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# Unitary Beamforming Techniques Enhancing VoIP Call Admittance Capacity

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# Introduction-Motivation

- Fourth Generation Networks will need to cope with increased data rate demands and improved QoS requirements
- MIMO-OFDMA identified as potential solutions
- 3GPP-LTE adopted unitary precoding techniques (SU-MIMO & MU-MIMO) for multiuser diversity exploitation
- This paper considers adaptive link and physical layer transmission techniques for multi-user MIMO systems, and resource allocation for wireless MIMO systems with QoS provision

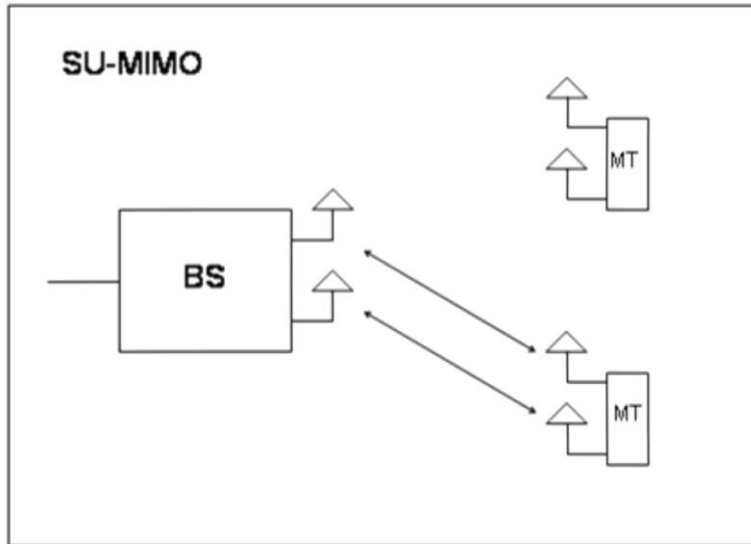


# Physical Layer Model

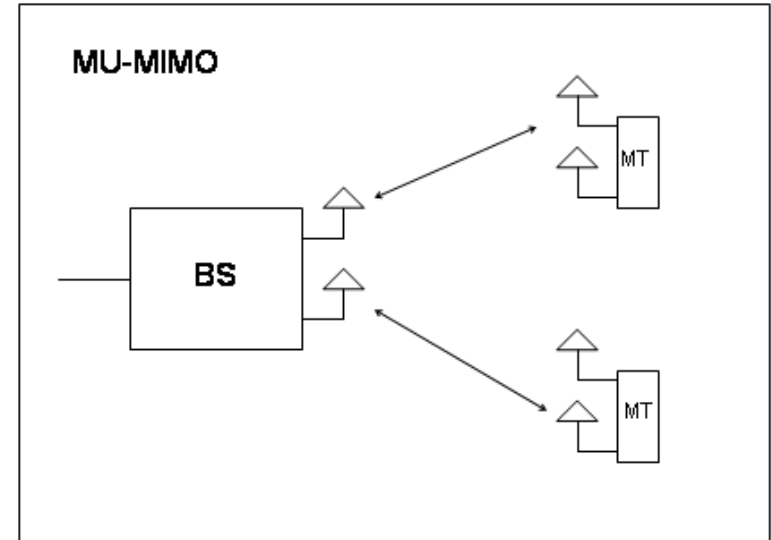
- Unitary codebook based beamforming is capable of achieving spatial multiuser diversity gain and spatial multiplexing gain
- Considerable lower overhead than the conventional eigen-beamforming approach
- Pre-defined set of precoding matrices applied to the transmitted signal.
- A delay oriented Link Adaptive (LA) scheme that incorporates an upper bound PER constraint (in order to avoid excessive delays arising from the retransmission of erroneous packets) is adopted



# 🔥 Physical Layer Model



- One MT is allocated across all spatial layers of the MIMO channel
- Aggregate channel strength information
- Loss in spatial diversity



- Different spatial streams assigned to different MTs
- Channel strength information across each stream
- Spatial Diversity Exploitation

