Performance Evaluation of Multi Antenna Techniques in LTE

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PERFORMANCE EVALUATION OF MULTI ANTENNA TECHNIQUES IN LTE

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ABSTRACT

High data rate requirements of the Long Term Evolution - Advanced (LTE-A) systems can be achieved by adopting advanced Multiple Input Multiple Output (MIMO) antenna techniques on both uplink and downlink. The LTE air-interface supports multiple-antenna transmit arrays and different modes of multiple antenna transmissions. In this paper, performance of different MIMO techniques is evaluated using QualNet network simulator. The MIMO techniques considered for performance evaluation are Single-Input/ Multiple-Output (SIMO), Open Loop Spatial Multiplexing (OLSM) and Space-Frequency Block Coding (SFBC). The performance metrics considered are throughput, delay and jitter.

KEYWORDS

LTE, LTE-A, MIMO, OLSM, SIMO, SFBC

1. INTRODUCTION

The increasing popularity of multimedia services in mobile communication demands higher data rate. Higher data rate can be achieved by increasing bandwidth and by using efficient antenna transmission techniques. Since bandwidth is limited in mobile communication, antenna transmission techniques play a vital role in achieving higher data rate. Multiple Input Multiple Output (MIMO) is one of the antenna transmission techniques which has been treated as an emerging technology to meet the demands of higher data rate and better cell coverage. MIMO structure successfully constructs multiple spatial layers where multiple data streams are delivered on a given frequency-time resource and linearly increases the channel capacity [1, 2].

Many of the recently specified wireless communications standards such as Wi-Fi, Long Term Evolution (LTE), Worldwide Interoperability for Microwave Access (WiMAX) and High Speed Packet Access+ (HSPA+) support MIMO techniques. With advanced MIMO techniques, LTE supports wireless broadband data service up to 300Mbps in the downlink and 75Mbps in the uplink [3]. MIMO also improves cell coverage and average cell throughput.

The aim of this paper is to study the performance of multiple antenna techniques such as Single Input/ Multiple Output (SIMO), Open Loop Spatial Multiplexing (OLSM) and Space-Frequency Block Coding (SFBC) with increasing the number of User Equipments (UE) in single cell scenario. This paper is organized as follows. Section 2 gives a brief insight on LTE overview. Section 3 discusses SIMO systems, OLSM and SFBC. Simulation studies are given in section 4 and Section 5 concludes the paper.

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2. LTE SYSTEM OVERVIEW

LTE is developed by Third Generation Partnership Project (3GPP) for providing true 4G broadband mobile access [3]. The architectural evolution of 3GPP LTE [4, 5] based on the functionality, the architecture is split into two parts: a radio access network called E-UTRAN (Evolved Universal Terrestrial Radio Access Network) and a core network called EPC (Evolved packet Core) (Figure1). The E-UTRAN supports all radio related services such as scheduling, radio-resource handling, retransmission protocols, coding and various multi-antenna schemes. It contains network elements called evolved NodeBs (eNBs), which provide E-UTRAN user plane and control plane termination towards the UE. EPC supports robust IP-based services with seamless mobility and advanced QoS mechanism. LTE has undergone many changes starting from the first version in release 8 to release 10 which is also known as LTE-Advanced (LTE-A). LTE-A has been approved by the International Telecommunication Unit (ITU) as a 4G technology. LTE air-interface supports both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes of operation. In TDD mode, several uplink/downlink allocations are allowed. The downlink of a LTE air-interface uses Orthogonal Frequency Division Multiple Access (OFDMA) and uplink uses Single Carrier Frequency Division Multiple Access (SC-FDMA). Table 1 gives the specifications of LTE. For enhancing air-interface capacity Link adaptation, Hybrid Automatic Repeat reQuest (HARQ) and various multiple antenna techniques are used [6].

