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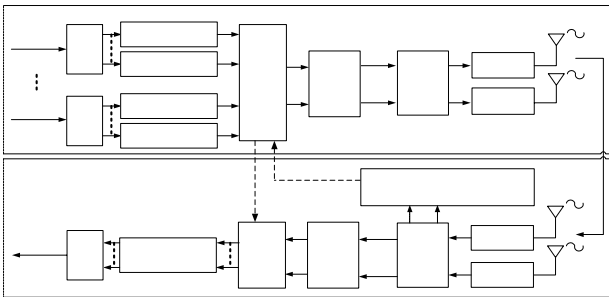
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## Introduction

- In a multi-user environment, combining MIMO layered random beamforming (LRB) technique and OFDMA is capable of achieving near maximal benefits from MIMO and multi-user diversity whilst requiring minimal feedback.
- 3 dynamic scheduling algorithms are proposed for LRB-OFDMA and they show a trade-off between maintaining fairness and minimising delay.

## Physical Layer Model of LRB-OFDMA

- Low Feedback Compared to Eigenbeamforming: LRB-OFDMA only requires the feedback of ESINR based data rate from every cluster of sub-carriers of each spatial layer of MIMO channels.
- Multi-user Diversity Gain: Achieve spatial multiplexing gain, spatial multi-user diversity gain, layer spatial multi-user diversity gain and spectral multi-user diversity gain.



Block Diagram of LRB-OFDMA PHY Model

$$Y_k^q = H_k^q V_k^q X_k^q + N_k^q = U_k^q D_k^q (V_k^q)^H V_k^q X_k^q + N_k^q$$

$$G_k^q = (H_k^q V_k^q)^H (H_k^q V_k^q) + \text{SNR}^{-1} \mathbf{I}$$

$$G_k^q Y_k^q = G_k^q H_k^q V_k^q X_k^q + G_k^q N_k^q$$

$$\text{ESINR}_{k,c}^q = \frac{E_s}{\|H_k^q V_k^q\|^2 (H_k^q V_k^q)^H (H_k^q V_k^q) + \text{SNR}^{-1} \mathbf{I}} - 1$$

$$R_{k,c}^q = \frac{1}{m-n} \sum_{i=1}^m \log_2(1 + \text{ESINR}_{k,c}^q)$$

Reduced Feedback LRB-OFDMA System

## PHY Parameters and Transmission Modes

Operating Frequency	5 GHz	Mode	Modulation	Coding Rate	Coded Bits (subcarrier)	Max. Data Rate (R) Overall
Bandwidth	100 MHz	1	BPSK	1/2	1	64 Mbps
FFT Size	1024	2	QPSK	1/2	2	128 Mbps
Useful Sub-carriers	768	3	QPSK	3/4	2	192 Mbps
Guard Interval Length	176	4	16 QAM	1/2	4	256 Mbps
Sub-carrier Spacing	97.656 KHz	5	16QAM	3/4	4	384 Mbps
Useful Symbol Duration	10.24 μs	6	64 QAM	3/4	6	576 Mbps
Total Symbol Duration	12.00 μs					

Parameters for the Proposed LRB-OFDMA

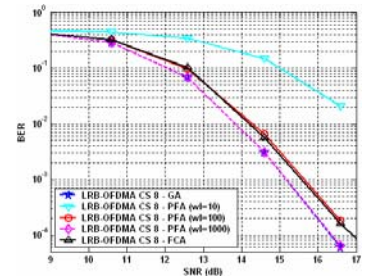
Transmission Modes and Data Rates

## Performance of LRB-OFDMA in Statistical Channel

An uncorrelated MIMO implementation of the statistical channel model E of the ETSI BRAN channel models is used for system simulation. Channel model E have a sampling period of 10ns and the rms delay spread of 250ns.

Algorithms	CoV Across Different MSs	System Throughput
GA	0.4553	561.02 Mbps
PFA (wl=100)	0.4340	537.70 Mbps
PFA (wl=10)	0.3164	380.74 Mbps
FCA	0.0478	536.54 Mbps

Overall System Throughput and CoV of Data Rate of LRB-OFDMA Employing Different Scheduling Algorithms Averaged Over 1000 Time Slots (Eb/N0=12dB)



BER Performance of LRB-OFDMA Employing Different Scheduling Algorithms in a 12-MS Environment (Cluster Size=8)

- Adjusting window length of PFA shows in a trade off between throughput and fairness.
- The BER performance of FCA is very close to PFA with a high window length at 100 and FCA distributes the resources more fairly than PFA with a window length of 10.

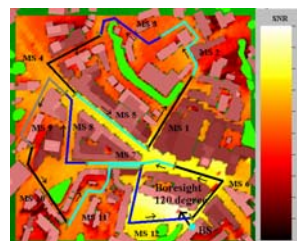
## Resource Scheduling Algorithms

$$k^* = \arg \max_{k,c} \{R_{k,c}^q\}$$

$$T_{k,c}^q(t+1) = \begin{cases} R_{k,c}^q(t) / T_{k,c}^q(t) & k = k^* \\ \left(1 - \frac{1}{t_c}\right) T_{k,c}^q(t) + \frac{1}{t_c} R_{k,c}^q(t) & k \neq k^* \end{cases}$$

$$P_k(t+1) = \sum_{i=1}^t a_k(t) / \sum_{i=1}^t b_k(t)$$

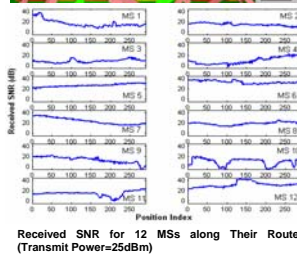
## Performance of LRB-OFDMA in Ray Tracing Channel



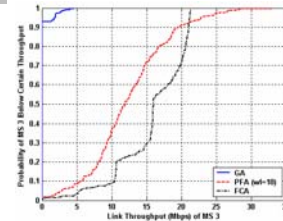
A 12-MS outdoor environment (Bristol city-centre, U.K.) is considered for simulation (2x2 MIMO channels) and each MS moves along a pre-defined and independent route.

Algorithms	Log Fairness Metric	System Throughput
GA	9.27	405.17 Mbps
PFA (wl=10)	14.77	263.10 Mbps
FCA	15.32	299.31 Mbps

Overall System Throughput and Level of Fairness of LRB-OFDMA Employing Different Scheduling Algorithms



Received SNR for 12 MSs along Their Routes (Transmit Power=25dBm)



Probability of MS 3 to be Below a Certain Throughput for Different Scheduling Algorithms

Mobile Station 3:  
GA: no signal at more than 90%.  
PFA (wl=10): 5Mbps at more than 90% of the locations.  
FCA: 10 Mbps at more than 90% of the locations.

## Fairness Metric

Two fairness metrics are adopted for fairness performance evaluation of different scheduling algorithms

$$\text{CoV} = \frac{\sigma_{M_k}}{M_k}$$

$$\log \left( \prod_{k=1}^K M_k \right)$$

## Conclusions

- A greedy algorithm, a proportional fair algorithm and a fair cluster algorithm considered for LRB-OFDMA are shown to have increasing fairness.
- For PFA, increasing the window length improves the overall throughput performance but degrades the fairness.
- The FCA achieves a good balance between the overall throughput and both short and long term fairness. However, overall throughput may be degraded while maintaining a fair resource allocation as the difference in fading statistics of MSs becomes more significant.