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Performance Evaluation of Mobility Effects on Various Transmission Modes in the LTE Network

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Abstract— Long Term Evolution (LTE) system uses Internet Protocol (IP) based network architecture and advanced multi-antenna techniques to provide higher system throughput and high user mobility, intern to support low delay multimedia services such as voice, real time video connections and effective internet connectivity without any disruption. Hence in this paper, an attempt has been made to analyze the impact of mobility on the Quality of Service (QoS) parameters such as average throughput, average jitter and average delay of a LTE network for various transmission modes such as Serial-Input Serial-Output (SISO), Transmit Diversity, Receive Diversity and Open Loop Spatial Multiplexing (OLSM).

Keywords- LTE, Mobility, OLSM, Receive Diversity, Random Way Point, SISO, Transmit Diversity, Transmission mode

1 INTRODUCTION

The increasing demand from social market for high speed broadband communications has motivated the network vendors to adopt more efficient technologies to cater higher system throughput and low latency in order to unite individuals and businesses to the global marketplace. LTE is one such network technology standardized by 3GPP, which supports new protocols, standards and all IP-based flat architecture to provide higher data rates (100Mbps in downlink and 50Mbps in uplink for 20MHz system bandwidth) and low latency, seamless mobility and varying user traffic patterns without any Quality of Service (QoS) degradation [1], [2]. The higher system throughput and low latency can be achieved in LTE network by using advanced multi-antenna techniques such as Multiple-Input-Serial-Output (MISO), Serial-Input-Multiple-Output (SIMO) and Multiple-Input- Multiple-Output (MIMO) [3],[4]. These advanced multi-antenna techniques are available with various transmission modes to offer diversity in data rates, reliability and system capacity which can directly affect the mobility performance in the LTE network.

The mobility of the system allows a user to move around its current channel or new channel while keeping an ongoing call or session on a terminal and it directly affects the QoS, since the UEs (User Equipments) in each area find their own optimal position according to their present location. Also at high mobility, the physical layer features of LTE network such as power control, hybrid automatic repeat request (HARQ), sub-channelization and link adaptation techniques facilitate users to support delay sensitive applications with appropriate QoS [2], [5]. These physical layer aspects depend on channel estimation techniques such as Channel Quality Indicator (CQI), Rank Indicator (RI), Received Signal Strength Indicator (RSSI) and Received Signal Strength Quality (RSSQ) which also influence the selection of transmission modes in LTE network. Hence in this paper an attempt has been made to evaluate the effects of mobility for various transmission modes of advanced multi-antenna techniques in the LTE network such as Single Input Single Output (SISO), Transmit Diversity (2×1 MISO), Receive Diversity (1×2 SIMO) and OLSM (2×2 MIMO). The performance metrics such as average throughput, average delay and average jitter are considered for the simulation study.

The rest of the paper is organised as follows. Section 2 gives a brief insight of mobility model. Section 3 gives a brief explanation of various transmission modes. Section 4 and 5 gives the detailed insight of simulation studies and results and Section 5 concludes the paper.

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2 MOBILITY MODELS

The mobility model is designed to describe the movement pattern of mobile users, and their location, velocity and acceleration change over time. Since mobility patterns may play a significant role in determining the protocol performance, it is desirable for mobility models to emulate the movement pattern of targeted real life applications in a realistic way [6]. There are four types of mobility models available to study the system performance namely, Random Way Point (RWP) Mobility Model, Pathway Mobility Model, Gauss Markov Mobility Model and Random Point Group Mobility Model [7]. The RWP model is a commonly used mobility model for simulations of wireless communication networks. Since, RWP allows the UEs to moves directly towards the next waypoint at a certain velocity and cell change rate to provide better system performance. Hence in this paper the RWP Mobility Model is considered for the simulation studies to evaluate the effect of mobility on system performance in the LTE network [8],[9].