Table 1. Performance Specifications

Metric	**Specifications**
Spectral Flexibility	1.4, 3, 5, 10, 15 and 20 MHz
Peak data rate	• Downlink (2 Channel MIMO): 100 Mbps • Uplink (Single Channel Tx): 50 Mbps (20 MHz channel)
Supported antenna Configurations.	• Downlink: 4x2, 2x2, 1x2, 1x1 • Uplink: 1x2, 1x1
Latency	• Control plane: Less than 100 ms to establish User plane • User plane: Less than 10 ms from User Equipment (UE) to server
Mobility	• Optimized for low speeds (0-15 km/hr) • High performance at speeds up to 120 km/hr • Maintain link at speeds up to 350 km/hr
Coverage	• Full performance up to 5 km • Slight degradation 5 km – 30 km
Spectrum efficiency	• Downlink: 3 to 4 times HSDPA Rel. 5 • Uplink : 2 to 3 times HSUPA Rel. 6

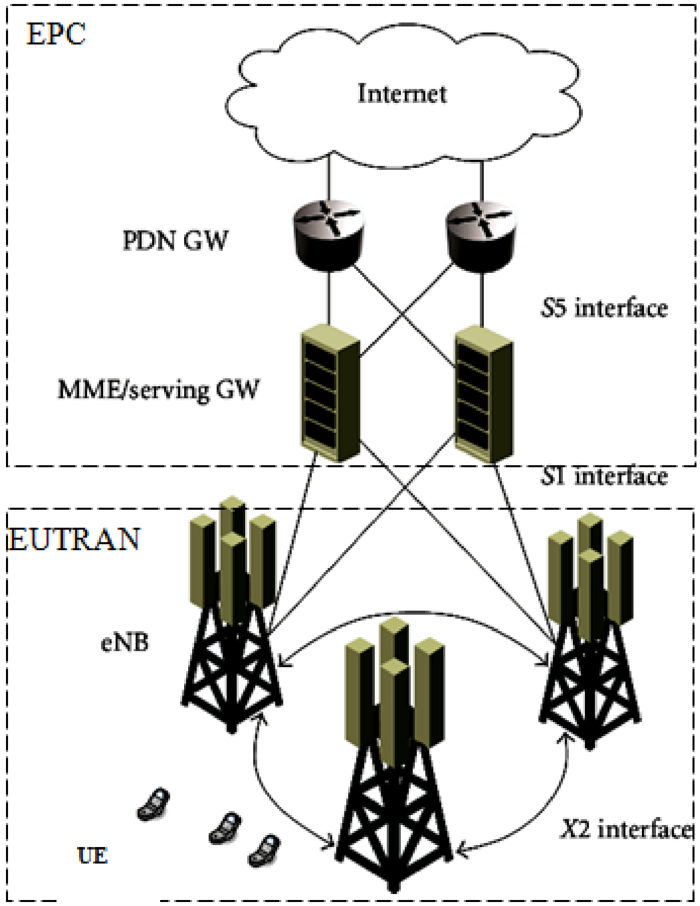


Figure 1. Simplified LTE architecture

3. MULTI-ANTENNA TECHNIQUES

Multi-antenna transmission techniques are used to improve system performance including system capacity (number of users), coverage, spectral efficiency and higher per-user data rates. MIMO can be realized by using multiple antennas at transmitter and receivers with an appropriate channel coding/decoding scheme. Depending on the number of antennas at transmitter/receivers and coding/decoding schemes used, MIMO techniques are classified into several modes (Table 1). Figure 2 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 $\mathbf{n_T}$x$\mathbf{n_R}$ paths between them. LTE supports different antenna configurations in both uplink and downlink (Table 1). The multi-antenna schemes for LTE downlink comprises of transmit diversity, open-loop and closed-loop spatial multiplexing, multi-user MIMO and beam-forming (Table 2) [7].

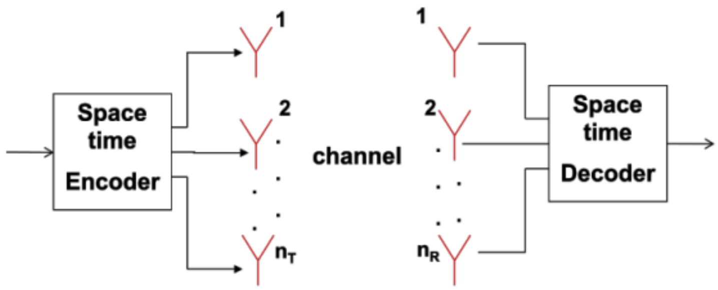


Figure 2. MIMO system model

Table 2. Supported Downlink Multi-Antenna Modes

<table>
<tr><th>Multiple antenna mode</th><th>Description</th><th>Number of eNB antennas</th></tr>
<tr><td>Single Antenna</td><td>None</td><td>1</td></tr>
<tr><td>Open Loop Transmit Diversity</td><td>SFBC</td><td rowspan="4">2,4</td></tr>
<tr><td>Open Loop Spatial Multiplexing</td><td>Large Delay-Cyclic Delay Diversity</td></tr>
<tr><td>Closed Loop Spatial Multiplexing (SU-MIMO)</td><td>codebook based</td></tr>
<tr><td>Multi-User MIMO</td><td>codebook based</td></tr>
<tr><td>Single-layer UE specific reference symbol based Beamforming (EBF)</td><td>reciprocity based (TDD only)</td><td>>1</td></tr>
</table>

