Performance Analysis of various MIMO Schemes in LTE Downlink

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ABSTRACT
This Paper aims at evaluating the performance of 3GPP Long Term Evolution (LTE) Downlink system under Urban Microcell Scenario for different MIMO transmission schemes. The performance parameters such as, Bit Error Rate (BER) and the Data Throughput are reported in terms of Signal to Noise Ratio (SNR) for different types of transmitting antenna and Modulation scheme. Transmit diversity scheme known as Space Frequency Block Codes (SFBC) and Open Loop Spatial Multiplexing (OLSM) scheme are considered in the evaluation. The investigations reported in this paper helps in estimating the optimum switching conditions between two MIMO approaches for fixed antenna spacing at transmitter and receiver.

Keywords
MIMO, BER , Spatial Multiplexing , Transmit Diversity.

1. INTRODUCTION
Third Generation Partnership Project Long Term Evolution (3GPP LTE) promises high peak data rates, low latency and delay, low error rates such that modern users and network applications have become increasingly dependent on these requirements for efficient functionality and performance [1]. LTE leverages on a number of technologies namely Multi Input Multiple Output (MIMO) antennas , Orthogonal Frequency Division Multiplexing Access (OFDMA) at the downlink, support Quadrature Phase Shift Keying (QPSK), 16 Quadrature Amplitude Modulation (16QAM), and 64QAM. OFDMA at downlink is well suited to achieve high peak data rates in high-spectrum bandwidth [2].

MIMO is one of the crucial enabling technologies in the LTE system to achieve the required peak data rate and the increase of the channel capacity. It involves the use of multiple antennas at the transmitter, receiver or both. There are different combinations of transmission and detection schemes that can be implemented to achieve different purposes in functional and performance terms. Future wireless systems will employ multiple antennas at both transmitter and receiver to improve quality, capacity, and reliability [3].

With the advent of MIMO, a choice needs to be made between transmit diversity techniques, which increase reliability (decrease probability of error), and spatial multiplexing techniques, which increase rate but not necessarily reliability [4]. Since practical systems make some trade-off between rate and reliability, it is unclear how to choose between spatial multiplexing or MIMO diversity for a given application. The present paper summarizes the studies undertaken pertaining to 2x2 MIMO for LTE downlink standard. In this paper we consider the multiplexing-diversity tradeoff from the point-of-view of Modulation scheme and type of transmitting antenna with variation in SNR. This paper work evaluates the performance of LTE downlink with two major MIMO techniques i.e. Transmit Diversity and Spatial Multiplexing in terms of different types of Transmitting Antennas like Omni Directional and Sectorial Antenna and Modulation schemes viz 16 QAM and 64 QAM.

2. MIMO SYSTEM
The hybridization of multiple Input Multiple Output (MIMO) technologies with LTE has generated features such as spatial multiplexing, transmit diversity, and beam forming. It offers higher data rates, lower latency and greater spectral efficiency than previous technologies to support future broadband data service over wireless links [5].

MIMO systems may be implemented in a number of different ways to obtain either a diversity gain to combat signal fading or to obtain a capacity improvement. In Transmit Diversity a single stream of data is assigned to the different layers and coded using various methods. In LTE for transmit diversity operation the Space Frequency Block Code (SFBC) is used. SFBC is based on the well-known Space Time Block Codes (STBC), also known as Alamouti codes [6]. STBC achieves robustness through temporal diversity by using different subcarriers for the repeated data on each antenna. Spatial multiplexing, on the other hand, is an approach where the incoming data is divided into multiple sub streams and each sub stream is transmitted on a different transmit antenna [7,8].

3. SYSTEM SETUP
A 2X2 MIMO LTE Downlink is developed using various building Blocks using Agilent's SystemVue and its Channel Builder tools. LTE Downlink configuration for MIMO is assumed as baseline configuration, i.e. 2 transmit antennas at the base station and 2 receive antennas at the terminal side. A typical urban microcell propagation scenario is modeled as high rise buildings and down town streets with base station antenna height of 10 meters. The mobile station height is assumed to be 1.5 meters. The urban microcell geometry is as shown in figure 1[9]. The resultant signal at the receiver is the vector sum of multiple rays reaching through multiple reflections off the building walls. The main street and perpendicular streets length are kept at 500 meter each. Minimum mean square error (MMSE) detection Technique is used at receiver.

The modulation type supported is 16 QAM and 64 QAM. The transmitter employs two types of Antennas viz. Omni Directional and 3-Sector antenna. The speed of mobile receiver is kept fixed at 20Km/hr. The key system parameters are tabulated below in table 1.

