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The Study and Analysis of Effect of Multi-Antenna Techniques on LTE network with Different Bandwidth Configurations in the Downlink

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ABSTRACT

Long Term Evolution (LTE) system adapts advanced Multiple Input Multiple Output (MIMO) antenna techniques on both uplink and downlink to achieve high peak data rates and higher system throughput. This enables LTE to support multimedia applications beyond web browsing and voice, which demands higher bandwidth configurations. LTE employs Orthogonal Frequency Division Multiple Access (OFDMA) in downlink to support spectrum flexibility in order to use upto 20MHz system bandwidth to improve the system throughput and robustness. Therefore the combined study of multi-antenna techniques and spectrum flexibility usage on the performance of LTE system becomes vital. Hence in this paper, an attempt has been made to evaluate the performance of different multi-antenna techniques with various system bandwidth configurations from 1.4MHz to 20MHz using QualNet 5.2 network simulator. The multi-antenna techniques considered for performance evaluation are Single Input Single Output (SISO), Multiple Input Single Output (MISO) and Multiple Input Multiple Output (MIMO). The performance metrics such as aggregate bytes received, average throughput, average delay and average jitter are considered for simulation study.

Keywords - **LTE, SISO, MISO, MIMO, OFDMA**

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1. INTRODUCTION

Long Term Evolution (LTE) is an emerging 4G broadband wireless communication system developed to support high peak data rates with quality of services (QoS), high spectrum efficiency, flexibility of spectrum usage, increased capacity, multimedia services etc [1, 2]. High peak data rate and higher spectrum efficiency can be achieved by the integration of MIMO and OFDMA technology using space time block code (STBC) system [3, 4]. Hence LTE system employs MIMO antenna techniques in both uplink and downlink and Orthogonal Frequency Division Multiple Access (OFDMA) in downlink. MIMO system is one of the advanced multi-antenna techniques which carry more than one spatial data stream over one frequency simultaneously to achieve high peak data rates suitable for Internet and multimedia services [5, 6]. The OFDMA is a spectral efficient multicarrier modulation scheme in which available system bandwidth is divided into several parallel closely spaced orthogonal subcarriers of 15KHz. Using OFDMA, radio resources are allocated to multiple users based on frequency (subcarriers) and time (symbols) domain. A unit of transmission radio resource consisting of 12 subcarriers in the frequency domain and 1 time slot (0.5ms) in the time domain to makes a Resource Block (RB) in the LTE system. Hence a RB occupies 180KHz in the frequency domain and 0.5 ms in the time domain [1, 7]. This allows LTE network to dynamically adjust the bandwidth usage according to the system requirements. The number of RBs are available for transferring data are depends on the transmission bandwidth, the available RBs for different bandwidth configurations is listed in Table 1[1]. Therefore, LTE network deployed with higher bandwidth configurations provides high peak data rate and higher system throughput due to the availability of more number of RBs for transferring data [8]. Also OFDMA assigns each user to required bandwidth for their transmission and

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the unassigned subcarriers are off to reduce power consumption and interference [9]. Further with OFDMA high spectrum efficiency can be achieved due to multiuser diversity in a frequency selective channel. Thus the combination of MIMO and OFDMA scheme can support multimedia applications such as high definition (HD) video, video conferencing, video streaming, teleconferencing, moving pictures, blogging, interactive gaming, voice over IP (VOIP) etc with reliability in the LTE system.

Table1: Channel bandwidth with Resource blocks

Channel bandwidth (MHz)	1.4	3	5	10	15	20
Number of resource blocks	6	15	25	50	75	100

The rest of this paper is organised as follows. Section 2 discusses SISO, MISO, and MIMO antenna techniques. Simulation studies are given in section 3 and Section 4 concludes the paper.

2. MULTI-ANTENNA TECHNIQUES

Multi-antenna techniques are employed in LTE systems to achieve high data rates, spectral efficiency, system capacity (number of users), and coverage. Multi-antenna systems can be realized by using multiple antennas at the transmitter and receivers with an appropriate channel coding/ decoding scheme. By increasing the number of transmit and receive antennas it is possible to linearly increase the throughput of the channel with every pair of antennas added to the system. Depending on the number of antennas at transmitter/receivers and coding/decoding schemes used, MIMO techniques are classified into several modes such as SISO, SIMO, MISO and MIMO. In this paper the system performance evolution of SISO, MISO and MIMO antenna techniques are considered. Figure 1 gives the system model of MIMO which consists of $\mathbf{n_T}$ transmission antennas and $\mathbf{n_R}$ receive antennas and a matrix channel which consists of all $\mathbf{n_T}\text{x}\mathbf{n_R}$ paths between them [10].