2.1 Random Way Point Mobility Model

The Random Waypoint Mobility Model is a variation of Random Walk model with spatial dependence [10]. It includes pause times between changes in direction and/or speed. A UE stays in one location for a certain period of time (a pause time), then chooses a random destination in the simulation area with parameters such as speed between zero and a maximum velocity with uniformly distributed pause time. The UE then travels toward the newly chosen destination at the selected speed. Upon arrival, the UE pauses for a specified time period before starting the process again. Therefore, the system performance relies on values of pause time and the UE speed. UEs moving with a higher velocity with long pauses produce a more stable network than UEs moving with a slow velocity with short pauses [11].

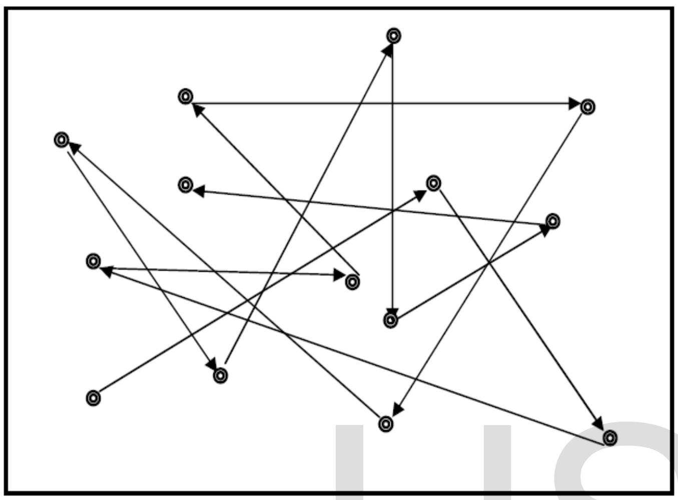

Fig.1. UE movement in the Random Waypoint Model

Mobility network comprises of V2V communication and vehicle-to-infrastructure (V2I) communication and it describes the mobility patterns of cars, railways, bicycles, motor bikes, etc [12]. The UE of various speed represent static, pedestrian and vehicular or high speed mobility. The static UEs always provide better system performance in the LTE network due to its high signal-to-noise ratio (SINR) and tremendous network connectivity. The Pedestrian mobility is low in speed, but it causes severe trouble when UEs move towards the places where obstacles frustrate the signal. Sometimes due to pedestrian mobility the UEs are not able to reach the access point (eNB), in such case the UEs need to be handed over rapidly to the next available access point and this directly affects the system performance [13]. The high speed mobility makes direct communication very challenging, since it directly affects the network topology, the availability of transmission range, link change rate and SINR. Hence high speed mobility causes the degradation of system performance due to huge variation in SINR, higher route change and route failure probability. LTE can support the optimized system performance at speed up to 15kmph, high system performance at speeds up to 120kmph and to maintain link at speeds up to 350kmph in order to support various multimedia services such as real time video connections, effective internet connectivity without QoS degradation.

3. TRANSMISSION MODES IN THE LTE SYSTEM

In a wireless data transmission system the multipath fading is known to arise due to the non-coherent combination of signals arriving at the receiver resulting in severe degradation of the QoS. Therefore, LTE adapts advanced multi-antenna techniques in order to support flat fading channels to provide higher system throughput and bandwidth efficiency of the system [14]. The advanced multi-antenna technique is available with various transmission modes such as SISO, Receive Diversity, Transmit Diversity and OLSM. These transmission modes offers spatial multiplexing and diversity gains which provide higher peak data rate, improved reliability and system capacity to ensure superior QoS [15], [16].