3.1. Single Input Multiple Output (SIMO)

A Single Input Multiple Output (SIMO) system has one transmitting antenna and typically two receiving antennas. Transmitted signal from the single antenna is received independently by two receiving antennas and combined using either Maximal Ratio Combining (MRC) or Interference Rejection Combining (IRC).

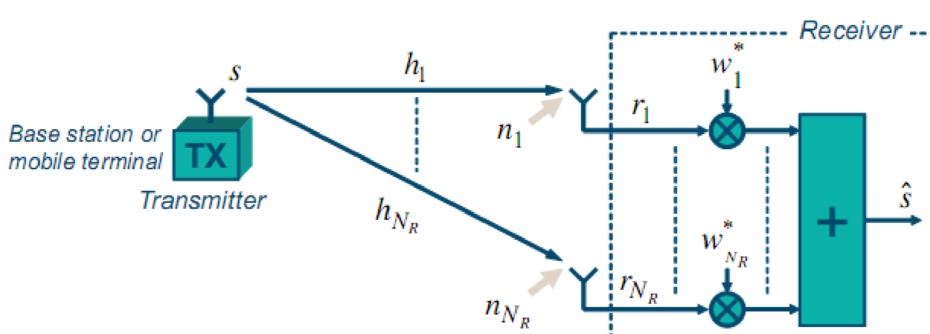


Figure 3. Linear receive-antenna combination.

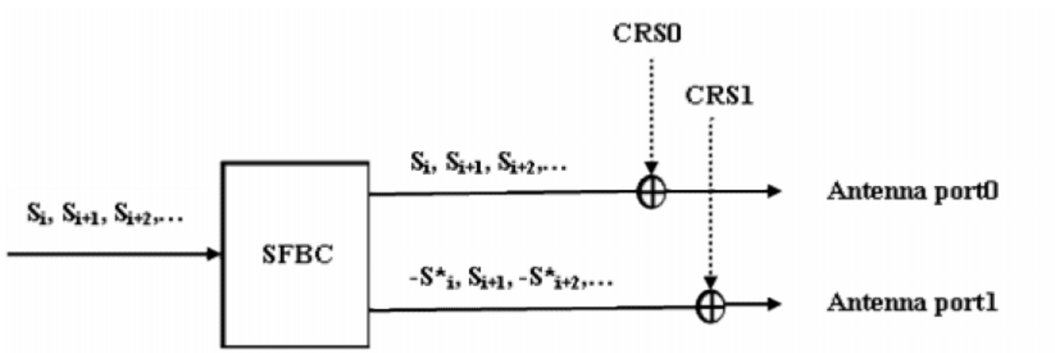
Figure 3 illustrates the basic principle of linear combination of signals r_1 to r_{NR} received at N_R different antennas. Here S is the transmitted signal, h_1 to h_{NR} are complex channel gains and n_1 to n_{NR} are noise elements impairing the signals received at the different antennas. The received signals are multiplied by complex weight factors w_1* to w_{NR}* before getting added up. For maximizing the signal to Noise Ratio (SNR), MRC is used in which weight vector w selected as $w_{MRC} = h$. MRC is an appropriate antenna combining strategy when the received signal is mainly impaired by noise. However in many cases of mobile communication, the received signal is mainly impaired by interference from other transmitters within the system rather than by noise. In a situation with a relatively large number of interfering signals of approximately equal strength, MRC is still a good choice as the overall interference will appear relatively “noise-like” with no specific direction of arrival. In case of a single dominating interferer or a limited number of dominating interferers, improved performance can be achieved using IRC in which the antenna weights are selected to suppress the interferer [8].

3.2. Open Loop Spatial Multiplexing (OLSM)

Open Loop Spatial Multiplexing (OLSM) is one of the downlink transmission modes that can support the higher data rate in current releases of LTE. 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 [9]. In a 2x2 antenna configuration, sending one data stream is known as Rank1 MIMO [9] 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 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 [10].