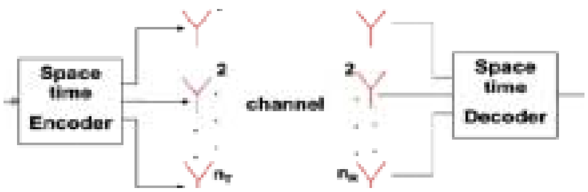

Figure 1. MIMO system model

2.1 SINGLE INPUT SINGLE OUTPUT (SISO):

A SISO system employs single antenna at the transmitter and receiver side. Due to single transmitter and receiver antenna it is less complex than MIMO, but reduction in data speed. The SISO systems are vulnerable to problems caused by multipath effects. Especially when an electromagnetic field is met with the obstructions such as hills, canyons, buildings, and utility wires, the wave fronts are scattered, and thus they take many paths to reach the destination. The late arrival of scattered portions of the signal causes problems such as fading, cliff effect, and intermittent reception [11].

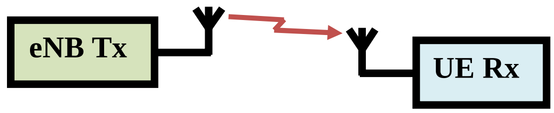

Figure 2: SISO - Single Input Single Output

2.2 MULTIPLE INPUT SINGLE OUTPUT (MISO):

A MISO system employs two transmitting antenna and one receiving antennas, it is also termed as transmit diversity. Transmit diversity techniques are used to reduce the effect of multipath fading and interference [12]. The transmit diversity based on Space Frequency Block Coding (SFBC) scheme which uses two transmit antennas to improve the signal quality at the receiver. However, the enhanced performance depends on the channel state information (CSI) available at the transmitter. The perfect CSI transmit beam forming for maximizes the signal-to-noise-ratio at the receiver [11, 13].

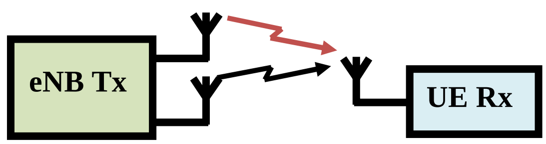

Figure 3: MISO- Multiple Input Single Output

2.3 MULTIPLE INPUT MULTIPLE OUTPUT (MIMO):

A MIMO enables multiple antennas at the transmitter and receiver to support a variety of signal paths to transfer more data in less time and it significantly increasing the bandwidth efficiency of the systems. The Open Loop Spatial Multiplexing (OLSM) is one of the MIMO techniques used in downlink transmission modes to support the higher data rate in LTE system. OLSM consist of two transmit antennas at the eNB and two receive antennas at the UE (2x2 antenna configuration), sending either one or two simultaneous data streams from the eNB to the UE [14]. In a 2x2 antenna configuration, sending one data stream is known as Rank1 MIMO [14] and sending two data streams is known as Rank2 MIMO. The number of independent data streams that can be sent to the UE is restricted to either one or two data stream, even if the number of transmit antennas at the eNB is increased to four. So a 2x2 configuration does not impose any overt simplification [15].

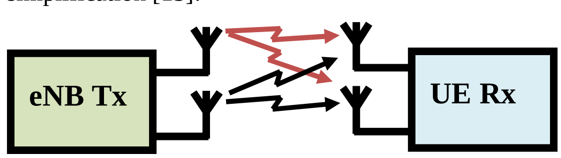

Figure 4: MIMO- Multiple Input Multiple Output

3. SIMULATION STUDIES AND RESULTS

The effect of multi-antenna techniques such as SISO, MISO and MIMO in the LTE downlink for different bandwidth configurations is evaluated using QualNet 5.2 simulator by considering an eNB and 20 UEs in a single cell environment. In this scenario, a downlink CBR connection of data rate 3.2768Mbps is established between an eNB and each UEs. Further two-ray path loss model with constant shadowing of mean 4dB is considered for the simulation studies and the remaining simulation parameters considered are listed in Table 2.