A SISO transmission mode employs single antennas at both ends of the wireless link. Therefore, it is less complex but reduction in data rate. In SISO the maximal system throughput depends on the available bandwidth and the parameter of the Orthogonal Frequency Division Multiple Access (OFDMA) signal such as the number of subcarriers and the modulation order (QPSK, 16QAM, 64QAM) [17]. LTE support two types of diversity modes such as Transmit Diversity and Receive Diversity to improve system performance in fading channels. The Transmit Diversity mode employs multiple antennas at eNB and single receiving antenna at UEs. When two eNB antennas are available for Transmit Diversity operation, the Space Frequency Block Code (SFBC) is used to improve the signal quality at the receiver [18]. The SFBC support frequency diversity together with time diversity and allows the transmitter to use different coding & modulation schemes to improve cell coverage, system throughput, reliability and SINR to makes transmission is more robust. This method does not require any feedback information from the receiver and is effective when the receiver is in a low SINR environment. It also reduces the effect of multipath fading and interference by providing multiple copies of the same signal to the receiver via different branches or paths [2]. The Receive Diversity mode employs one transmitting antenna at eNB and multiple antennas at the receiver (UEs). Therefore in this mode the receiver can choose either the best antenna to receive a stronger signal or combines signals from all antennas using Maximal Ratio Combining (MRC) or Interference Rejection Combining (IRC) techniques to maximize the SINR at the output [18]. The Receive Diversity mode also enables the receiver system to receive signals from a number of independent sources to combat the effects of fading. The Open Loop Spatial Multiplexing (OLSM) mode is one of the Multiple Input Multiple Output (MIMO) antenna techniques which uses multiple antennas at both ends of the wireless link to support several signal paths to transfers multiple of data streams at the same time and it significantly increases the data rates and bandwidth efficiency of the systems [19],[20]. Hence various transmission modes of the advanced multi-antenna techniques offer diversity in data rates, reliability and system capacity which can directly affect the system performance in the LTE network. Thus in this paper the effects of mobility on system performance in the LTE network is evaluated for various transmission modes.

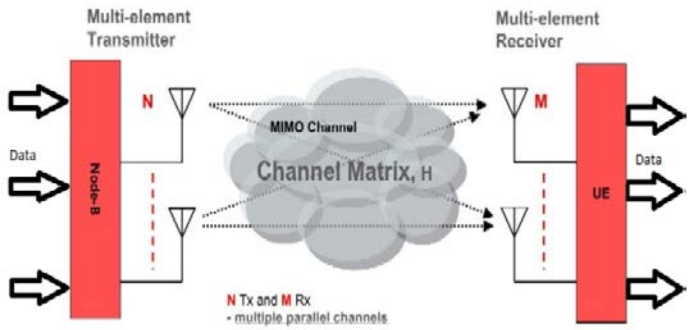

Fig. 2. MIMO Transmission using OLSM.

4. SIMULATION STUDIES AND RESULTS

The effect of mobility on LTE system performance is evaluated for different transmission modes such as SISO, Transmit Diversity, Receive Diversity and OLSM using QualNet 7.1 simulator by considering an eNB and a 20 UEs in a single cell environment of an simulation area 5Km x 5Km. In the considered simulation scenario, a downlink Constant Bit Rate (CBR) connection of 50Mbps data rate is established between eNB and each UE. Further, the two-ray path loss model and Rayleigh fading environment with constant shadowing are considered for simulation studies. The remaining parameters considered for the simulation studies are listed in Table 1.

