MULTI-USER MIMO TRANSMISSION MODES FOR TRANSMIT DIVERSITY AND SPATIAL MULTIPLEXING IN LONG TERM EVOLUTION

Patteti Krishna[1], Kalithkar Kishan Rao[2] and Tipparti Anil Kumar[3]
[1]Department of Electronics and Communication Engineering, JNTUH College of Engineering, Hyderabad, Telangana, India
[2]Vaagdevi College of Engineering, Warangal, Telangana, India
[3]Department of Electronics and Communication Engineering, SR Engineering College, Warangal, Telangana, India
E-Mail: kpatteti@gmail.com

ABSTRACT

Third Generation Partnership Projects Long Term Evolution –LTE downlink multiuser Multiple Input Multiple Output (MIMO) systems are analyzed in this paper. Two spatial multiplexing and transmit diversity multiuser MIMO schemes .To achieve high throughput required by the downlink LTE system, Adaptive Modulation and Coding (AMC) has to ensure a Block Error Rate (BLER) value . In this paper, we made a comprehensive study to evaluate the performances of open loop spatial multiplexing (OLSM) and transmit diversity (TxD) in downlink LTE system for different transmission mode are investigated.

Keywords: MIMO, MU-MIMO, LTE, BLER, throughput.

1. INTRODUCTION

3rd Generation Partnership Project (3GPP) has recently completed the specification of the Long Term Evolution (LTE) standard. Majority of the world's operators and vendors are already committed to LTE deployments and developments, making LTE the market leader in the upcoming evolution to 4G wireless communication systems. Multiple input multiple output (MIMO) technologies introduced in LTE such as spatial multiplexing, transmit diversity, and beam forming are key components for providing higher peak rate at a better system efficiency, which are essential for supporting future broadband data service over wireless links. Orthogonal Frequency Division Multiple Access (OFDMA) has been selected for downlink transmission [1] and Single Carrier Frequency Division Multiple Access (SC-FDMA) [2] for uplink transmission.

LTE adapted various MIMO technologies including transmit diversity, single user MIMO, multiuser-MIMO, closed loop rank-1 precoding and dedicated beam forming [10-13]. Two or four transmit antennas configuration are used in single user MIMO schemes supports the transmission of multiple spatial layers with up to four layers to a given user equipment(UE). The MU-MIMO scheme allows allocation of different spatial layers to different users in the same time-frequency resource, and is supported in both uplink and downlink. The closed-loop rank-1 precoding scheme is used to improve data coverage utilizing SU-MIMO technology based on the cell-specific common reference signal while introducing a control signal message that has lower overhead. The dedicated beam forming scheme is used for data coverage extension when the data demodulation based on dedicated reference signal is supported by the UE.

In this paper we evaluate and compare the performances of different transmission mode of TxD and OLSM techniques in a multipath channel which use the profile ITU-pedestrian B (Ped-B). These simulation results are compiled on based standard parameters of LTE Release8 specified by the 3GPP working group [3].

2. SYSTEM MODEL

In this section, we describe the system model of multiuser MIMO transmission schemes for 3GPP LTE downlink transmission with packet scheduling. The basic scheduling unit in LTE is the Physical Resource Block (PRB), which consists of a number of consecutive OFDM sub-carriers reserved during the transmission of a fixed number of OFDM symbols. One PRB of 12 contiguous subcarriers can be configured for localized transmission in a sub-frame. With the localized transmission scheme, two spatial division Multiplexing (SDM) schemes are now under investigation. In LTE MIMO transmission, the supported multi-antenna transmit mode employ transmit diversity (TxD) or spatial multiplexing (SM) transmission in order to increase diversity, data rate, or both [4].

