



A Survey on Multi-Layer MIMO for Lte/Lte-Advanced

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Abstract

The primary intention of the paper is to explore on various Multi-Layer MIMO approaches for the higher system performance. MIMO technique is said to be the key technology in LTE-A to achieve the spatial diversity in the system. Multi-Layer MIMO is the enhancement to the MIMO technology where multiple streams of data could be transferred to different layers for optimization with increased capacity in the network in high SNR condition. In a massive MIMO system, the cell interference hinders the system performance due to high channel dimensionality. The main design objective of the Multi-Layer MIMO techniques studied is to reduce the Cell Interference with lower complexity.

Keywords: MIMO, Multi-Layer, LTE-A

1. Introduction

The data-intensive applications are being used widely in the present generation. The transmission of the data for the applications including social networks, video streaming, web browsing etc, requires a high bandwidth and uninterrupted transmission paths with high coverage for the increased throughput in the network. These requirements has led to the evolution of the new, next generation of mobile communication technology called Long Term Evolution (LTE) / Long Term Evolution-Advanced (LTE-A). The main goal of the LTE/LTE-A networks is to provide the high speed, reliable transmission in low cost. The maximum downlink speed in LTE-A network is 1 Gbps and for the uplink it is 500 Mbps. The LTE-A systems also aims at the effective utilization of the resources with the spectrum reuse and successful transmission even at the cell edges.

LTE-A network is the enhancement to the LTE network with the technologies of multi-antenna system of Multiple Input and Multiple Output (MIMO), increasing the bandwidth with carrier aggregation (CA), heterogeneous network and relaying technology[10,11].The Network Coding techniques of transmitting the data to receivers in reduced time slots with the MIMO reduces the overall delay in the network[12,13].

The heart of LTE-A network is the MIMO technology to increase the overall capacity of the network. In a scattering environment of signals, MIMO proves to be successful with the signals taking different path from different transceiver (TX) to reach the User Equipment (UE) which could be with multiple receivers (RX) as shown in figure.1.Thus, MIMO enhances both the transmit and receive diversity where the fading signals at the receiver end could be regained with the data travelling in multiple paths [9]. When multiple independent data streams are transmitted to the User Equipment, Spatial Multiplexing could be achieved with massive MIMO technique.

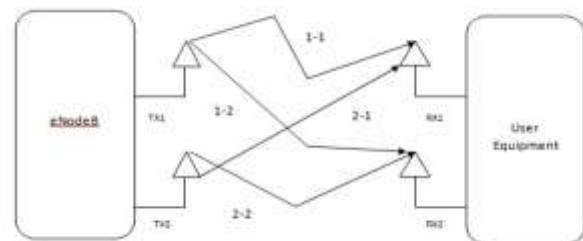


Figure 1: MIMO System

The four modes most prominent mode for achieving the downlink transmissions with spatial multiplexing are transmit diversity, Open-Loop Spatial Multiplexing, closed-Loop Spatial Multiplexing and Closed-Loop Rank-1 Spatial Multiplexing. The differences between the open loop and closed loop condition are the amount and the frequency of details about the channel condition by the User Equipment. The open loop condition is used when UE is in mobility with high speed and hence the detail of information will be less compared to the closed loop. With transmit diversity mode, the MIMO system acts as MISO system where the User Equipment receives the data from multiple transmitters and reconstructs its code. The Closed-Loop Rank-1 Spatial Multiplexing is similar to the transmit diversity mode but incorporates the linear precoding matrix to enhance the multipath condition. The term 'rank' refers to the number of layers that could carry the data streams simultaneously [6,8].

2. Multi-Layer MIMO

2.1 LMPIF:

The multilayered scheme named layered Multi-paths Information based CSI Feedback (LMPIF) proposed in [1] overcomes the

difficulty of maintaining the huge codebook for MIMO. A system with dual polarized antenna is considered where both the number of transmitting and receiving antenna is an even number. The antennas are arranged in the horizontal and vertical polarization where the directions are orthogonal in nature with 90 degrees. Transmitting antennas and Receiving antennas of 90/0 degrees polarized constitutes Configuration I and +/- 45 degree constitutes for Configuration II.

The MIMO channel is decomposed into two components. The first component is multipath directions with the amplitudes and the other is of the phases for multipath. In practicality the first component of the direction and magnitude remains almost a constant but the phases might change with the moving User Equipment. With the time 't' and $V_{n,m}$ as the moving velocity in the m^{th} ray of the cluster 'n', the phase of the path is said to be proportional to the expression $exp(j2\pi V_{n,m} t)$. For the report with amplitudes and direction it is said to remain for long term in Wideband with less number of bits and those involving the phase weight lasts only for the short term with Subband frequency. The report types in short band requires a total of 4 bits or 6 bits which is independent of the number of antennas being used. Thus in a massive MIMO system the feedback overhead is said to be reduced achieving good spectrum efficiency.

2.2 Multi-Layer Precoding:

Multi-layer precoding proposed in [2] prevails over the inter-cell interference problem with less amount of channel knowledge. The system considered is a MIMO system with antenna array in two-dimension of horizontal and vertical antennas and the User Equipments with one antenna. A count of three precoded matrix is used each for one layer. The objective behind each precoded matrix will be different. The first precoded matrix, P_1 aims at minimizing the inter-cell interference, the second precoded layer P_2 's, objective is to maximize the signal power and the third precoded layer P_3 to reduce the multi user interference. The resultant precode matrix, P is the product of the entire three precoded layer.

$$P = P_1 * P_2 * P_3$$

The channel state overhead is minimized with the reduced channel dimensions. This reduction is made successfully at each layer. So, the P_1 matrix is said to be large with more channel information and could be updated once in a while on a long term basis. The P_2 and P_3 matrix have fewer dimensions with frequently updated channel information with P_2 depending on P_1 and P_3 depending on P_2 . As shown in figure.2.

