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MIMO Techniques in Downlink LTE Networks: A Review

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Abstract - 3rd Generation Partnership Project (3GPP) has completed the Long Term Evolution (LTE) standard. Majority of world's operators and vendors are already dedicated to LTE deployment, making the LTE market in the upcoming evolution to 4G wireless communication systems. One of the major tools in the toolbox of LTE as far as radio features are concerned is Multiple Input Multiple Output (MIMO) antennas. MIMO helps radio systems to gain significant performance gains by using multiple antennas at their transmitters and receivers. Multiple input multiple output (MIMO) technologies introduced in LTE are such as spatial multiplexing, transmit diversity, and beamforming are key components for providing higher peak rate at a better system efficiency, which are necessary for supporting future broadband data service over wireless links. In this paper, performance of different MIMO techniques used in uplink and downlink are discussed.

Index terms- Long term evolution (LTE), Multiple input multiple output (MIMO), 3rd Generation Partnership Project (3GPP), LTE-Advanced (LTE-A).

I. INTRODUCTION

The multimedia communications are becoming increasingly popular, mobile communications are required to reliably support higher data rate transmissions. Multiple input multiple output (MIMO) has been considered as an emerging technology to meet the requirement for higher data rate and good coverage of the network cell without significantly changing the bandwidth used and the transmit power of the base station [1], as it has been showed that the capacity of the channel is increased by using MIMO as in this multiple number of data streams can be delivered over single time frequency resource as it can form different spatial layers. A lot of wireless standards that are recently specified are almost ready to support this technology [2].

The antennas used in MIMO technologies are beneficial to the base station in a number of ways as it provides benefits in terms of working in poor Poor channel condition and its reliable working by increasing the spectral efficiency. So, in this way the data rate available to individual users increases and increasing the overall performance of the system. As MIMO is a complex technology, there are a number of variations made from its basic principle. The LTE standard mentioned support number of different modes that are used in the operation of MIMO which are required in different radio channel conditions like the dynamic switching between different modes for different conditions. The principle of MIMO is reviewed here along with some of the basic practical benefits and problems faced in terms of implementation of LTE MIMO. The multiplexing and diversity gains are facilitated by using Multiple input multiple output (MIMO) technology. A lot of researchers are attracted towards MIMO because of the improvement in the performance without using more transmit power and bandwidth. But, the gain achieved is limited due to the complexity of MIMO [3]. An alternative is multiuser MIMO (MU-MIMO) where there are number of different individual antenna users that are served by transmitter having many antennas. If this is compared to single antenna MIMO its performance in terms of gain is better. Orthogonal frequency division multiple access (OFDMA) is considered better for high speed wireless multiuser communication networks, such as 3GPP Long Term Evolution Advanced (LTE-A) [4,5].

II. MIMO CLASSIFICATION WITH RESPECT TO ANTENNA CONFIGURATION

In MIMO, the basic communication systems are divided into four categories as considering the number of antennas in the transmitter and the receiver as given below:

1. SISO – Single Input Single Output system – 1 Tx antenna , 1 Rx antenna
2. SIMO – Single Input Multiple Output system – 1 Tx antenna, *NR* Rx antennas (*NR*>1)

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3. MISO – Multiple Input Single Output system – *NT* Tx antennas, 1 Rx antenna (*NT*>1)
4. MIMO – Multiple Input Multiple Output system – *NT* Tx antennas, *NR* Rx antennas (*NT*, *NR*>1).

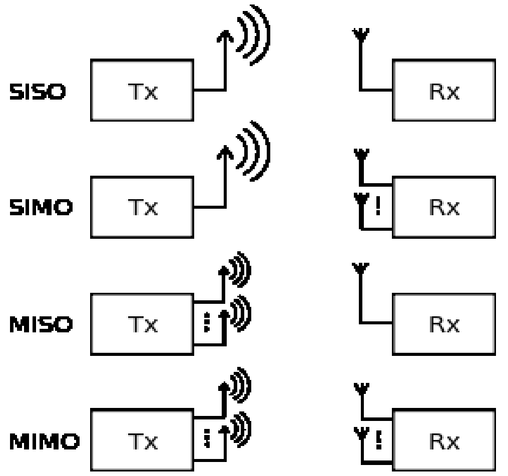

Fig. 1 Types of Systems considering number of antennas

III. MIMO OPERATION

Fig. 2 shows an example of MIMO operation using two transmit antennas and four receive antennas, which is generally known to as 2×4 MIMO. MIMO can achieve better performance in a condition when the radio waves are facing scattering and multipath propagation as compared to a situation when there is a single antenna using same power. With this placement of antennas as given in this example, the throughput becomes double between the transmitter and receiver [6].