The received signal at the kth user equipment (UE) can be represented by

$$Y = HPx + \eta \quad (1)$$

Where Y represents the received signal vector, H MIMO channel Matrix, P is the applied Precoding matrix and x transmitted signal vector and the additive white gaussian noise (AWGN). We consider MU-MIMO transmission; with N_{UE} UEs by adding (N_{UE} -1) UE signals into the downlink transmission. The received signals at the kth UE can be represented by,

$$Y_k = \sum_{n=1}^{N-1} H_k P_k x_k + \eta_k \quad (2)$$

Different transmission modes are supported in LTE systems. Transmission Mode 2 and 3 are used for open-loop transmissions with TxD and SM [6] [8], respectively. Transmission Mode 4, 5 and 6 are related to the closed-loop transmission with precoding matrix index (PMI) feedback for SU-MIMO SM, MU-MIMO and SU-MIMO

VOL. 10, NO. 5, MARCH 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

with single layer, respectively. In the context of this paper, we concentrate our discussion on Transmission Mode 5 and for the reference purpose Transmission Mode 6. For Transmission Mode 6 in LTE systems, we represent the system function by setting in $N_L = 1$ by

$$Y = HPx + \eta \tag{3}$$

In which the precoding matrix is degraded to be a precoding vector P. Precoding matrix selection at UE1 is

$$\tilde{y}_{12} = \begin{bmatrix} \tilde{y}_1 \\ \tilde{y}_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \end{bmatrix} P \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} H_{21} & H_{22} \end{bmatrix} \begin{bmatrix} x_3 \\ x_4 \end{bmatrix} \tag{4}$$

For Transmission Mode 5, MU-MIMO transmission, two UEs with single layer to each UE are scheduled in LTE systems [8]. Using (2) and setting $N_{UE} = 2$, we can represent the system function for the kth UE by

$$Y_k = H_1 P_1 x_1 + H_k P_2 x_2 + \eta_k \quad \text{k=1, 2.} \tag{5}$$

In MIMO -OFDM systems, the key factor of the link error predication and performance is the signal to noise ratio (SNR) which represents the measurements for the channel quality information. In practice there are different measure for calculating SNR in SISO and MIMO system but here we consider the below equation for SNR calculations

$$Y_k = \frac{\left\| H_k x_k \right\|^2}{N_R . \sigma^2} \tag{6}$$

3. TRANSMISSION MODES IN MIMO LTE SYSTEM

In MIMO system has most popular two modes that are utilized in our LTE analysis which are Transmit Diversity mode and Spatial Multiplexing modes. Diversity modes can be used in the receive Diversity or Transmit Diversity side. Where in received diversity side is simply combining operation of different replicas of the same transmitted signal; Transmit Diversity requires Space Time Coding operation of different transmitted signals. In LTE Transmit Diversity modes are defined as below.

a) Transmit diversity mode

The Transmit Diversity techniques where are only transmitted signal replicas to minimize error rate in the receiver side. Transmit Diversity with 2 transmitter side antennas and one receiver side antenna with one data stream is defined as below codes.

When two eNodeB antennas are available for transmit diversity operation is called Space Frequency Block Coding (SFBC). SFBC is based on Space Time Block Coding popularly known is Alamouti codes. The diversity created by the transmitter utilizes space diversity and either time or frequency diversity. The Alamouti space-time coding scheme can achieve full spatial diversity gain. The issue for the TxD that it is single ranks i.e. it does not support multi stream transmission [5]. In LTE for SFBC transmission, the symbols are transmitted from two eNodeB antenna ports on each pair of adjacent subcarriers as follows

$$\begin{bmatrix} y^0(1) & y^0(2) \\ y^1(1) & y^1(2) \end{bmatrix} = \begin{bmatrix} x_1 & x_2 \\ -x^*_2 & x^*_1 \end{bmatrix} \tag{7}$$

Where $y^p(k)$ denotes the symbols transmitted on the kth subcarrier from antenna port p.

One important characteristic of such codes is the transmitted signal streams are orthogonal and a simple linear receiver required for optimal performances. Diversity scheme increase the reliability by the so called diversity gain utilization. As a consequence of the diversity gain the error rate decreases. The data rate also logarithmically improved with respect to the number of antennas as antenna diversity increases the SNR linearly.

$$C = B \log_2 \left(1 + SNR\right) \tag{8}$$

The diversity gain in MIMO systems is usually characterized by the number of independent fading diversity branches, also called Diversity Order. The diversity order defined as the slope of BLER versus SNR curves on a log-log scale. In a MIMO system has N_t transmit antennas and Nr receive antenna, then it has diversity order of Nd = $N_t.N_r$. The diversity order has effect on the system reliability since probability of one of the diversity branches having high SNR is higher compared to only one branches.

