Performance Evaluation of Proportional Fair Scheduling Algorithm on MIMO Techniques in LTE

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***Abstract*—**The Radio Resource Management of LTE uses dynamic packet scheduling and link adaptation technique to allocate the resources. Scheduling algorithm can be effectively utilized along with Multiple-Input Multiple-output (MIMO) techniques. This paper makes an attempt to evaluate the QoS (Quality of Service) parameters of LTE using Qualnet 7.1 simulator in the downlink. The Multiple antenna technique simulations are carried out based on Proportional Fair (PF) scheduling algorithm in different Adaptive Modulation and Coding (AMC) regions at constant bit rates (CBR) traffic scenario. The simulation is also carried out for increased number of users. The simulation results show the comparison of the performance of the antenna techniques.

Keywords*—MIMO, AMC, SFBC, OLSM, OFDM, CBR, eNB.*

I. INTRODUCTION

LTE radio interface is designed with clean state approach using packet switched data transfer which includes Orthogonal Frequency Division Multiplexing (OFDM) and antenna techniques (MIMO) for air interface. LTE supports Orthogonal Frequency Division Multiple Access (OFDMA) in the Downlink with peak data rates of 100Mbps and Single Carrier Frequency Division Multiple Access (SC-FDMA) in the Uplink with 50Mbps. The peak data rate is enhanced to 300Mbps (4x4 MIMO) and 150Mbps (2x2 MIMO) [1-2].

The radio access network of LTE, E-UTRAN (Evolved–UMTS Terrestrial Radio Access Network), was designed to have minimum number of network components which supports QoS Class of services [2].

The eNodeB does the following functions of the radio resource management (RRM) [2]:

- Transmission power management,
- Mobility management
- Radio resource scheduling.

For every transition time (TTI) of 1ms, RRM algorithm performs the dynamic functions [2]:

- Hybrid Adaptive Repeat and Request (HARQ) Management,
- Dynamic packet scheduling, and
- Link Adaptation

The radio resource is best utilized by choosing appropriate scheduling algorithms to increase the network performance by bandwidth utilization, with data rates at high speed and low latency, fairness among users within the entire system [3--12] .

The Channel Quality Indicator (CQI) report sent by UE is processed by the eNB which is used for scheduling decisions and link adaptation purpose in Downlink to estimate the QoS parameters such as Average delay, Jitter and Average Throughput [2].

In this paper the simulation studies are carried out on PF algorithm for different antenna techniques for evaluating the performance metrics using Qualnet 7.1. The paper is organized in the following sections. Section II discus research contributions. LTE network architecture and PF scheduling algorithm in section III, AMC and MIMO techniques in section IV and V. The simulation studies are described in section VI and the conclusion is drawn in section VII.

II. RELATED WORK

There are a number of scheduling algorithms [3-12] available where each yields different level of performance. In paper [5], the performance of different types of scheduling algorithms are compared, the throughput and Jain's fair index is evaluated for all the scheduling algorithms by increasing the number of users for SISO. In paper [6] simulation is carried out in AMC regions with CQI values, paper [7] with RR and PF scheduling for random and pre-defined path. Papers[7,8] discuss about PF scheduling, paper [9] on spatial, frequency and multiuser diversity, paper [10] on channel aware scheduling, Papers [11-13] give the survey of scheduling algorithms using the LTE-Sim network simulator. The paper [13] briefs on a survey of scheduling algorithms and operation and comparison in the downlink direction of LTE networks. The paper [14] shows the increase in channel capacity with "Alamouti's Space-Time Block Coded (ASTBC) MIMO-OFDM systems"[14]. Paper [15] shows better performance of MIMO with AMC. Papers [6,7,9,14,15] show the advantage of AMC and MIMO for the scheduling algorithms to improve the performance metrics.

In papers [9, 11] packet scheduling is applied using spatial division multiplexing (SDM-MIMO) techniques on LTE downlink, in order to maximize the PF scheduling performance. In [6] simulation of scheduling algorithms in all AMC regions with CQI values are performed in the downlink without considering MIMO techniques. In paper [7] the RR and PF algorithms considered for evaluating the QoS parameters to examine a better comparison for downlink transmission.