3.3. Space-Frequency Block Coding (SFBC)

In the case of two antenna ports, LTE transmit diversity is based on Space-Frequency Block Coding (SFBC). SFBC is the encoding scheme carried out in the frequency domains. Thus, space–frequency coding is applicable to OFDM and other “frequency-domain” transmission schemes. SFBC implies that two consecutive modulation symbols S_i and S_{i+1} are mapped directly to frequency-adjacent resource elements on the first antenna port (Figure 4). On the second antenna port the frequency-swapped and transformed symbols S_{i+1}*and S_i* are mapped to the corresponding resource elements, where “*” denotes complex conjugate [3].



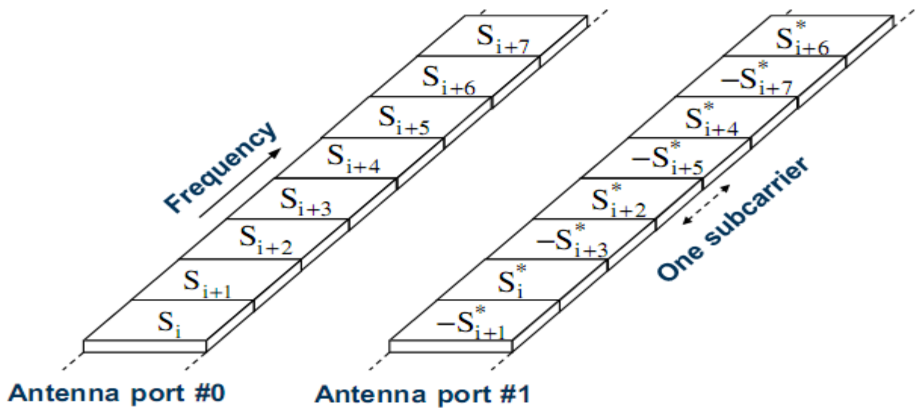


Figure 4.Transmit diversity for two antenna ports – SFBC.

4. Simulations And Results

The performances of OLSM, SIMO and SFBC multi-antenna schemes are evaluated using QualNet 5.2 simulator and their performances are compared. A single cell is considered in the simulation area of 1Km x 1Km working at a frequency 2.4GHz for channel0 and 2.5GHz for channel1. The path loss model selected is two-ray with constant shadowing model of shadowing mean 4dB. The simulation parameters settings are mentioned in Table 3.

Table 3. Simulation parameters

Property		**Value**
Terrain-Dimensions		(1000, 1000) meters
Simulation-Time		100S
Propagation-Channel-Frequency[0]		2.4G Hz
Propagation-Channel-Frequency[1]		2.5GHz
Propagation-Model		Statistical
Propagation-Pathloss-Model		Two-Ray
Propagation-Shadowing-Model		Constant
Propagation-Shadowing-Mean		4.0 dB
Propagation-Fading-Model		Rayleigh
Propagation-Fading-Max-Velocity		10.0
Propagation-Speed		$3x10^8$ mps
MAC-LTE-UE-Scheduler-Type		Simple-Scheduler
MAC-LTE-eNB-Scheduler-Type		Round-Robin
PHY-LTE-Tx-Power		23
Antenna-Model		Omni directional
PHY-LTE-Num-Tx-Antennas	SIMO	1
	SFBC	2
	OLSM	2
PHY-LTE-Num-Rx-Antennas	SIMO	2
	SFBC	2
	OLSM	2

In this scenario, a single LTE cell consisting of a single eNB and two pairs of UEs is considered. Between each pair of UEs (uplink and downlink) two Constant Bit Rate (CBR) connections are established with a data rate 8.192 Kbps, so that the total number of traffic connections becomes 4 (Figure 5). Results are obtained for average throughput, average end-to-end delay and jitter for all the three multi-antenna schemes through simulation. The simulation is repeated by increasing the number of UEs pairs up to twenty pairs in steps of two pairs, in turn increasing the number of connections from 4 to 40.