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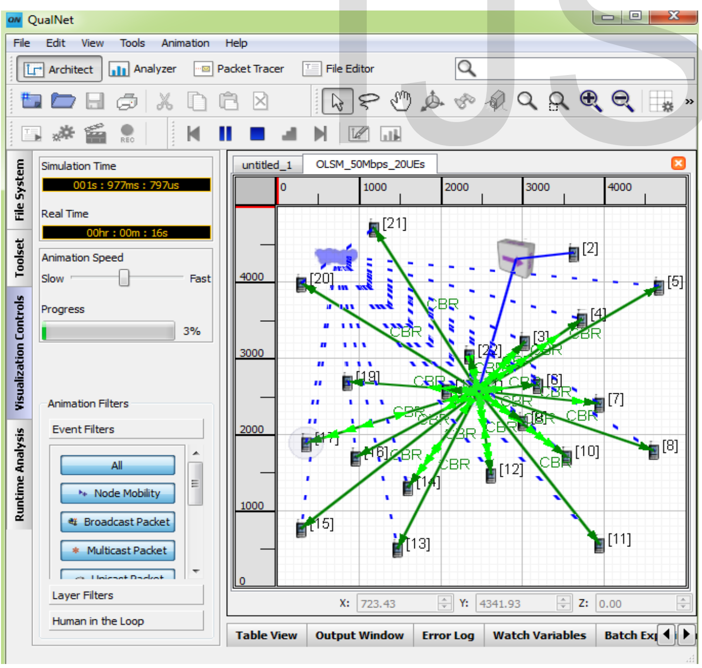

Fig. 3. Snapshot of the Scenario designed for simulation study

The snapshot of the scenario designed for simulation studies using QualNet 7.1 simulator is shown in Figure 3. Initially, simulation is carried out by considering SISO transmission mode for a 20 stationary UEs. The performance metrics such as average throughput, average delay and average jitter are evaluated. Simulation studies are repeated by enabling random way point mobility of 5Kmph, 15Kmph, 30Kmph, 50Kmph, 80Kmph, 100Kmph, 120Kmph, 150Kmph and 180Kmph to all the UEs. Further, simulation studies are also repeated by considering Transmit Diversity, Receive Diversity and OLSM transmission mode.

TABLE 1.
Simulation Parameters

Property			Value
Simulation-Time			30S
Propagation-Channel-Frequency[0]			2.4GHz
Propagation-Channel-Frequency[1]			2.5GHz
Mobility Model			Random Way Point
Pause Time			1 micro-second
Propagation-Model			Statistical
Shadowing Means			4dB
Channel Bandwidth			20MHz
Antenna Model			Omni directional
Antenna Gain(dB)			0
eNB	MAC-Scheduler-Type		Proportional Fair
	PHY-Tx-Power		23
	Antenna Height		15meters
	MAC Transmission Mode		Single antenna scheme, Transmission Diversity (SFBC), OLSM
	SISO	PHY- Num-Tx-Aneannas	1
	Transmit Diversity (MISO)	PHY- Num-Tx-Aneannas	2
	Receive Diversity (SIMO)	PHY- Num-Tx- Aneannas	1
	OLSM (MIMO)	PHY- Num-Tx-Aneannas	2
UE	MAC-Scheduler-Type		Simple-Scheduler
	PHY-Tx-Power		23
	Antenna Height		1.5meters
	SISO	PHY-Num-Rx-Aneannas	1
	Transmit Diversity (MISO)	PHY-Num-Rx-Aneannas	1
	Receive Diversity (SIMO)	PHY-Num-Rx-Aneannas	2
	OLSM (MIMO)	PHY-Num-Rx-Aneannas	2

Figure 4 shows the average throughput performance of SISO, Transmit Diversity, Receive Diversity and OLSM transmission modes for various UEs mobility. It is depicted from figure 4 that the average throughput decreases with increasing mobility for all the transmission modes. Since the increasing mobility directly affects the network topology, transmission range, link change rate and link availability, causing more variations in SINR and higher route failure probability [13], [21]. It is also observed from figure 4 that average throughput achieved is better for OLSM transmission mode, since the OLSM mode supports several signal paths to transfer multiple of data streams at the same time [22]. From figure 4 it is also evident that the average throughput achieved in diversity transmission modes (Transmit Diversity and Receive Diversity) is better than SISO, since diversity mode increases the SINR and mitigate channel fading effects leading to higher throughput [15], [19].