In this paper, a comparative performance evaluation of PF scheduling is carried out using Qualnet 7.1 simulator for multiple antenna techniques in downlink connection in the cell regions. The simulation is carried out with 10 UEs for the cell centre, then for the near centre and finally at the edge of the cell. The simulation is repeated for 50 users with the same scenario.

III. THE RADIO ACCESS NETWORK AND PF SCHEDULING ALGORITHM

The major components of LTE are the UEs, E-UTRAN and EPC. The EPC is an all-IP based network architecture for mobile network.

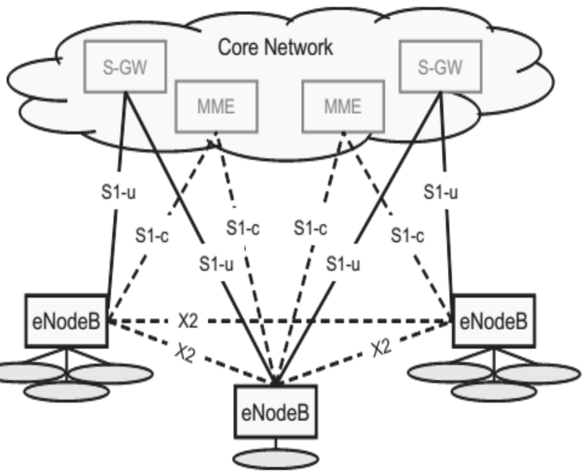

Fig.1: Radio-access-network interfaces [1]

The radio related operations between the UE and the EPC is managed by the E-UTRAN [2]. Each eNB communicates with the UE in one or more cells [2]. The eNB can communicate to all the elements in the core network with the help of the interfaces as shown in Fig 1[1].

PF scheduling algorithm is one of the basic algorithms employed to allocate the radio resources to different users in time domain based on the channel conditions to optimize system throughput and fairness among the users [3-5]. The PF scheduling algorithm calculates PF metric $m_{i,k}^{PF}$ for each user in the cell at every scheduling instant using equation (1) [5].

$$m_{i,k}^{PF} = \frac{d_k^i\ (t)}{\bar{R}^i(t-1)} \tag{1}$$

The average throughput factor $d_k^i(t)$ for the i[th] user on the k[th] resource block at time 't' expressed as (2) [5].

$$d_k^i(t) = \log\left(1 + SINR_k^i(t)\right) \tag{2}$$

$\bar{R}^i(t-1)$ represents the past average throughput accomplished by the i[th] user till the time 't'. When the UE is at the centre of the cell, then its past average throughput $\bar{R}^i(t-1)$ would be large.

IV. ADAPTIVE MODULATION AND CODING

In mobile communication systems, the signal quality received by the UE depends on the distance between the eNB and UEs, and the neighbouring interfering base stations. The signal impairment due to multipath effect is reduced by the signal transmitted to or from the user for better reception. AMC greatly improves the overall system capacity. The Fig. 2 shows the schematic representation of AMC operational concept [14].

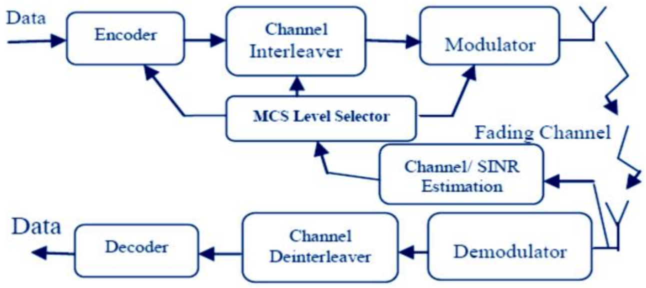

Fig.2: Structure of AMC System [14]

In the system which incorporates the AMC techniques, when the users is closer to the eNB (at the cell centre) uses higher order modulation techniques such as 64 QAM, 16 QAM for transmission and those users which are located far away from the eNB or at the cell edges uses lower order modulation techniques like QPSK for transmission. The Fig.3 shows the AMC regions chosen for the purpose of simulation studies and the CQI values used are shown in the Table I [2].