b) Spatial multiplexing mode

In contrast to the diversity modes described above section, the Spatial Multiplexing mode which refers to splitting the incoming high data rate stream into Nt transmit independent data rate streams. The Spatial multiplexing modes is most important in the data throughput point of view in LTE system. In MIMO system with N_t transmit antennas the nominal spectral efficiency can be increased by a number of N_t stream can be successfully and independently decoded. The factor N_t is known as Multiplexing gain. In spatial multiplexing (N_t x N_r) MIMO system, the maximum data rate grows as

$$\min\left(N_t, N_r\right) \log_2 \left(1 + SNR\right) \tag{9}$$

In LTE, the Spatial Multiplexing mode is designed as mode 4 and it is known as closed loop Spatial Multiplexing mode .In SISO OFDM systems, the maximal data throughput depends on the available bandwidth and the parameter of the OFDM signal, like the number of subcarriers and the modulation order like QPSK, 16QAM, 64QAM. For given Frequency bandwidth B the maximal data Throughput in bits per second can be approximated as given in below equation:

$$Throughput(T)_{bps} = \frac{N_{FB}.N_{SC}.N_{OFDM}..ECR}{T_{sub}} \tag{10}$$

VOL. 10, NO. 5, MARCH 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Where N_{FB} is the number of frequency Block in the given frequency band (B); N_{SC} is the number of subcarrier in one frequency block; N_{OFDM} is the number of OFDM symbols in one sub frame equal to 12 and 14 respectively . Now we have 5 MHz bandwidth N_{FB} =25, N_{SC}=12, N_{OFDM} =14, in LTE system has 16QAM modulation scheme so N_b= 4 and ECR=0.369, also here sub frame duration 1ms. Now putting all this values in equation (10) we got maximum data Throughput for 5 MHz bandwidth equal to 6.1Mbps.

4. SIMULATION RESULTS

For simulating the radio link performance of OLSM and TxD techniques for downlink LTE, in this paper, different parameters have been chosen as shown in Table-1. As shown, 3HARQ retransmissions were used for simulation. For transmission over ITU-Pedestrian B channel, simulation has been performed on 5000 sub-frames. To performs and compare the MIMO OLSM and TxD system, we have choose these different transmissions modes settings: SU-SISO (111), SU-MIMO transmit diversity (222 and 242) and SU-MIMO open loop spatial multiplexing (322 and 342).

Table-1. Simulation parameters.

Parameters	Values
Transmission bandwidth	1.4 MHz
Carrier frequency	2.1 GHz
Modulation scheme	16QAM,64QAM
Channel	Ped B
Retransmission algorithm	HARQ
No. of retransmissions	3
Channel estimations	Perfect

a) Block error rate and throughput results

To obtain the Block error rate and throughput for adaptive modulation and coding scheme (AMC) corresponding to each CQI values. In LTE, adaptive modulation and coding has to ensure a BLER value smaller than 10%. The Block Error Rate (BLER) vs. SNR (dB) result, for different transmission modes, is shown in Figure-1 and Figure-2, for both CQI value 8 and 11 respectively. We use a multi-path channels which use the profile of ITU-Pedestrian B for configuration CQI 8 and CQI 11 respectively. For CQI 8, In MIMO 2X2 and compared with Single antenna, we see that performances enhancement almost than 3 dB and 10 dB at a BLER=10-2 when we use OLSM and TxD respectively. But compared with OLSM, we can see that considerable gain is achieved, when we use Transmit diversity (Almost than 6 dB).

This is because the equalizer who exploit the diversity offered by the multiple antenna. In Figure-3(CQI 11), we see that as to CQI 8, the TxD performances are larger than that of OLSM but the gain value decreases because we use the 64QAM modulation that is very sensible to the multipath effect.