Table 2. Simulation Parameters

Property		**Value**
Simulation-Time		30S
Simulation-Area		1.5Km X 1.5Km
Downlink-Channel-Frequency		2.4GHz
Uplink-Channel-Frequency		2.5GHz
Propagation-Model		Statistical
Channel-Fading-Model		Rayleigh
Propagation-Speed		3.2768 Mbps
MAC-LTE-UE-Scheduler-Type		Simple-Scheduler
MAC-LTE-eNB-Scheduler-Type		Round-Robin
PHY-LTE-Tx-Power		23
Antenna-Model		Omni directional
Channel-Bandwidth		1.4, 3, 5, 10, 15 and 20MHz
PHY-LTE-Num-Tx-Antennas	SISO	1
	MISO	2
	MIMO	2
PHY-LTE-Num-Rx-Antennas	SISO	1
	MISO	1
	MIMO	2

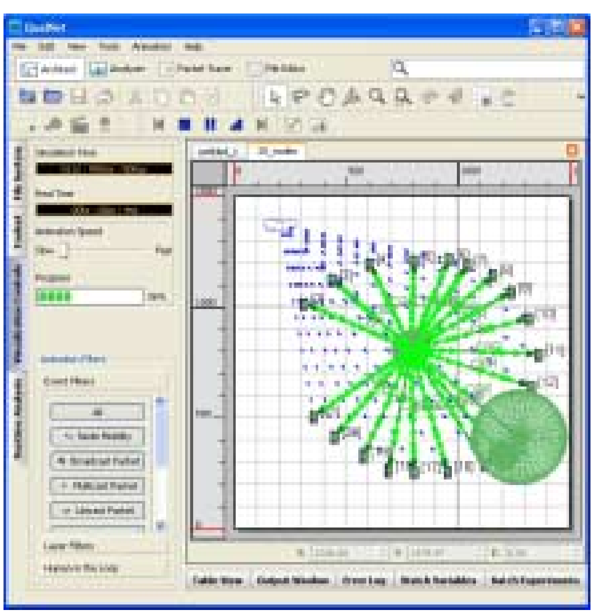

Figure 5. Snapshot of the Scenario designed for simulation study

The snapshot of the scenario designed for the simulation studies using QualNet 5.2 simulator is shown in Figure 5. Initially simulation studies are carried out by considering SISO multi-antenna technique with a system bandwidth of 1.4MHz. The performance metrics such as aggregate bytes received, average throughput, average delay and average jitter are evaluated. Simulation studies are repeated for 3MHz, 5MHz, 10MHz, 15MHz and 20MHz system bandwidth.
Simulation studies are also repeated by considering the MISO and MIMO multi-antenna techniques.

