Abstract—Long Term Evolution is designed to have wider channels up to 20MHz, with low latency and packet optimized radio access technology. The peak data rate envisaged for LTE is 100 Mbps in downlink and 50 Mbps in the uplink. Unfortunately, different constraints have a strong influence on system performance such as the velocity of user equipment and effect of multipath channel. To achieve data rate compliance with LTE standard, Different transmissions techniques are deployed such as MIMO transmission, Adaptive Modulation and Coding (AMC) and Hybrid Automatic Repeat request (HARQ) Technique. In this paper, we simulate and discuss the MIMO Transmit Diversity technique which standardized by the 3GPP group for downlink LTE cellular network.

Keywords—MIMO; Coefficient Quality Indicator; Transmit Diversity; Long Term Evolution

I. INTRODUCTION

In modern world, requirement of high data rate communication has become inevitable. The applications like Streaming, video and images transmission and browse the World Wide Web require high speed data transmission with mobility. In order to fulfill these data requirements, the 3rd Generation Partnership Project (3GPP) introduced Long Term Evolution (LTE), in order to provide high speed data rate for mobile communication [1].

The physical layer and multiple access schemes for downlink LTE, which is chosen by 3GPP, is the Orthogonal Frequency Division Multiple Access (OFDMA), in both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD), because of the high degree of flexibility in the allocation of radio resources to the Users Equipments (UEs) and its robustness to the selectivity of multipath channels [2][3]. LTE is capable of supporting different transmission band of spectrum allocation, ranging from 1.4 to 20 MHz, for both paired and unpaired bands. The high peak transmission rate reaches the LTE system is 100 Mbps in downlink (DL) and 50 Mbps in uplink (UL). To achieve the performance objectives, LTE employs the several enabling technologies which include Hybrid Automatic Repeat Request (HARQ) technical and different multiple input multiple output (MIMO) transmission methods are deployed [1] [4].

In wireless communication, the use of multiple antennas at both the transmitter and receiver improve communication performance and efficiency. The 3GPP has standardized different MIMO transmission, scheme such as Transmit Diversity (TxD) and Spatial Multiplexing (SM), in LTE system. In this paper we focus our work to study the transmit diversity for downlink LTE cellular network. We have to simulate the performance of LTE system for both SISO and MIMO technique to improve the effect of the MIMO transmit diversity in wireless communication. These simulation results are compiled on based standard parameters of LTE Release8 specified by the 3GPP working group [1] over multipath channel which use the profile ITU-Vehicular-A (Veh-A). the performance of downlink LTE system are simulated for CQI 9.

II. OVERVIEW OF DOWNLINK LTE PHYSICAL LAYER

LTE physical layer implements a number of technologies to deliver on requirements for high data rates and spectral efficiency. The design of the physical layer and system parameters are well matched with the characteristics of mobile propagation channel to allow optional downlink and uplink frequency selective scheduling thereby enhancing throughput performance. Adaptive modulation and coding maximizes throughput to individual subscribers and increases overall cell capacity.

In time domain, different time intervals within LTE are expressed as multiples of a basic time unit \( T_S = 1/30720000 \) s. The radio frame has a length of 10 ms \( T_{frame} = 307200 \) s. Each frame is divided into ten equally sized sub frames of 1 ms in length \( T_{subframe} = 30720 \) s. Scheduling is done on a subframe basis for both the downlink and uplink. Each subframe consists of two equally sized slots of 0.5 ms in length \( T_{slot} = 15360 \) s. Each slot in time consists of a number of OFDM symbols which can be either seven (Normal Cyclic Prefix) or six (extended cyclic prefix). The useful symbol time is \( T_u = 2048 * T_s = 66.7 \) µs. For the normal mode, the first symbol has a cyclic prefix of length
data throughput and link range without additional bandwidth LTE specifications because it offers significant increases in Fig. 1. [11].

of the functional blocks are common to both SC FFT size.

prefix duration.

calculated as in equation (3).