TABLE I. CQI VALUES FOR MODULATION SCHEMES

Adaptive Modulation Scheme	CQI
QPSK	1-6
16 QAM	7-9
64 QAM	10-15

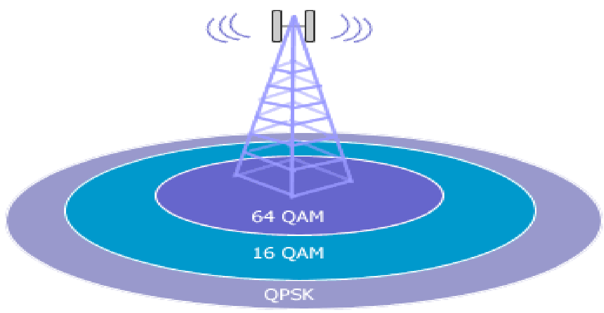

Fig.3 AMC Regions [19]

V. MULTIPLE INPUT MULTIPLE OUTPUT (MIMO) ANTENNA TECHNIQUES

The high data rate wireless communication system, employs MIMO with effective utilization of frequency resources. The MIMO scheme uses multiple antennas both at the transmitter and receiver to improve the channel capacity Fig. 4.

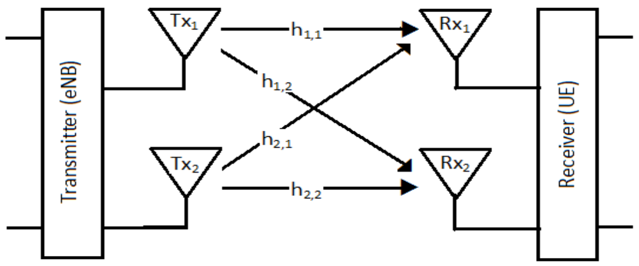

Fig. 4 MIMO with (2x2) Antenna Configuration

The same information carrying signals are transmitted by multiple antennas at the transmitter [9]. The signals transmitted are constructively or destructively added at the receiver depending on the multiple antennas at receiver. The signal received at a specific geographical location is unique at different times. The types of MIMO techniques [14-19] are

- Single-Input Single-Output (SISO)
- Single-Input Multiple-Output (SIMO)
- Space Frequency Block Coding (SFBC)
- Open Loop Spatial Multiplexing (OLSM).

SISO is the basic antenna technique, where the radio transmission uses single antenna at both the transmitter and at the receiver site.

SIMO antenna technique identical to SISO except this uses multiple antennas at the receiver end and the signals received are added, which improves the data rate when compared to SISO method [19].

SFBC is a transmit diversity technique with one receiving antenna and multiple and transmitting antenna, sending different data streams. This method improves SINR and reduces interference [19].

The OLSM (2 x 2) antenna configuration employs two transmit antennas and two receive antennas, and two independent data streams can be transmitted simultaneously.

The system reliability is improved by MIMO diversity for a low SNR. This concept has created a great curiosity and interest in the researchers to combine the transmit diversity and spatial multiplexing MIMO schemes in a single system and to work on the advantage of both the schemes [15-17]

VI. SIMULATION STUDIES AND RESULTS

The performance of SISO, SIMO, SFBC and OLSM antenna techniques in various AMC regions is evaluated using Qualnet7.1 network simulator by considering single cell environment with Rayleigh Fading Channel. The simulation is carried out for 100 secs, for each of the MIMO technique, with a terrain area of (5x5) km. The remaining parameters chosen for the simulation studies are listed in Table II.