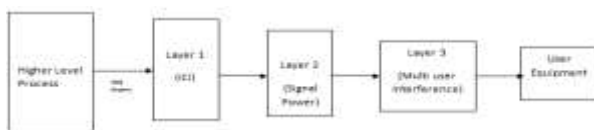


Figure 2: Multi-Layer Precoding

2.3 Multi-Layered Rate Control:

Multi-Layered Rate Control (MLRC) proposed in [3] reduces the inter-cell interference problem. A network with two cells with eNodeB1 and eNodeB2 in each cell is considered. User Equipement1 and User Equipement2 are in the overlapping ranges of both the cells. In the multi-antenna environment eNodeB divides the data stream is divided into two parts of common data and private data which are multiplexed at the transmit antennas. eNodeB1 tries to transmit data to UE1 and eNodeB2 transmits both common data and the private data to UE2. During the interference UE1 decodes the common data and private data from eNodeB2. With the common data and received data UE1 computes its data. Similarly UE2 after decoding the common data obtains its private data with the received signal.

2.4 Multi-Layer HARQ:

Traditional HARQ broadcasting scheme achieves higher throughput compromising the delay in the network. The enhanced multi-layer HARQ proposed in [4] overcomes the delay problem by achieving the optimal amount of throughput with lower latency. The multi-layer HARQ is implemented with the undecoded layers thus reducing the overhead. The combination of multi-layer coding with Incremental Redundancy-HARQ (IR-HARQ) has proven to be successful with the simulation results. In IR-HARQ for a single data block multiple streams of data are generated with different code bits which could be transmitted in different data path with varying channel conditions. Upon receiving the negative ACK, the transmitter retransmits the data block with a new parity bit. A two level coding is proposed in which the data to be received in the second layer depends on the proper decoding of the data in the previous first layer. For the m^{th} block of data if the first layer decodes on n^{th} retransmission, then the second layer will be involved only with (m-n) transmissions.

2.5 Multi-Layering with Diagonal Permutation:

A two layer coding scheme has been proposed in [5], in which the first transmission considers the MAC outage where multiple different coded streams are forwarded by every different antenna and the second layer transmission could be composed with space-time Hadamard permutation or with diagonal permutation where the every coded data streams are forwarded using all the antennas. The optimal decoding at the first stage involves the decoding joint decoded region of both the layers. Two layer approach of decoding with reference to the figure 3, Layer 1 is decoded considering the layer 2 as interference in region A. Layer 2 is decoded considering layer 1 as interference in a contained region B, and region C is the joint decoding region [14]. If the decoding here fails then the decoding with single layer is attempted.

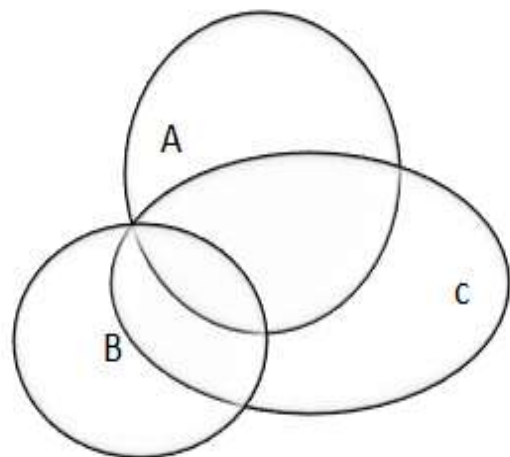


Figure 3: Two-Layers Decoding approach

The transmitted signals with the coded layers S_1 and S_2 at the time 't' is given by,

$$\begin{bmatrix} x(2t) \\ y(2t) \\ x(2t+1) \\ y(2t+1) \end{bmatrix} = M \cdot \begin{bmatrix} S_1(2t) \\ S_2(2t) \\ S_1(2t+1) \\ S_2(2t+1) \end{bmatrix} \text{ where } M = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

The diagonal permutation technique achieves higher efficiency with the straight forward and less complex implementation compared to Hadamard permuted implementation.

Techniques/ Algorithms	Parameters			
	Channel knowledge required	Intra-Cell Interference (ICI)	Overhead Analysis	Design Objective
Multi-Layer Precoding	Less channel knowledge is needed	Closed loop spatial multiplexing	Minimal overhead with interference elevation covariance	Achieves clear gains
Multi-Layer HARQ	CSI is not mandatory	Open loop spatial multiplexing	Broadcasting approach is used to reduce the overhead	Reduced delay
Layered Multi-paths information based CSI Feedback (LMFIF)	Novel CSI feedback scheme channel direction magnitude and phase is employed	Open loop spatial multiplexing	Only the phase weight is updated frequently reducing the overhead	Achieve higher spectrum efficiency
Multi-Layered Rate Control (MLRC)	Scheduling and SNR information	Transmit Diversity	Overhead is reduced with collaborative levels	Improves the cell-edge performance UE
Multi-layer MIMO with diagonal precoding technique	Requires channel state information (CSI) at the receiver end	Closed loop spatial multiplexing	Overhead is reduced to half with CSI at receiver	Broadcasting gain over outage is reduced.

3. Conclusion

In this paper various multi-layer MIMO techniques for the LTE-Advanced network has been reviewed. It has been analyzed that multi-layer techniques with minimal overhead is proven to be successful in various systems. There always exists the natural harmony between the MIMO and Network Coding techniques. Designing an optimal multi-layer MIMO algorithm enhances the spatial diversity in the system. When multi-layer MIMO is incorporated with the appropriate Network Coding for the minimized time slot enhances the overall system performance and is the current research topic which requires an extra focus from the researchers for the advanced communication system.

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