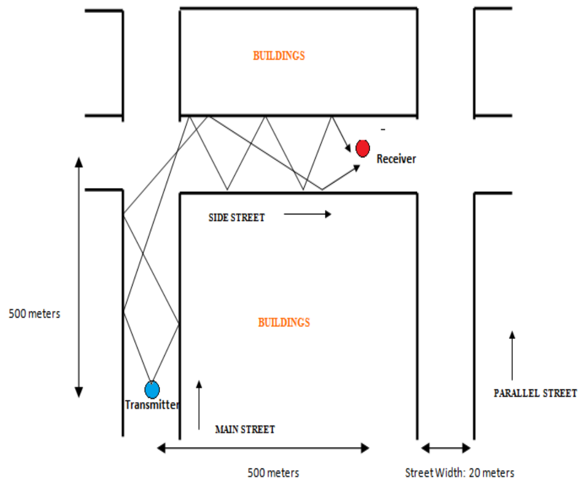

Fig 1 : Geometry of Urban Microcell

Table 1: System Parameters

Parameters	Specifications
Mode	Transmit Diversity / Open loop Spatial Multiplexing
System	Downlink
Duplex Scheme	Frequency Division Duplex
Multiple Access	Orthogonal Frequency Division Multiple access
Transmitting Antenna	Omni Directional/ 3 Sector
Receiving Antenna	Omni Antennas
Frequency	2.4 GHz
Modulation Scheme	16QAM (½ Code rate) / 64 QAM (½ Code rate)
Detection scheme	Minimum mean square estimation
Channel Bandwidth	10 MHz
Transmit antenna height	10 meters
Receiver antenna height	1.5 meters
Transmit power	10 dBm
Main Street	500 meters
Perpendicular Street	500 meters
No. of frames	100
Base Station Antenna Separation	2λ
Mobile Station Antenna Spacing	0.5λ

4. RESULTS & DISCUSSIONS

The performance of LTE Downlink with multiplexing and Diversity MIMO techniques is studied in terms of the Bit Error Rate (BER) and Throughput for two major types of Antenna at transmitter viz. Omni Directional and 3-Sector antenna with 16QAM and 64 QAM modulation scheme.

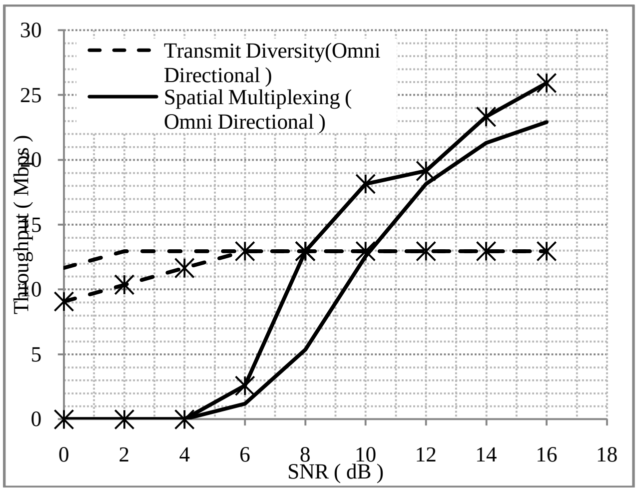

Fig.2 Throughput versus SNR for SM and TD mode using 16 QAM

Figure 2 depicts the throughput versus SNR curves using Omni Directional antenna and 3 Sector antennas at transmitter for 16 QAM modulation scheme. It is observed that for Low SNR range (<=6dB) TD mode outperforms SM mode with peak throughput of 12.96 Mbps. In TD mode Omni-directional antenna provides a marginal improvement of about 3% over 3 Sector antennas in terms of throughput. For moderate SNR range (>=6dB & <=10dB) SM exhibits good performance with average throughput of 10 Mbps. Moreover, 3- Sector provides 2 dB gain (40% throughput improvement) over Omni-Directional antenna. For high SNR range (>=10 dB) throughput for SM improves and attain maximum value of 25.92Mbps at around 16dB.

