On Scheduling Mobiles Equipped with Multiple Antennas to Share a Slot in WiMAX Networks

Phani Krishna P

MS Seminar
High Performance Computing & Networking Lab (HPCN)
Department of Computer Science & Engineering
Indian Institute of Technology Madras
Chennai, India

Outline

1. Introduction to WiMAX Networks
   - Advanced Antenna Techniques
   - Interference Minimizing Techniques
2. Problem Formulation
3. Proposed Solution
4. Conclusion

Introduction to WiMAX Networks

- Popular wireless broadband solution at 2.4 GHz frequency
- Use Orthogonal Frequency Division Multiple Access (OFDMA) scalable from 1.25 MHz to 20 MHz
- Support advanced antenna techniques
- Per subscriber adaptive coding and modulation
- Support multiple QoS classes
- Support Point-to-Multipoint mode and Mesh mode

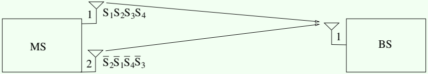
MIMO Techniques

- Spatial Multiplexing
- Spatial Diversity
- Hybrid techniques
- Collaborative Spatial Multiplexing

Necessary Condition

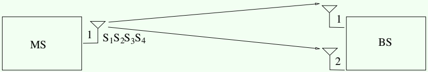
Antennas are separated by a minimum of $\frac{\lambda}{4}$ distance, where λ is wavelength of transmitted signal

Transmit Diversity



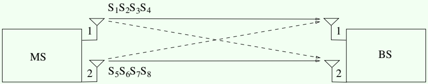
- Several antennas transmit variants of same signal
- Overlapping signals maximize SNR

Receiver Diversity



- One signal is received at several antennas
- Receiver combines signals to maximize SNR

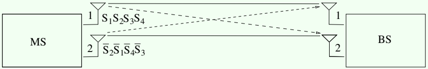
Spatial Multiplexing



- Different signals at different antennas
- Exploits multi-path propagation

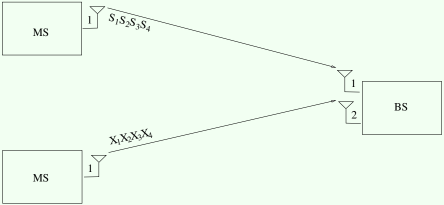
Hybrid Techniques

Alamouti Technique



- Variant of diversity techniques
- Simple receiver combining technique

Collaborative Spatial Multiplexing



- Two Mobile Stations (MSs) transmit at same time
- MSs are scheduled such that interference is negligible
- Improves throughput of the network
- Each MS is equipped with only one antenna
- Typically known as Virtual MIMO (V-MIMO)

Interference Minimizing Techniques

Beamforming

- Data is transmitted along a vector
- Received along another vector
- Choosing vectors is dependent on channel quality between transmitter and receiver

Interference Nulling

- Transmitter 2 nulls its signal at receiver 1
- Choosing vectors is dependent on channel quality between transmitter 2 and receiver 1

Interference Alignment (IA)

- Each transmitter nulls its signals at **every** receiver except one receiver
- Choosing vectors is dependent on channel quality between **every** transmitter and receiver in the network

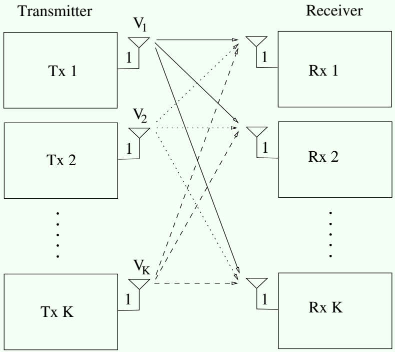


Figure: Interference Alignment

Motivation

In a distributed network

- Each user pair (with one antenna) can transmit data successfully for half the time
- Each user pair with antennas greater than the on-going number of streams can transmit data in same slot

- Similar Studies are unavailable in a centralized network
- C-SM proposes only **two** MSs to share slot

Problem Statement

Find the maximum number of MSs that can share a slot in a centralized network

How to schedule MSs in a typical WiMAX network?