In case of complex environment of MIMO having radio propagation, the benefit can be achieved if coding is done at the transmitter and signal is processed to the receiver.

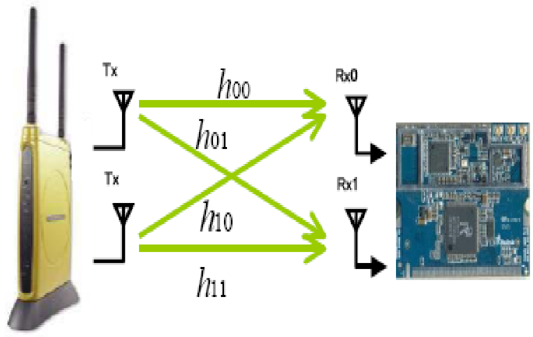

Fig. 2 4X2 MIMO Operation

MIMO is a major element of the LTE system design and 2X2 MIMO is supported in 3GPP release 8 when initially LTE standards are defined and introduced in both uplink and downlink transmission. As developments are made in recent technological advances to 3GPP release 11 now, LTE Advanced is introduced and it can support 8X8 MIMO in downlink transmission and 4X4 MIMO in uplink transmission. The different modes of operation and techniques used increases the flexibility of MIMO like spatial diversity, open and closed loop spatial multiplexing and closed loop multi-user MIMO, and switching can be done between different modes under different conditions [7]. The algorithms used for making are not standardized, which provides opportunities for equipment manufacturers and network operators to differentiate their implementations.

IV. MIMO TECHNIQUES IN DOWNLINK

1. SPATIAL DIVERSITY

Different channels can be created between transmitter and receiver for independent transmission by using multipath transmission by using which different signal streams can be transmitted simultaneously as shows in Fig. 3. The signal can be extracted at the receiver end by using suitable coding techniques and proper processing of the signal. The throughput achieved by each user is increased as well the by multiplex data received from multiple users known as MU-MIMO by using this method [8]. As more and more channels can be multiplexed this will correspond to the lesser number of antennas that can be used at the transmitter and receiver side. As in example given here that if the radio conditions are suitable then it can transmit two different transmissions [9]. The data rates achieved can be doubled by using this technique.

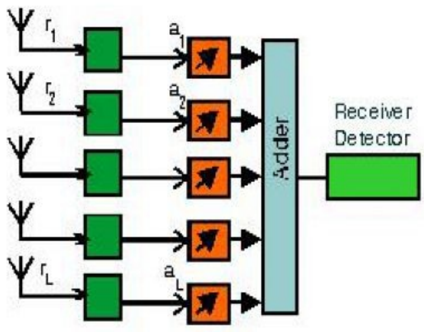

Fig. 3 Spatial Multiplexing

2. CLOSED LOOP FEEDBACK AND PRECODING

In this method or technique, the transmitter takes benefit of the information that it is receiving from the receiver about the channel. The modification in

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the coding can be done by the transmitter according to the channel characteristics if feedback can be made available and this can be done simply to improve the performance and to minimize the requirement of signal processing at the receiver. [10]. The codebook based precoding uses fixed codebook at both transmitter and receiver and loaded with set of vectors and metrics and considered as a very major technology adopted by LTE. It is necessary to achieve flexible support for different data streams and antenna configurations along with higher precoding gain and less feedback overhead for designing this coding. This method of codebook generation provides detail illustration in LTE and further improvement in wireless communication can be made in LTE-Advanced (LTE-A) [11, 12].

Codebook index	Number of layers	
	1	2
0	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\j & -j\end{bmatrix}$
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	-

Table 1 Codebook for two antennas

V. CONCLUSION

In this paper, the different MIMO features of LTE, which are downlink spatial diversity, closed-loop rank-1 precoding are described with technical backgrounds for specifying those technologies. Uplink feedback mechanisms for support of downlink MIMO technologies can also described to provide better understanding about LTE system operation. In addition, the MIMO schemes being studied for LTE- Advanced can also be used.

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