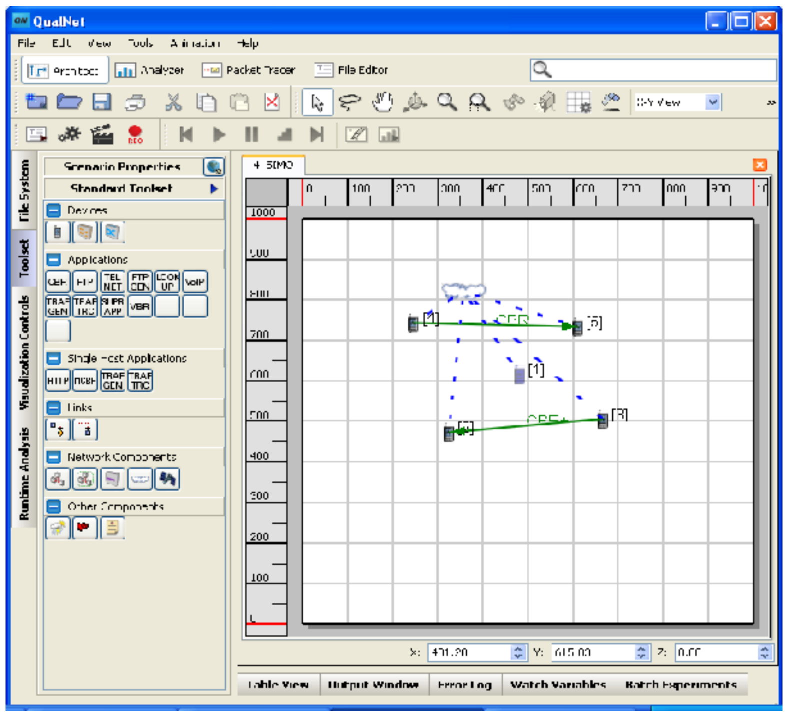


Figure 5. Simulation scenario considered for performance evaluation

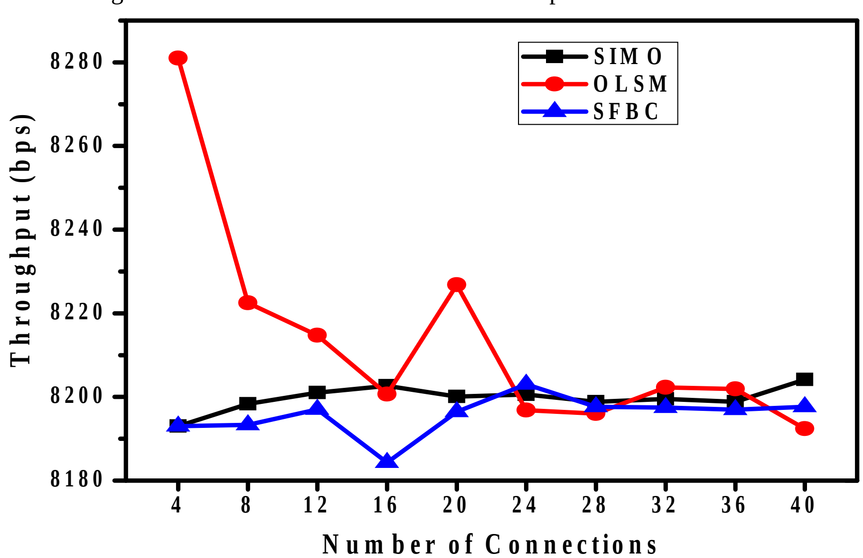


Figure 6. Average throughput performance for varying number of connections

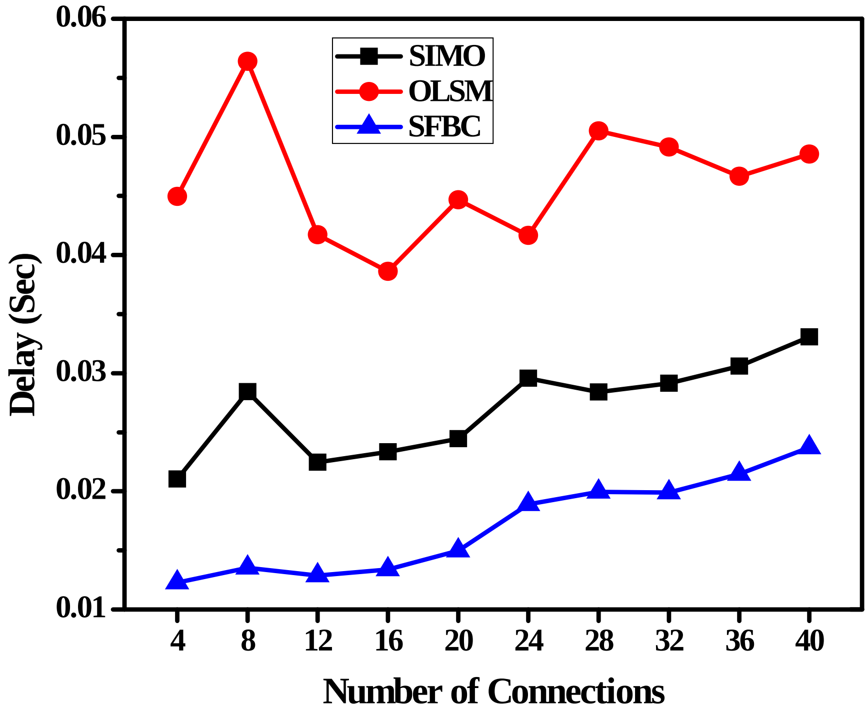


Figure 7. Average Delay performance for varying number of connections

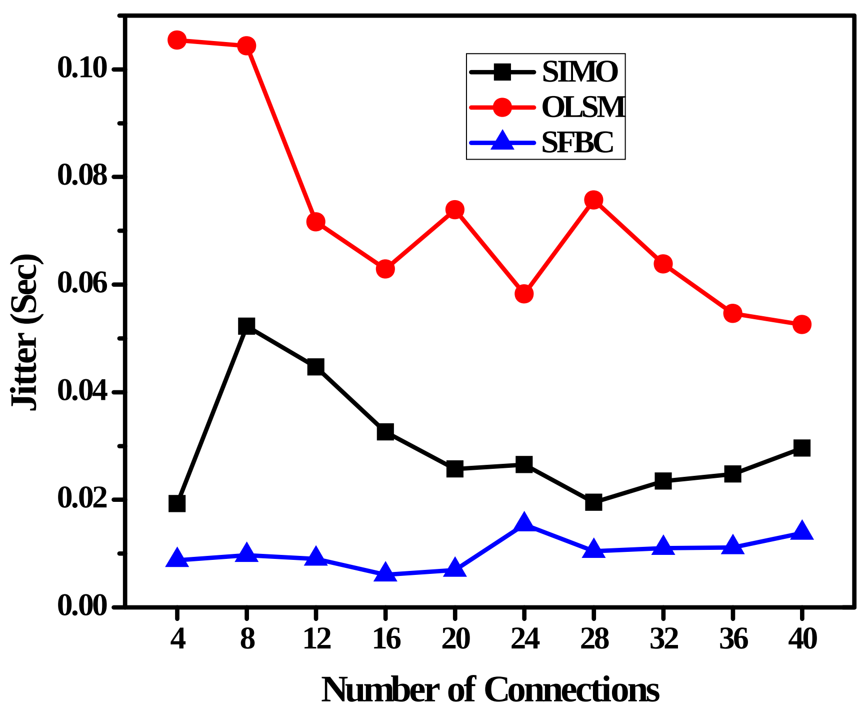


Figure 8. Jitter performance for varying number of connections

Figure 6 shows Average throughput performance for varying number of connections. It is observed that OLSM shows better throughput performance compared to other two antenna schemes and SFBC shows least performance. In OLSM, multiple transmit and receive antennas create multiple parallel channels, using which multiple data streams are sent simultaneously. Hence OLSM perform better than SFBC and SIMO [7, 11]. In SFBC, data stream is sent over the one channel and its conjugate is sent over the other which increases transmit diversity rather than throughput, hence throughput is least. In SIMO, transmitted signal from the single antenna is received independently by two receiving antennas and combined together. Figure 7 and 8 gives the delay and jitter performance respectively, with respect to number of connections. Delay and jitter performance for SFBC is better than the SIMO and OLSM. OLSM has least delay and jitter performances. Since maximum transmit diversity is offered by SFBC it performs better.

5. CONCLUSIONS

This paper studies the performance of multiple antenna techniques such as SIMO, OLSM and SFBC with increasing the number of user equipments in a single cell scenario. The performance metrics considered are average throughput, average delay and jitter. Simulation studies shows that OLSM has highest throughput compared to all other three multiple antenna schemes. SFBC is robust to jitter and has highest delay performance.

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