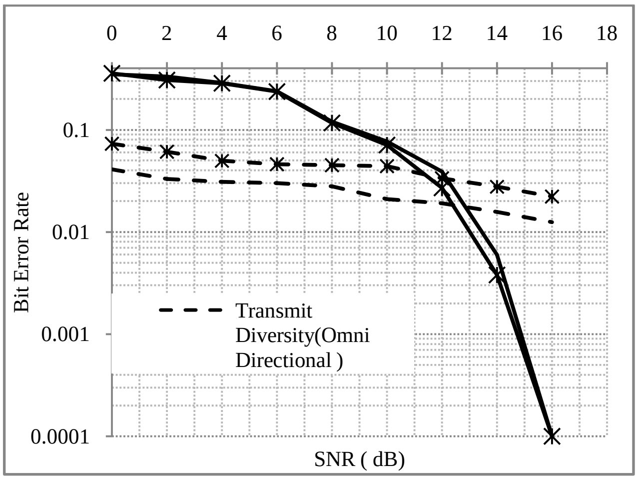

Fig.3 BER versus SNR for SM and TD mode using 16 QAM

Figure 3 shows the BER versus SNR curves using Omni Directional antenna and 3 Sector antennas at transmitter for 16 QAM Modulation. The figure reveals that TD has better error rate performance (< = 5%) than SM to SNR value of 12 dB. 3-Sector has slightly improved BER than Omni-Directional antenna in TD mode. An alluring observation is that above 12 dB SM has a fast decay or roll off compared to TD. Error rates in SM remain almost similar for both antenna types.

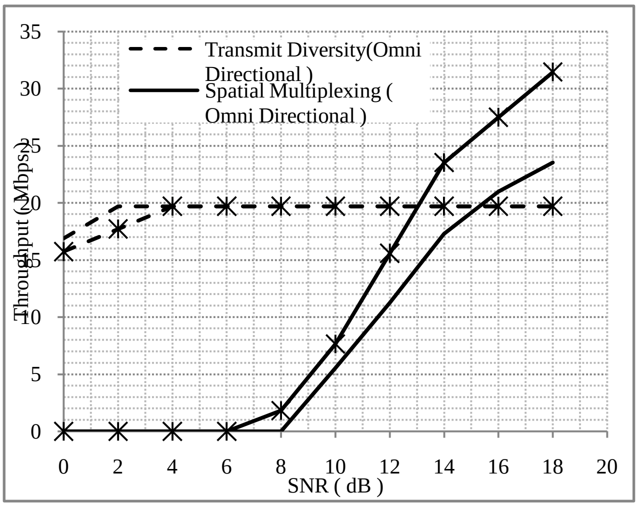

Fig.4 Throughput versus SNR for SM and TD mode using 64 QAM

Figure 4 depicts the throughput versus SNR curves using Omni Directional antenna and 3 Sector antennas at transmitter for 64 QAM modulation scheme. It is observed that increasing the order of modulation increases the peak throughput of the system. For Low SNR range SM shows insignificant results.

TD achieves maximum throughput of 19.7 Mbps irrespective of type of antenna. For moderate SNR range the throughput of SM mode starts improving but its value remains lower to that of TD mode. Remarkably at high SNR range, in SM mode 3 Sector provides exhibits better performance with 4 dB SNR Gain over Omni-directional antenna.

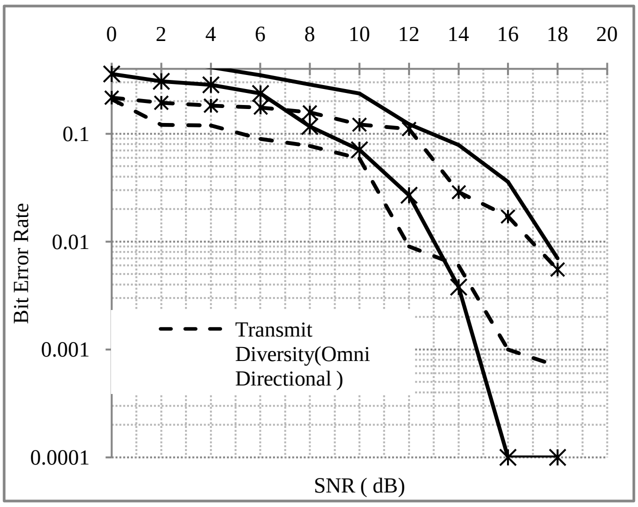

Fig.5 BER versus SNR for SM and TD mode using 64 QAM

Figure 5 depicts the BER versus SNR curves using Omni Directional antenna and 3 Sector antennas at transmitter for 64 QAM modulation scheme. It reveals that due to increase in order of modulation all modes exhibits high error rats at low SNR range. One critical observation is that for moderate SNR range the error rates of SM with 3- Sector shows a abrupt fall in BER. At a reference error rate of 1% 3-Sector antenna in SM mode provides 0.5 dB gain over TD mode with omnidirectional antenna and 4 dB gain over TD mode with 3-Sector antenna.