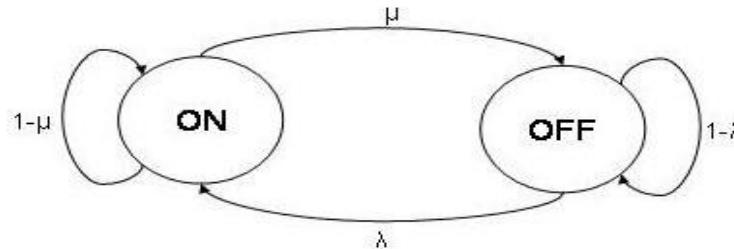
# VoIP Traffic Model

- **Unsolicited Grant Service (UGS):**
  - Fixed amount of bandwidth for the duration of the call, no periodic bandwidth request or polling service
  - MAC overhead and uplink access delay can be minimised
  - Bandwidth Wasteful
- **Extended real-time variable rate (ERT-VR) with Voice Activity Detection (VAD)**
  - Resources are assigned for only the duration of talk spurts
  - The ERT-VR VoIP transmission with VAD modelled as a variable bit rate (VBR) system with active and silent periods



# 🔥 VoIP Traffic Model

- Two-state Markov process is used to model VoIP, representing the active voice and silent periods respectively



- Alternating periods of activity and silence exponentially distributed

Component	Distribution	Parameters
Active state duration ( $1/\lambda$ )	Exponential	Mean =0.4 s
Inactive state duration ( $1/\mu$ )	Exponential	Mean =0.6s
Packet Inter-arrival rate within a burst	Fixed	$r = 5\text{packet/s}$
Probability of transition from active to inactive state	N/A	$\mu=0.6$
Probability of transition from inactive to active state	N/A	$\lambda=0.4$



# PERFORMANCE ANALYSIS OF SU-MIMO and MU-MIMO

## OFDMA Parameters

Parameter	Value
FFT size	1024
Useful Subcarriers	768
Guard Interval Length	176
Subcarrier Frequency Spacing	10.94 KHz
Useful Symbol Duration	102.9 $\mu$ S
MAC Frame Duration	5 ms
Channel coding	Punctured $\frac{1}{2}$ rate, convolutional code, constraint length 7, $\{133,171\}_{\text{octal}}$

## Transmission Modes

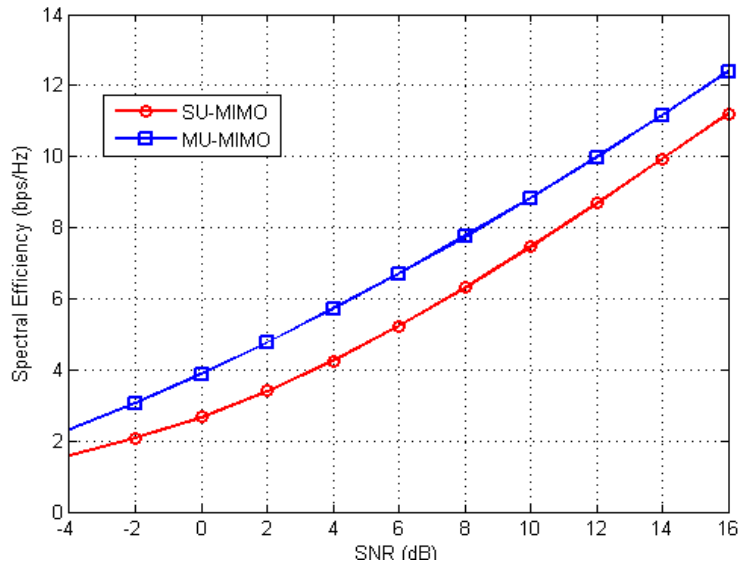
Mode	Modulation	Coding Rate	Coded Bits per OFDM symbol	Data Bits per OFDM symbol ( $B$ )
1	BPSK	$\frac{1}{2}$	768	384
2	QPSK	$\frac{1}{2}$	1536	768
3	QPSK	$\frac{3}{4}$	1536	1152
4	16 QAM	$\frac{1}{2}$	3072	1536
5	16 QAM	$\frac{3}{4}$	3072	2304
6	64 QAM	$\frac{3}{4}$	4608	3456

- SCM urban micro path loss model for Line-of Sight (LOS) based on the Walfish-Ikegami-Model (COST-W1)
- 2x2 MIMO antenna configuration
- Link Throughput calculated according to  $LT = B \left( 1 - \sum_1^{\infty} (PER)^r \right) R \approx B(1 - PER)$   
*B* being the number of encoded data bits per OFDM symbol  
*r* the number of required re-transmissions