TABLE II. PARAMETERS FOR SIMULATION

Property		Value
Terrain Area		5km x 5km
Simulation-Time		100 sec
Channel Frequency (Downlink)		2.4GHz
Channel Frequency(uplink)		2.5GHz
Path Loss Model		Two ray model
Shadowing Model		Constant
Shadowing mean		4 dB
Channel-Fading-Model		Rayleigh
eNB	PHY- Tx-Power	23 dBm
	PHY-Num-Tx-Antennas	1(SISO,SIMO) 2(SFBC,OLSM)
	Antenna-Height	12m
	MAC-LTE-Transmission-Mode	1(SISO),2(SIMO), 3(SFBC,OLSM)
UE	PHY-Tx Power	12 dBm
	PHY-Rx Antennas	1(SISO),2(SIMO), 1(SFBC), 2(OLSM)
	Antenna Height	1.5m

In this scenario, 10 UEs are placed in 64 QAM (cell centre) region as illustrated in the Fig 5a. The simulation is carried out for a period of 100 seconds with Rayleigh channel fading model with the setup for SISO as shown in Table-II. The performance metrics average delay, average throughput and average jitter are shown in Fig 6(a-c) respectively. The simulation is again carried out for other multi-antenna techniques such as SIMO, SFBC and OLSM.

Now 10 UEs are placed in 16QAM region (near centre) Fig.5b and the simulation is carried out for the antenna techniques with the same setup and the performance metrics are evaluated. The process is again repeated for the QPSK (cell edge) as shown in the Fig 5(c) for all the antenna techniques to obtain the performance metrics, as shown in Fig 6(a-c). For the same scenario simulation is again repeated by increasing the number of UEs to 50 in all the AMC regions with different antenna techniques and the performance metrics are measured are shown in Fig 6(d-f).

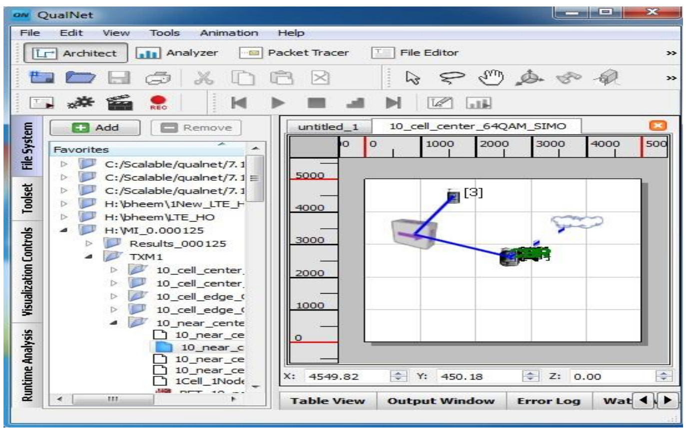

Fig.5(a) Cell Centre (64 QAM)

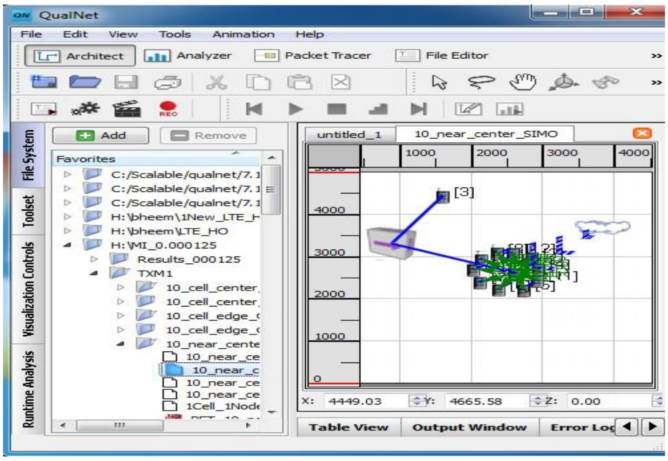

Fig. 5(b) Near Cell Centre (16 QAM)

