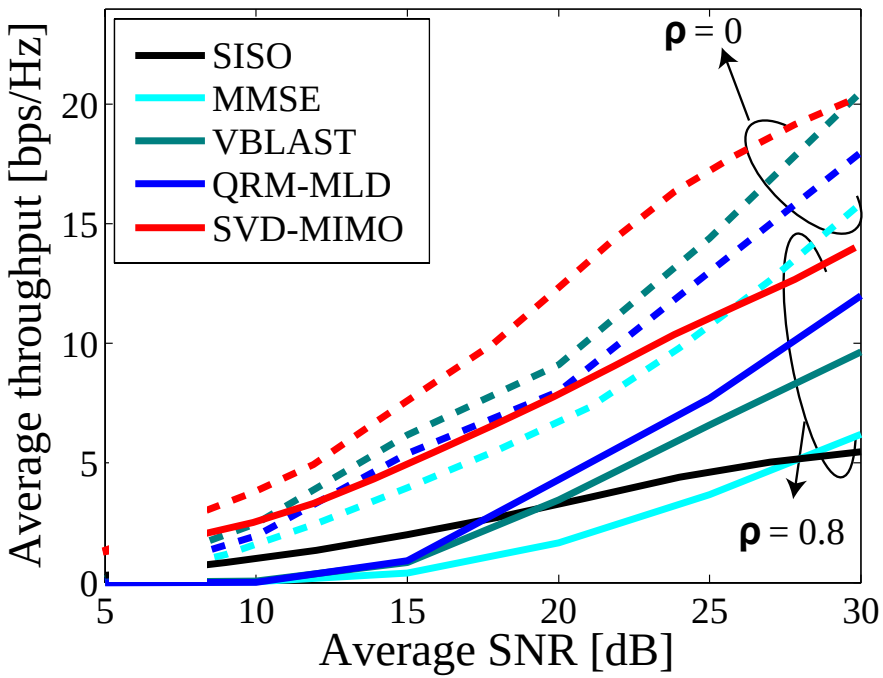
$$\mathbf{H} = \sqrt{\mathbf{R}}\,\mathbf{G}\,\sqrt{\mathbf{R}}$$

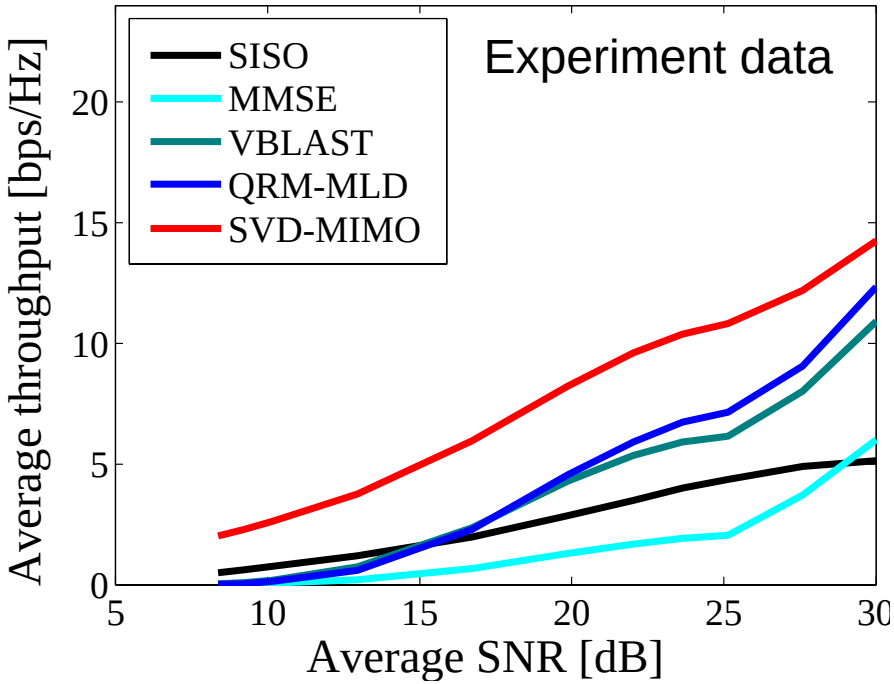
$$\mathbf{R} = \begin{pmatrix} 1 & \rho & \rho^2 & \rho^3 \\ \rho & 1 & \rho & \rho^2 \\ \rho^2 & \rho & 1 & \rho \\ \rho^3 & \rho^2 & \rho & 1 \end{pmatrix}$$

Conclusion

- Performance degradation due to the effect of spatial correlation
- Especially for MMSE case