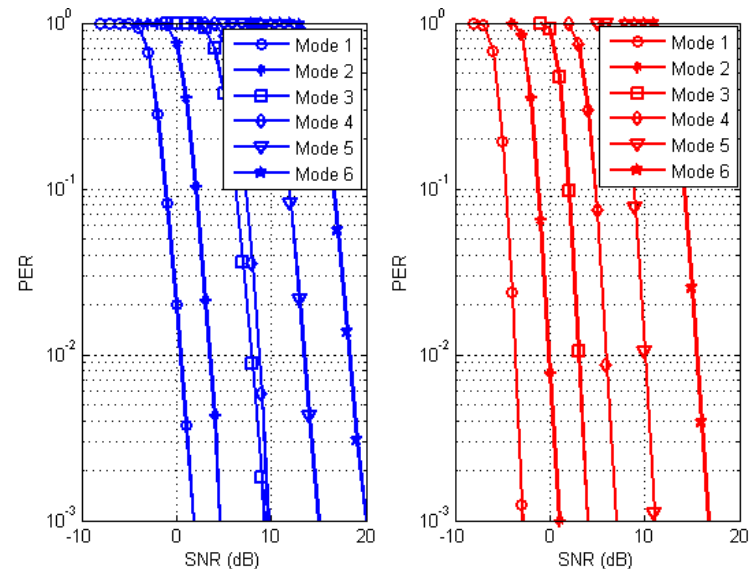


# PERFORMANCE ANALYSIS OF SU-MIMO and MU-MIMO

- Theoretical Spectral Efficiency for SU-MIMO and MU-MIMO



- PER SU-MIMO-& MU-MIMO-OFDMA under different modes



- MU-MIMO achieves a higher data rate than SU-MIMO
- MU-MIMO tolerates lower SNR for the same PER requirement
- This can either be translated into a higher call admittance capacity, greater cell coverage or reduced power requirements

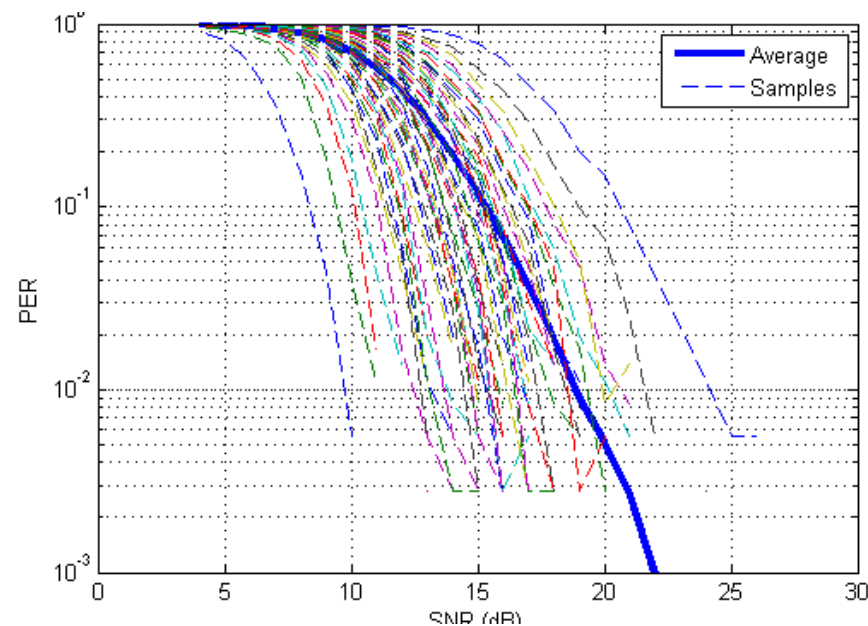
# QoS PERFORMANCE WITH LINK ADAPTATION FOR VoIP

- Received signal quality in wireless systems is affected by various channel factors, e.g.
  - Distance of the MT from the serving BS
  - Path loss exponent
  - Log-normal shadowing
  - Fast Rayleigh fading and noise
- Systems that do not employ a Link Adaption (LA) strategy use a fixed transmission scheme designed to maintain acceptable performance for worst case conditions



# 🔥 QoS PERFORMANCE WITH LINK ADAPTATION FOR VoIP

- Wireless channels suffer from frequency selective fading
- The conventional notion of performing LA based on the average PER performance fails, since the stochastic nature of individual fading channel realisations can vary considerably from the average
- PER performance of a given fading realisation can vary by more than 10dB from the average