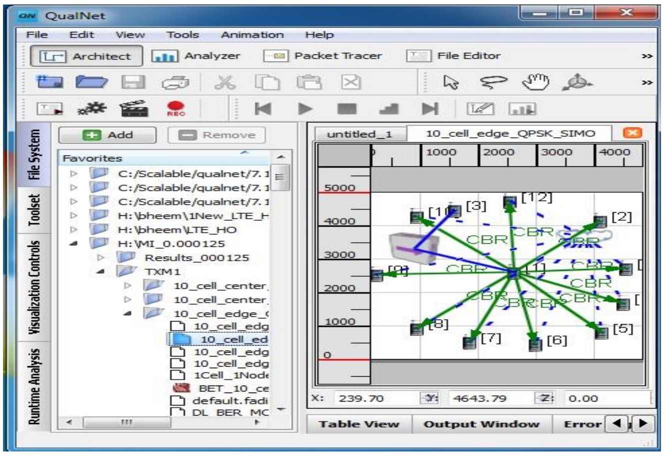

Fig: 5(c): Cell Edge (QPSK) for 10 UEs

Fig 5: Snapshot of the scenario designed for simulation studies (a) Cell Centre (64 QAM), (b) Near Cell Centre (16 QAM) and (c) Cell Edge (QPSK) for 10 UEs

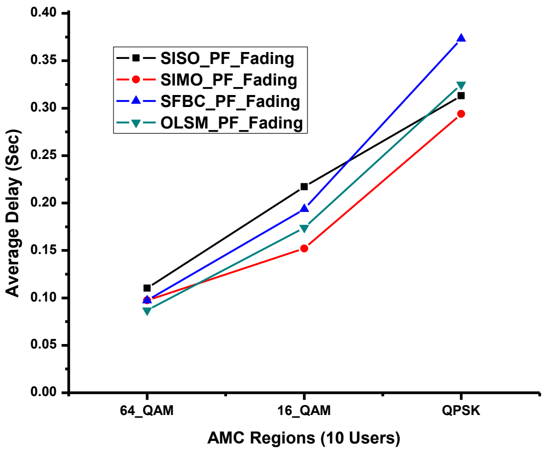

Fig.6a Average Delay put for multi-antenna schemes with PF scheduling algorithms for 10 UEs.

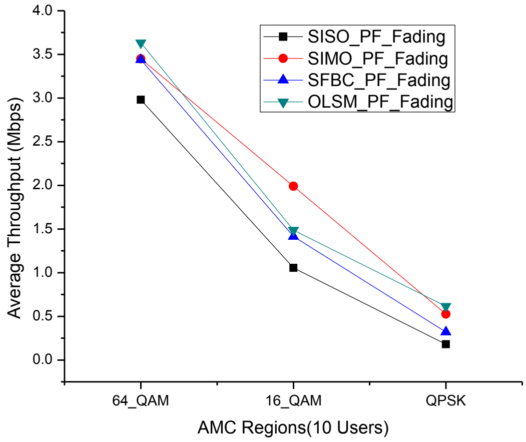

Fig.6b Average Throughput for multi-antenna schemes with PF scheduling algorithms for 10 UEs.

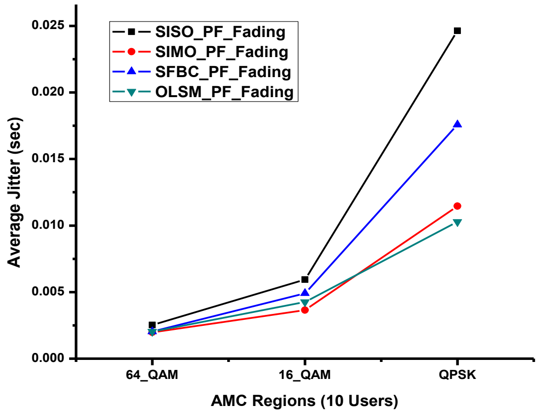

Fig.6c Average Jitter for multi-antenna schemes with PF scheduling algorithms for 10 UEs.