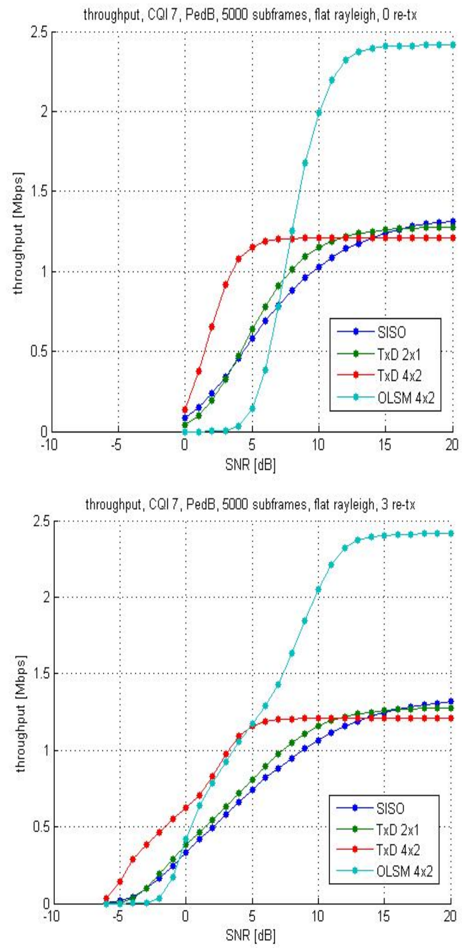


Figure-1. Throughput of transmit diversity and spatial multiplexing compared with a single transmit antennas for PedB MIMO Configurations, CQI=7.

In Figure-1 and 2, the throughput of SISO, 2x1 transmit diversity (TxD), 4x2 transmit diversity, and 4x2 Open Loop Spatial Multiplexing (OLSM) is compared when transmitting over an uncorrelated ITU Pedestrian B channel. In this simulation we set the CQI to a fixed value of seven and the maximum number of HARQ retransmissions to three.

We can see that at low SNR, the TxD technique give the best performance in terms of throughput as compared with that of the OLSM and single antenna. In case of high SNR, it is also observed that the OLSM technique outperforms the transmit diversity technique in term of throughput vs. SNR. While the TxD technique gives a constant throughput at high SNR. This is because the data rate is saturated in TxD technique whereas independent data streams are transmitted in the OLSM technique.

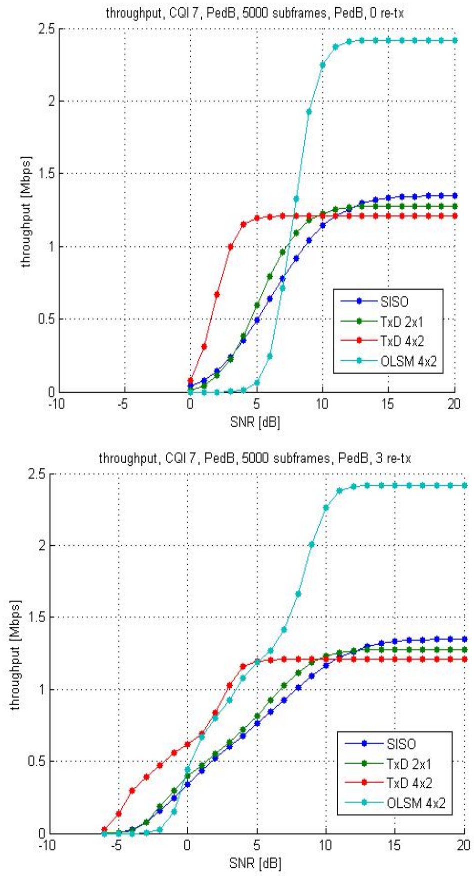
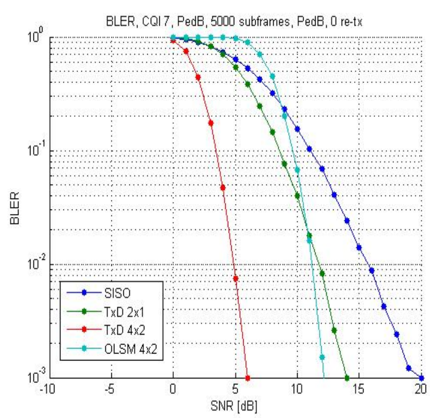


Figure-2. Throughput of transmit diversity and spatial multiplexing compared with a single transmit antennas for Pedestrain B Channel (CQI=7, 3 HARQ 3 retransmissions).