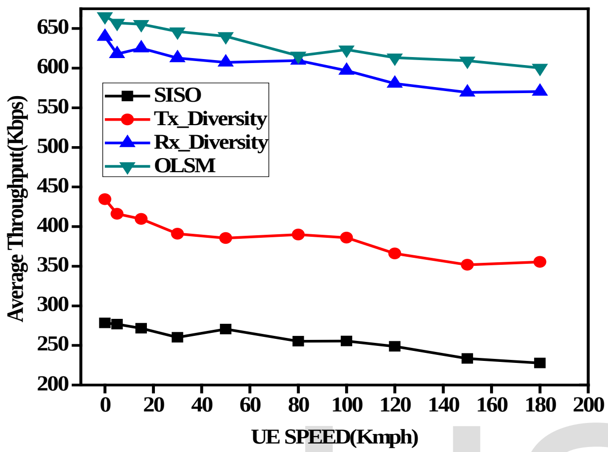

Figure 4. Average Throughput for different transmission modes.

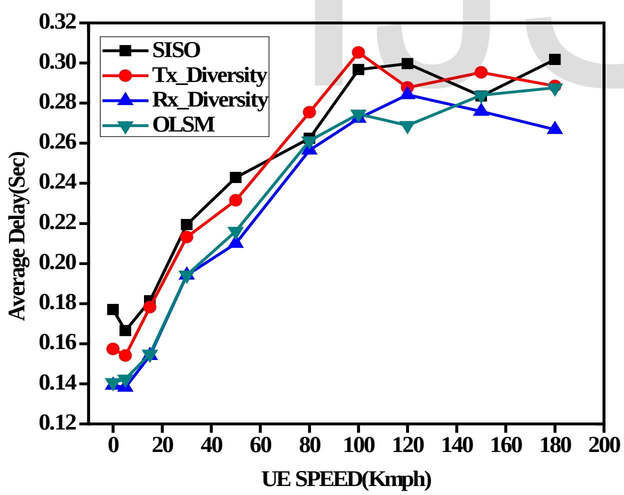

Figure 5. Average Delay for different transmission modes

Figure 5 and 6 illustrates the average delay and average jitter performance of SISO, Transmit Diversity, Receive Diversity and OLSM transmission modes for various UEs mobility. It is evident from figure 5 and 6 that the average delay and average jitter increases with increasing mobility for all transmission modes due to the more variations in SINR, and higher route failure rate [13], [21]. From figure 5 and 6 it is also observed that the average delay and average jitter performance is better for OLSM transmission mode. Since OLSM mode transmits and receives multiple streams of independent data over different antenna at the same time and it reduces the queuing delay and jitter [19].

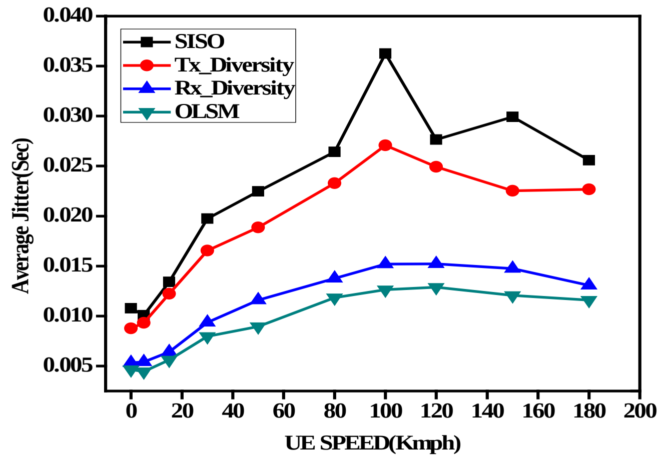

Figure 6. Average Jitter for different transmission modes

5. CONCLUSION

In this paper, the effect of mobility for various transmission modes such as SISO, Transmit Diversity, Receive Diversity and OLSM is evaluated using QualNet 7.1 simulator considering average throughput, average delay and average jitter as performance metrics. The simulation results show that the performance of OLSM and Receive Diversity transmission modes is better than SISO and Transmit Diversity transmission modes.

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