- Each MS is equipped with multiple antennas
- Each MS has a constant rate requirement
- Each MS moves with a velocity of $0 - 120$ Kmph

Finding Maximum Number of Mobiles that can Share a Slot

Example

Data received at each antenna can be represented as

$$Y = HX + N$$

- Data received at antenna 1 can be taken as
- $Y_1 = H_{11}X_1 + H_{12}X_2 + N_1$

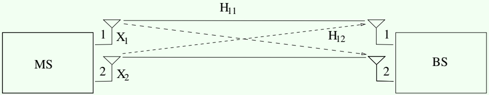


Figure: Typical Transmitter and Receiver

Applying IA Technique

- Data received at antenna '$2T'$' can be noted as
- $Y_{2T} = W_1 X_1 H_{2T,1} W_1^H + W_2 X_2 H_{2T,2} W_1^H + N_{2T}$
- Signal to Interference Ratio $SIR_{2T} = \frac{|W_1 H_{2T,1} W_1^H|^2}{|W_2 H_{2T,2} W_1^H|^2}$

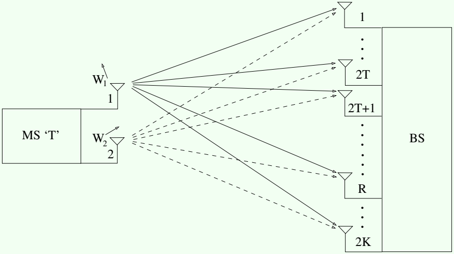


Figure: System Model using IA at each MS

MIMO techniques

Choose W_1, W_2 for achieving different MIMO techniques

System Model

- K MSs, each with two antennas share a slot for transmission
- Each MS utilizes different MIMO technique for transmission
- Inter Carrier Interference (ICI) occurs in the network

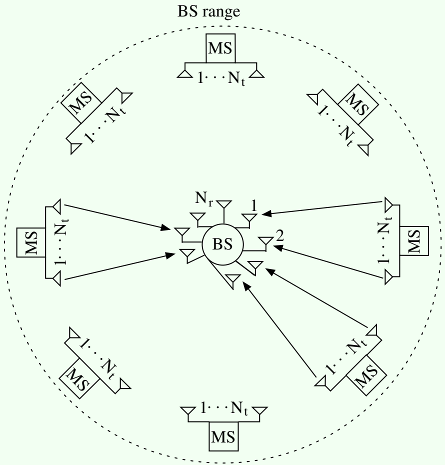


Figure: System Model using IA at each MS

Analysis

- $$SIR_{2T}(s) = \frac{\left|W_i H_{i,2T}(s) W_{2T}^H\right|^2}{\sum\limits_{\substack{j=1 \\ r=s-1,s+1}}^{j=2K} \alpha \left|W_j H_{j,2T}(r) W_{2T}^H\right|^2 + \sum\limits_{\substack{j=1 \\ j\neq i}}^{j=2K} \left|W_j H_{j,2T}(s) W_{2T}^H\right|^2}$$
- $SIR_{2T}(s)$ follows F-Distribution with $(1, 6K-1)$ degrees of freedom when each MS uses Multiplexing technique
- $SIR_{2T}(s)$ follows F-Distribution with $(1, 6K-2)$ degrees of freedom when each MS uses Diversity technique