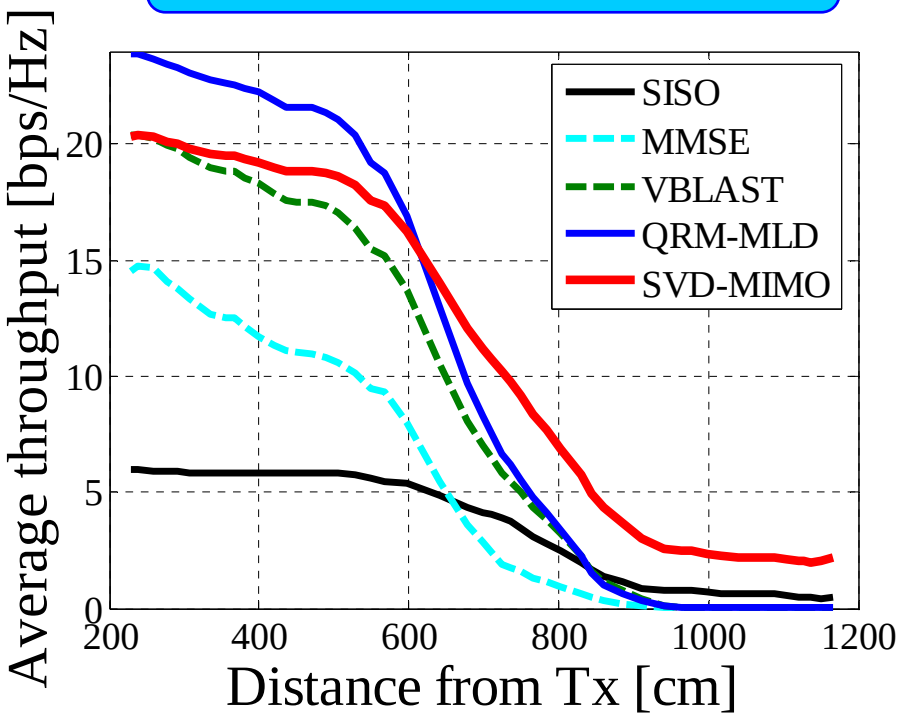
ρ : spatial correlation coefficient



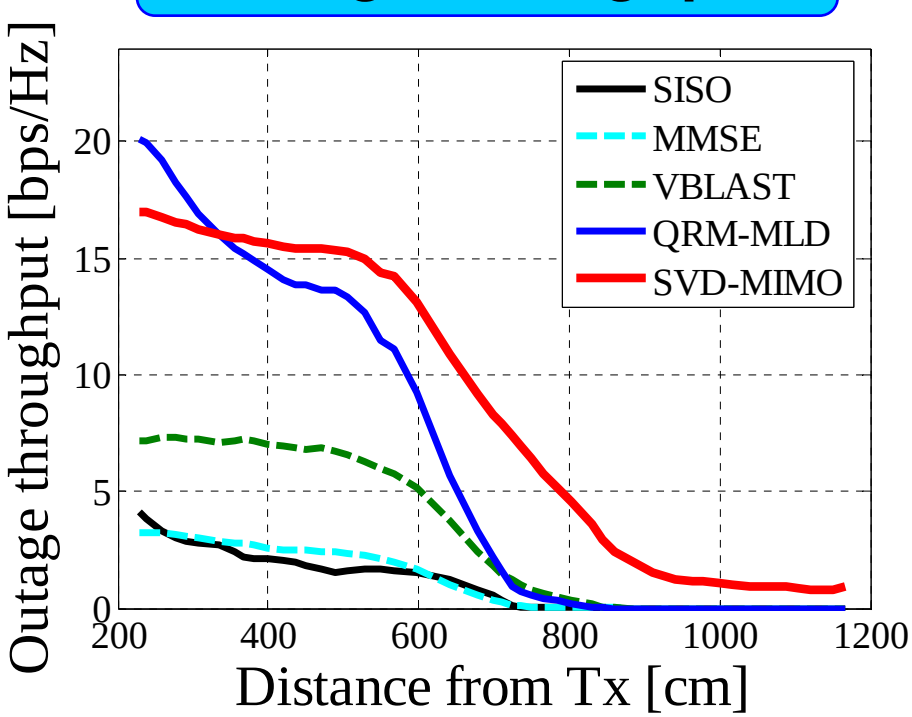


1% Outage Throughput Performance

Average throughput



Outage throughput



- Small different in average and outage performance of QRM-MLD and SVD-MIMO implies reliable schemes
- Large different in average and outage performance of MMSE implies the sensitiveness to channel variation

Conclusion

- Improvement in throughput performance of MIMO in high SNR region.
- MIMO performance degradation in low SNR region.
- In case CSI not available at Tx, QRM-MLD can be seen as a candidate for high throughput scheme.
- SVD-MIMO performs as the optimal scheme with high throughput and reliability.

Future work

- Consider the effect of feedback delay on the performance of SVD-MIMO.
- Consider the effect of channel estimation error on performance of MIMO schemes.

Thank you for your attention!