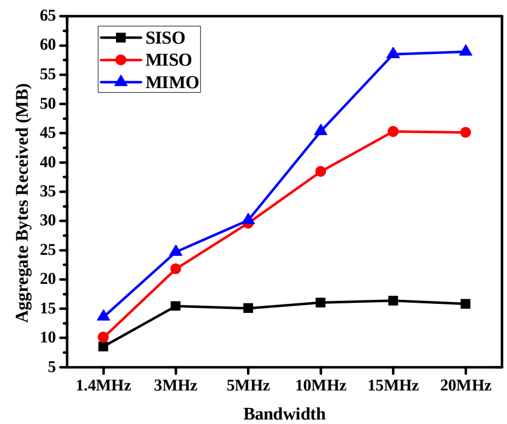

Figure 6. Aggregate bytes received for different bandwidth configurations

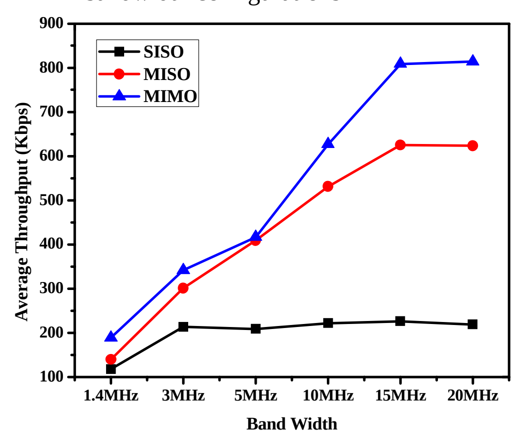

Figure 7. Average throughput for different bandwidth configurations

Figure 6 and 7 shows aggregate bytes received and average throughput performance for SISO, MISO and MIMO multi-antenna techniques for different system bandwidths from 1.4MHz to 20MHz. It is depicted from Figure 6 and 7 that the aggregate bytes received and average throughput increases with increase in bandwidth, since the increase in system bandwidth increases the number of RBs and hence more RBs are available for transferring data [16, 17]. Further, it is observed from Figure 6 and 7 that MIMO shows better aggregate bytes received and average throughput performance. Since in

MIMO, multiple transmit and receive antennas create multiple parallel channels using which multiple data streams are sent simultaneously [10, 18]. In MISO, data stream is sent over one channel and its conjugate is sent over the other which increases transmit diversity rather than throughput, hence aggregate bytes received and average throughput is lesser than MIMO [19]. The SISO shows least aggregate bytes received and average throughput system performance, since it employs single antenna for transmission and reception and hence only less numbers of available RBs are utilized for transferring data.

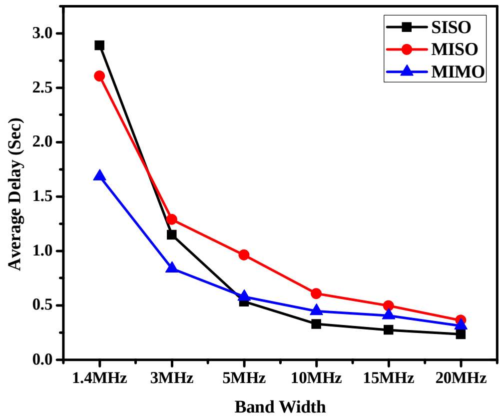

Figure 8. Average Delay for different bandwidth configurations

Figure 8 illustrates the average delay performance for SISO, MISO and MIMO multi-antenna techniques for different system bandwidth from 1.4MHz to 20MHz. It is evident from Figure 8 that for all multi-antenna techniques average delay decreases for increase in system bandwidth. Since the increase in system bandwidth increases the number of RBs and hence more RBs are utilized for transferring data leading to decrease in average delay [19]. It is also observed from Figure 8 that delay performance for MIMO is better up to 5MHz as compared to MISO and SISO. Since in MIMO several data streams are transmitted by the base station over the same carrier simultaneously and hence delay occurred is less [20]. The SISO performs better than MISO and MIMO at higher bandwidth due to its less complexity [11]. The MISO performs least at higher system bandwidth configurations due to transmit diversity [11].

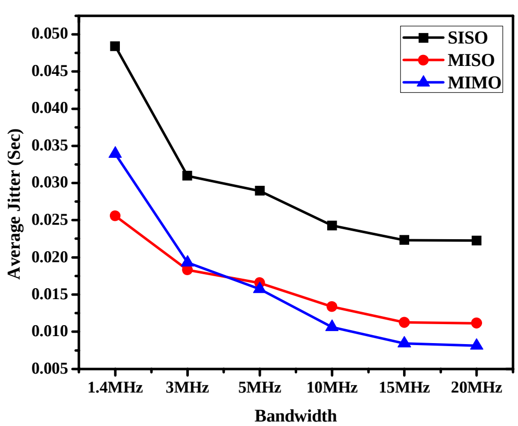

Figure 9. Average Jitter for different bandwidth configurations

Figure 9 shows the jitter performance for SISO, MISO and MIMO multi-antenna techniques for different system bandwidth from 1.4MHz to 20MHz. The average jitter performance for SISO, MISO and MIMO decreases for increase in system bandwidth. Since the increase in system bandwidth increases the numbers of RBs for transferring data [19]. The average jitter performance is better for MIMO, Since in MIMO the multiple transmit and receive antennas create multiple parallel channels using which multiple data streams are sent simultaneously [10, 18].

4. CONCLUSION

In this paper, the effect of SISO, MISO and MIMO antenna techniques for different bandwidth configuration is compared through simulation studies considering aggregate bytes received, average throughput, average delay and average jitter as performance metrics. The simulation results show that the performance of MIMO scheme is better than SISO and MISO antenna scheme.

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