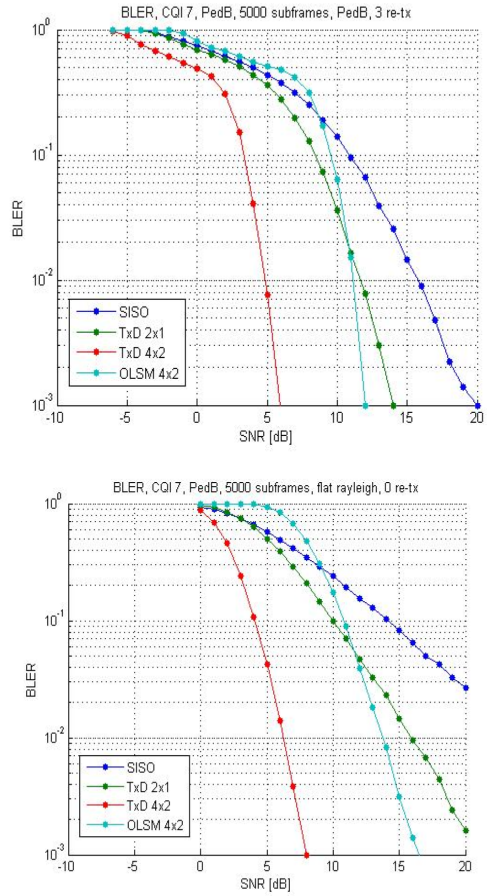


Figure-3. BLER of transmit diversity and spatial multiplexing compared with a single transmit antennas for PedB MIMO Configurations, CQI=7.

5. CONCLUSIONS

In this paper we evaluate the performances of downlink LTE system in multi-path channels which use the profile of ITU-Pedestrian B and we compare the transmit diversity to open loop spatial multiplexing technique. We showed that the TxD technique achieved a considerable gain compare to the OLSM technique in term of BLER. But the OLSM technique outperforms the TxD technique in term of throughput in case of high SNR. This provides us with another option to achieve optimal BLER and throughput while we use the minimum number of antennas in case of high SNR transmission.

REFERENCES

[1] 3GPP TR 25.814 V7.0.0, .Physical Layer Aspects for Evolved UTRA,. Tech. Rep., June 2006.

[2] H. G. Myung, J. Lim. and D. J. 2006. Goodman. Single carrier FDMA for uplink wireless transmission. IEEE Vehicular Technology Magazine. Vol. 1, no. 3, pp. 30–38, September.

ARPN Journal of Engineering and Applied Sciences

[3] T. S. G. R. A. N. G. R. A. 2009. Network. Evolved universal terrestrial radio access (e-utra); multiplexing and channel coding. 3rd Generation Partnership Project (3GPP), vol. TS 36.212, March.

[4] Rasmus Birkelund Nielsen. and Mauritio B.G.M. Nielsen. 2012. Physical Layer measurements in 3GPPLTE. Thesis Report. Aalborg University, February 3.

[5] S. Caban, Ch. Mehlfuhler, M. Rupp. and M. Wriliich. 2012. Evolution of HSDPA and LTE. Ltd. Published by John Wiley & Sons.

[6] Niru Desai. and G. D. Makawana. 2013. Space Diversity for Wireless Communication System– A Review International Journal of Engineering Science and Innovative Technology (IJESIT). Volume 2, Issue 3, May.

[7] Y. S. Cho, J. Kim, W. Y. Yang. and C. G. Kang. 2010. MIMO-OFDM Wireless Communications with Matlab. John Wiley and Sons (Asia) Pte Limited, Singapore.

[8] 3GPP36.211. Evovled Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation. 3GPP, Sophia Antipolis, Technical Specification 36.211 v8.9.0, December 2009.

[9] 3GPP36.213. Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures. 3GPP, Sophia Antipolis, Technical Specification 36.213 v8.8.0, September 2009.

[10] 3GPP, TS 36.201 Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Physical Layer-General Description (Release 8).

[11] 3GPP, TS 36.211. Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 8).

[12] 3GPP, TS 36.212. Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding (Release 8).

[13] 3GPP, TS 36.213. Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 8).