# 🔥 QoS PERFORMANCE WITH LINK ADAPTATION FOR VoIP

- Bit errors can be broadly attributed to the average received channel strength and the probability of resource allocation on fading instances
- An indication of resource allocation on fading instances, the ratio of the frequency channel responses with channel strength lower than the average received response is selected

$$I_{fad} = \frac{|\overline{H}|^2}{\frac{1}{N_{sc}} \sum_i F(i)}$$

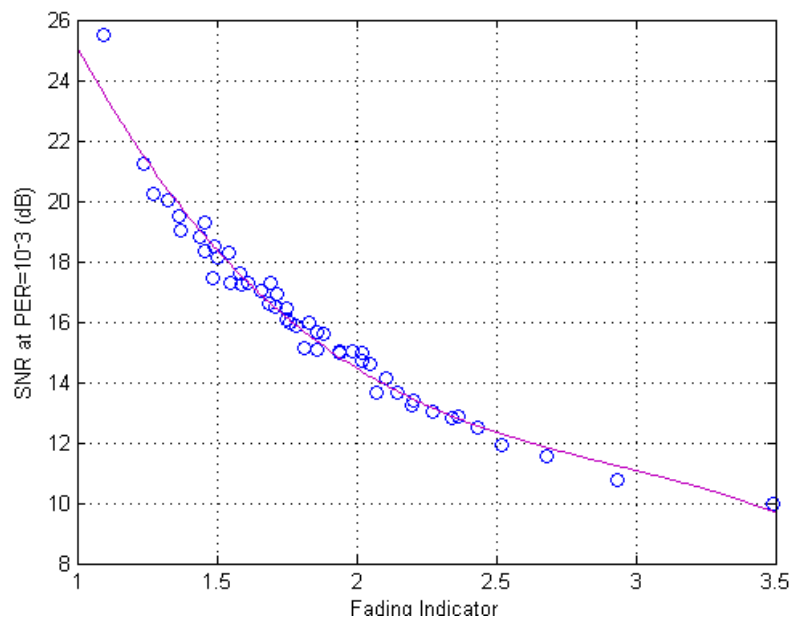
where  $F(i)=1$  if  $|H_i| < |\overline{H}|$  and  $F(i)=0$  otherwise,

$|H_i|$  indicates channel strength on each frequency resource  $i$



# 🔥 QoS PERFORMANCE WITH LINK ADAPTATION FOR VoIP

- A high  $\overline{|H|}$  value and a low number of deep fades describe a channel with a low likelihood of bit errors
- By mapping each fading realisation to a corresponding fading indicator value, a prediction on the required SNR for which a target PER requirement is met, can be made