Analysis Validation

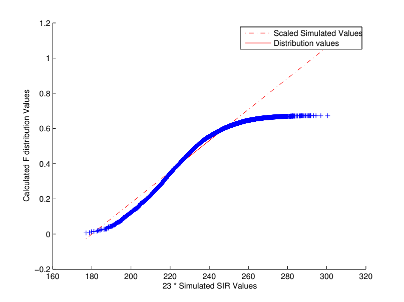


Figure: Multiplexing Technique

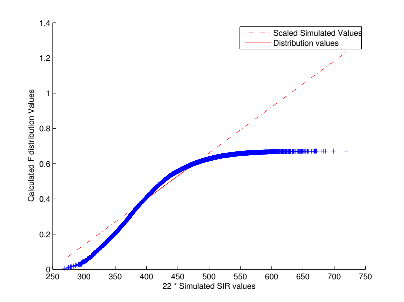


Figure: Diversity Technique

Numerical Results

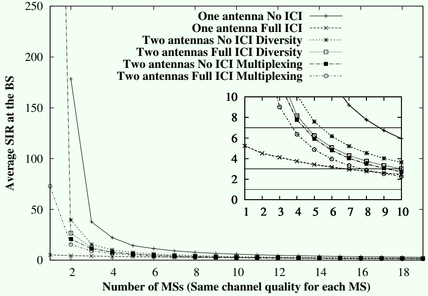


Figure: Same SNR Values at Each MS

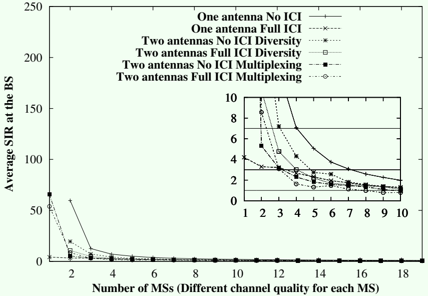


Figure: Different SNR Values at Each MS

Numerical Results

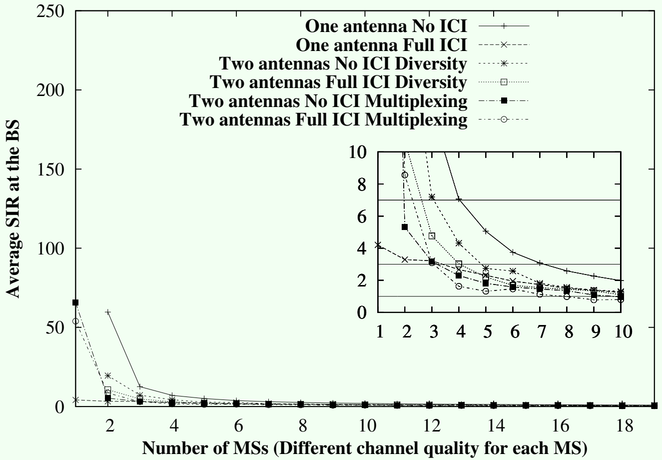


Figure: Different SNR Values at Each MS

Observations

Number of MSs that can share a slot depends on

1. Probability of occurrence of ICI in the network
2. MIMO technique used at each antenna
3. Number of antennas at each MS
4. Rate requirement at each MS

Scheduling Mobiles in a WiMAX Network

Existing Pairing Techniques

- Random Pairing:
  Select 2 MSs for pairing randomly
- Double Proportional Fair pairing:
  Select 2 MSs for pairing such that total achievable rate is maximum
- Other pairing techniques do not consider equal rate requirement at each MS

Toy Example Illustration

- Each MS moves with a velocity of upto 120 Kmph
- SNR of each MS varies continuously
- It is **possible** to find MSs satisfying the pairing requirements

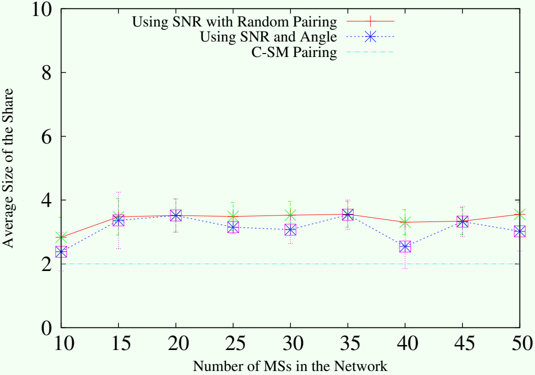


Figure: Average Number of MSs

Challenges to Schedule MSs

- Computing IA vectors
- Channel quality estimation precision
- Delayed IA vectors relevance

Computing IA Vectors

Assumptions:

- Channel reciprocity:
  Applicable in a WiMAX network, for MS sending channel quality once in each frame
- Proposed Algorithm converges

Challenges:

- Existing algorithms are highly complicated and computational intensive

Proposed Algorithm

- Sort MSs based on SNR
- Pick the MS with highest SNR and allocate the slot
- Pick C MSs using Correlative Angle as parameter
- Pick τ MSs from C MSs using *Max-SINR-Optimized* algorithm
- Share the slot among τ MSs

Optimized IA Vector Computation Algorithm

Max-SINR-Optimized:

1. Generate initial precoding vectors as IA vectors of each MS in previous frame
2. Find interference plus noise covariance matrix
3. Reverse the link and use receiver combining vectors as precoding vectors
4. Find interference plus noise covariance matrix
5. Find receiver combining vectors
6. Reverse the link and use receiver combining vectors as precoding vectors
7. Goto Step 1 until precoding and receiver vectors of at least τ MSs converge