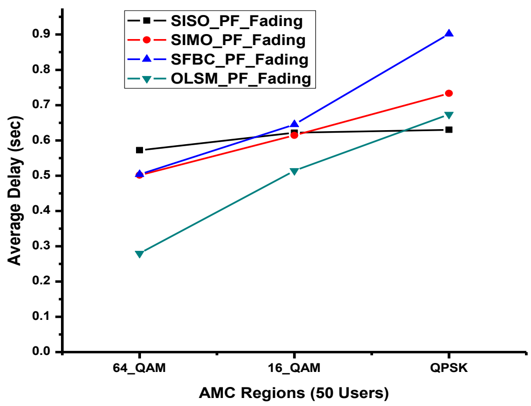

Fig.6d Average Delay for multi-antenna schemes with PF scheduling algorithms for 50 UEs.

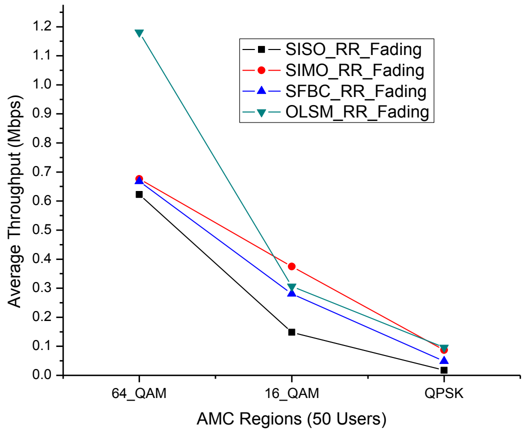

Fig.6e Average Throughput for multi-antenna schemes with PF scheduling algorithm for 50 UEs.

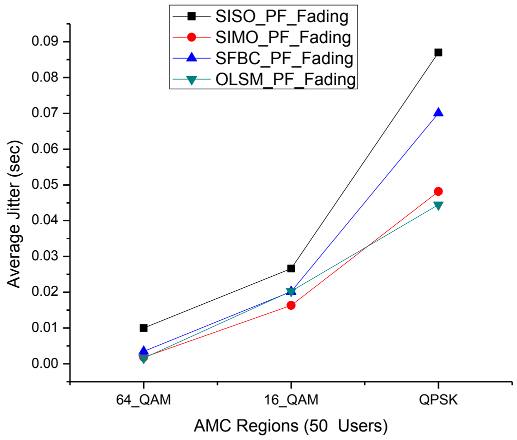

Fig 6f: Average Jitter for multi-antenna schemes with PF scheduling algorithm for 50 UEs

In 64 QAM region, the average delay performance Fig 6(a) is almost identical for all multi-antenna techniques. The delay increases as the UEs are moved from 64 QAM region (cell centre) to QPSK region. This is because 64 QAM has higher spectral efficiency than QPSK. The transmission power and time required by using 64-QAM modulation technique is less compared to 16 QAM and QPSK for the same number of bits. Queuing delay occurs at various layers of eNB resulting in average delay as evident in Fig 6(a). From Fig 6(a) the simulation results of OLSM show the increase in average delay approximately 3times from cell centre (64QAM) to cell edge (QPSK). Similarly the simulation results for 50 UEs also show the improvement in OLSM compared to other antenna techniques. In Fig 6(b) and Fig 6(e), the average throughput is higher in OLSM than other antenna techniques .The average jitter in SISO is much higher compared to MIMO techniques and OLSM.

OLSM (2x2) uses two levels for data transmission whereas SISO, SIMO, SFBC use single level transmission. From the results it is evident that OLSM has higher throughput than any other antenna techniques. SFBC and SIMO use diversity techniques which increase the throughput by increasing the SINR.

VII CONCLUSION

The simulation results using Qualnet 7.1 network simulator show the comparison of performance metrics for multiple antenna techniques in the downlink connection. OLSM and SFBC antenna technique performed better in all the AMC regions in Rayleigh fading because of its high data rate compared to other antenna techniques even when the number if UEs were increased from 10 to 50. Future scope of this work can be extended for antenna techniques with increase in the number of users and the data rate for other scheduling algorithms.

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