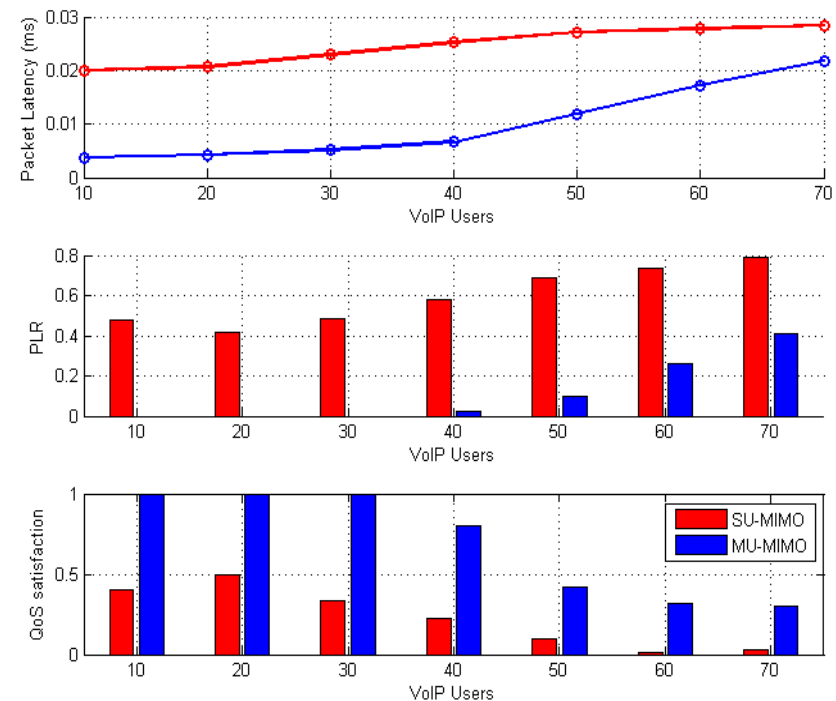
# Simulation Results

- Max. tolerable packet delay: *30ms*
- Max. VoIP packet timeout ratio: *4%*
- Satisfied Customer Ratio: *The ratio of VoIP calls not exceeding max. packet timeout ratio over total number of calls*
- Users are randomly distributed within the cell, with a minimum range of 75m from the BS to the cell edge at 800m
- A BS transmit power: *43dBm*. Receiver Sensitivity: *-120dBm*.
- MU-MIMO provides significant benefits over SU-MIMO in terms of throughput
- The exploitation of spatial diversity can also improve the overall system fairness



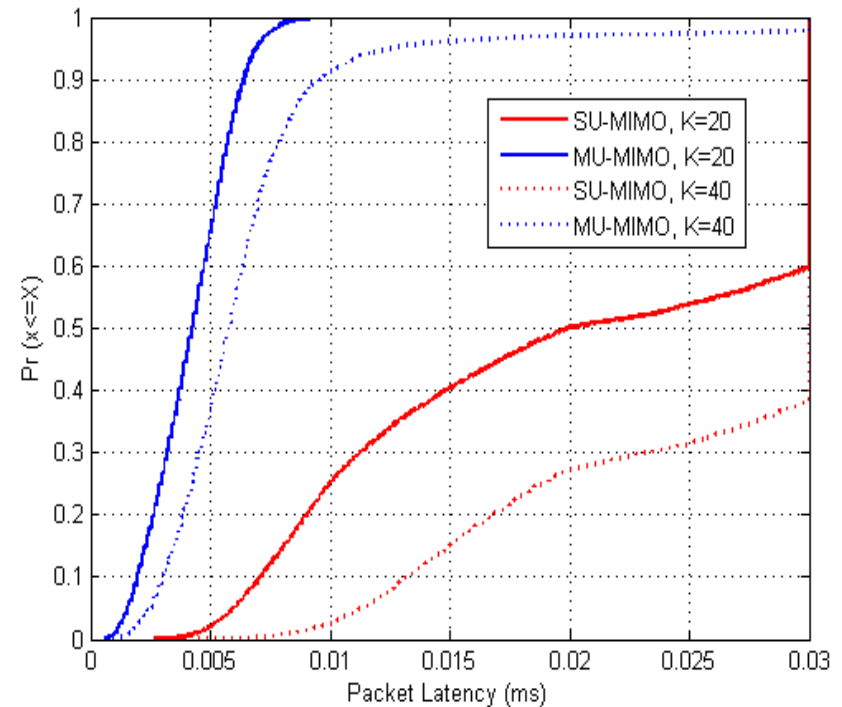
# Simulation Results: Packet Latency-Packet Loss Ratio (PLR)-Satisfied Customer Ratio

- MU-MIMO allows for lower delays due to increased number of available radio resources and enhanced resource allocation
- Correlation between packet latencies and PLRs. As the network becomes more congested, the resulting scarcity of available resources gives rise to increased buffer waiting times
- Maximum number of admitted VoIP calls with no QoS outage is significantly higher for MU-MIMO than for SU-MIMO



# Simulation Results: Cumulative Distribution of Packet Delays

- CDF of packet delays arising from SU-MIMO and MU-MIMO for a total number of users,  $K=20$  and  $K=40$
- Average packet delay is directly related to the traffic load and the degree of diversity exploitation
- Fairer distribution of delays arising from MU-MIMO over SU-MIMO





# Conclusions

- Examined QoS performance of two MIMO precoding schemes proposed for 3GPP-LTE, in a VoIP traffic system under a realistic channel environment
- A novel Link Adaptation strategy that considers the stochastic variability of fading channels has also been proposed
- Efficient exploitation of multiuser diversity across the spectral and spatial domain in form of MU-MIMO allows for notable increases at the call admittance capacity
- A more uniform distribution of packet delays across users experiencing distinctly diverse channel conditions has been observed
- These benefits have been attributed to the increased data rates and improved resource allocation, attained by MU-MIMO