5. CONCLUSION

In this paper, an effective study, analysis and evaluation of the LTE downlink Urban Microcell Scenario with different MIMO techniques has been carried out. The performance is evaluated with respect to two definitive metrics namely throughput and BER, considering the use of different types of antennas namely 3-Sector and Omni Directional at the transmitter with 16QAM and 64 QAM modulation scheme.

Figure 6 shows the performance comparison of types of antennas for MIMO Diversity and Multiplexing mode as a function of SNR using 16 QAM modulations. It is observed error rate of TD is generally better than SM at low SNRs (<8dB), but later becomes equivalent at higher SNR values . MIMO SM and TD curves cross at approximately SNR= 10 dB in terms of throughput. Use of 3-Sector antenna is preferred in SM mode for high SNR range (SNR >8dB) . In contrast to SM, Omni Directional antenna is suggested in TD mode for Low and moderate SNR range (< 8dB).

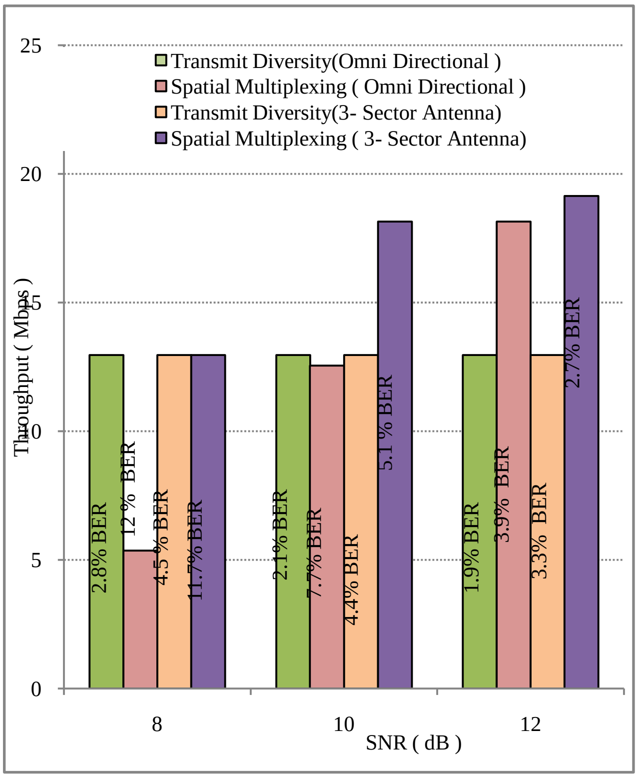

Fig 6: Throughput v/s SNR for TD and SM Mode using 16 QAM modulation scheme

Figure 7 shows the performance comparison of types of antennas for MIMO Diversity and Multiplexing mode as a function of SNR using 64 QAM modulations. For 64 QAM, there is virtually no performance at low SNRs (< 10 dB). It reveals that when high order modulation is utilized, the switching from TD to SM shifts to 14 dB from that of 10 dB in 16 QAM. Omni directional antenna in TD mode and Sector antenna in SM mode show similar variations between 10dB SNR to 12dB SNR. Above 12 dB 3-Sector Antenna in SM mode outperforms all other modes.

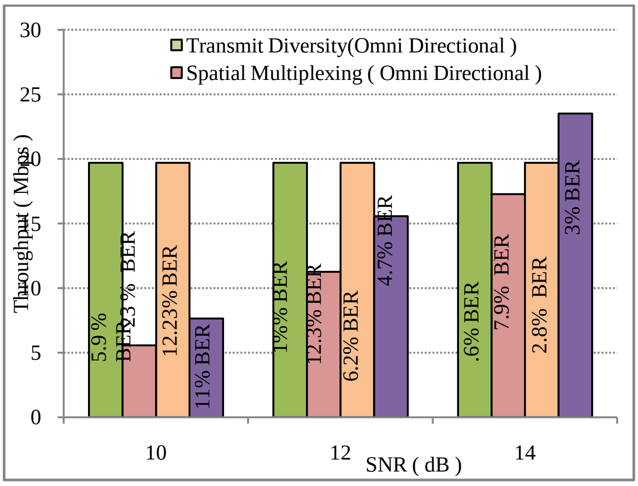

Fig 7: Throughput v/s SNR for TD and SM Mode using 64 QAM modulation scheme

It is suggested that for both modulation schemes Omni directional antenna is preferred in TD mode and 3- Sector Antenna in SM mode. Spatial multiplexing is ideal for achieving very high peak rates, while transmit diversity is a valuable scheme to minimize the rate of bit error occurrence thereby improving signal quality. It is therefore suggested that transmit diversity be utilized whenever channel conditions deteriorates that for Low SNR Range and multiplexing for High SNR Range.

6. ACKNOWLEDGMENT

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