IA Vector Computation Time

- Optimization reduces the computation time to almost $\frac{1}{3}$ of original computation time

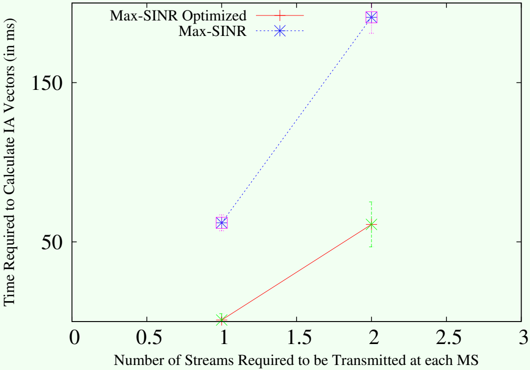
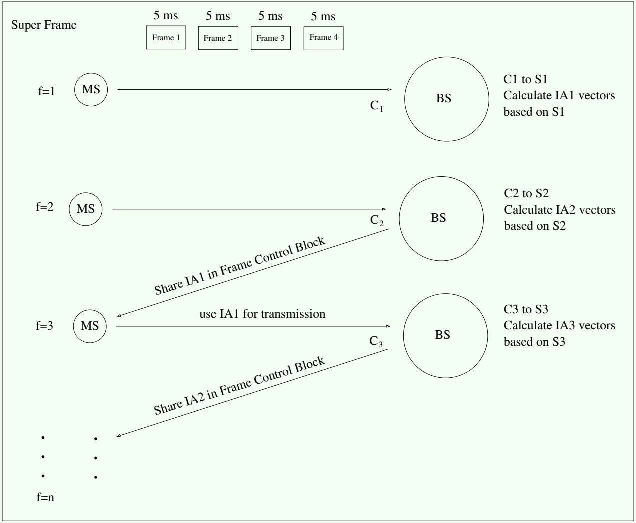


Figure: Time Consumed to Compute IA Vectors for 10 Iterations

Delayed IA Vector Relevance

- Channel quality measured once in each frame is sufficient to compute IA vectors similar to that of generating Modulation and Coding Schemes



Simulation Parameters

Table: Simulation Parameters

Parameter	**Value**
Number of Antennas at MS	2
Carrier Frequency	2.4 GHz
Channel Bandwidth	10 MHz
OFDM Symbol Duration	102.86 μs
UGS Traffic	Constant Bit Rate - 64 Kbps
Confidence Interval	95%
Simulation Time	500 seconds

Performance Measurements

- Proposed technique attains higher system throughput compared to existing techniques

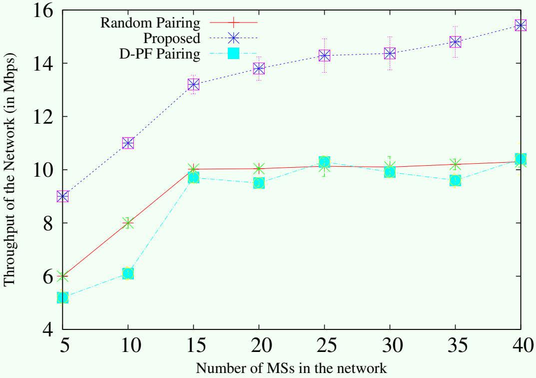


Figure: Measured Throughput

Conclusion

- Determined maximum number of MSs that can share a slot
- Proposed a scheduling algorithm that executes at the BS
- Proposed a working solution to implement IA vectors in a WiMAX network

Future Work

- Study the system for varying rate requirements at each MS
- Study the system for varying number of antennas at each MS

Publications

1. Phani Krishna P, Saravana Manickam R, Siva Ram Murthy C, “MIMO Enabled Efficient Mapping of Data in WiMAX Networks”, in Proceedings of the 13th International Conference on Distributed Computing and Networking, 2012, pp. 397-408.
2. Phani Krishna P, Siva Ram Murthy C, “On Bounding the Number of Mobiles Sharing a Slot in a Point-to-Multipoint Network”, Accepted at the 15th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems, 2012.

Thank you!