This factor F accounts the inherent system losses and is the Shannon in estimation \[\text{[3]}\]

transmission of a Cyclic Prefix (CP) to avoid inter

bandwidth of channel in hertz (Hz) and SNR refers to Signal
to Noise Ratio (dB).

512*Ts \approx 16.7 \mu s

The remaining six symbols have a cyclic prefix of length \(T_{cp} = 144*Ts \approx 4.7 \mu s\). The reason for different cyclic prefix (CP) length of the first symbol is to make the overall slot length in terms of time units divisible by 15360. For the extended mode, the cyclic prefix is \(T_{cp} = 512*Ts \approx 16.7 \mu s\). The CP is longer than the typical delay spread of a few microseconds typically encountered in practice \[\text{[5]}\] [10].

The system capacity (C) of an Additive White Gaussian Noise (AWGN) channel is calculated with Shannon–Hartley theorem:

\[ C = B \times \log_2(1 + SNR) \] (1)

Where C is channel capacity in bits per second (b/s), B is bandwidth of channel in hertz (Hz) and SNR refers to Signal to Noise Ratio (dB).

The transmission of an OFDM signal requires the transmission of a Cyclic Prefix (CP) to avoid inter-symbol interference and the reference symbols for channel estimation \[\text{[6]}\]. Therefore, some arrangements are made on the Shannon in equation (1) by the factor F in equation (2). This factor F accounts the inherent system losses and is calculated as in equation (3).

\[ C = F \times B \times \log_2(1 + SNR) \] (2)

\[ F = \frac{T_{frame} - T_{cp}}{T_{frame}} \times \frac{N_{sc} \times N_s/2 - 4}{N_{sc} \times N_s/2} \] (3)

Where \(T_{frame}\) is the frame duration, \(T_{cp}\) is the cyclic prefix duration. \(N_{sc}\) is the number of subcarrier and \(N_s\) is the FFT size.

The basic OFDMA transmitter / receiver arrangement, normalized by the 3GPP, is shown in Fig. 1. Note that many of the functional blocks are common to both SC-FDMA and OFDMA, thus there is a significant degree of functional commonality between the uplink and downlink transceiver \[\text{[11]}\].

\[ y = Hx + b \] (4)

Where \(y = [y_1, y_2, \ldots y_{M\text{R}}]\) is the received vector, \(H\) is the channel coefficient matrix of the dimensions \(M\text{R \times N}_T\) expresses the channel gain and \(b = [b_1, b_2, \ldots, b_{M\text{R}}]^\top\) is the noise vector.

Fig. 2. Block diagram of typical 4x4 MIMO Antenna system

The matrix \(H\) is written as follow \[\text{[8]}\]:

\[ H_{M\text{R},N_T} = \begin{pmatrix} h_{1,1} & h_{1,2} & \cdots & h_{1,N_T} \\
                       h_{2,1} & h_{2,2} & \cdots & h_{2,N_T} \\
                       \vdots & \vdots & \ddots & \vdots \\
                       h_{M\text{R},1} & h_{M\text{R},2} & \cdots & h_{M\text{R},N_T} \end{pmatrix} \] (5)

Where \(h_{ij}\) is the channel coefficients from \(j^{th}\) transmitter to \(i^{th}\) receiver.

Received data is processed with sphere decoders which give the Maximum Likelihood (ML) solution with soft outputs. The Sphere Decoding (SD) signal detection scheme is intended to find the transmitted signal vector with minimum ML metric. Let \(y_{R}\) and \(y_{I}\) denote the real and imaginary parts of the received signal at the \(i^{th}\) receive antenna, that is \(y_{R} = \Re\{y_i\}\) and \(y_{I} = \Im\{y_i\}\). Similarly, the input signal \(x_i\) from the \(i^{th}\) antenna can be represented by \(x_{R,i} = \Re\{x_i\}\) and \(x_{I,i} = \Im\{x_i\}\). The received signal can be expressed as follow:

\[ \begin{bmatrix} y_{1R} \\ y_{2R} \\ y_{1I} \\ y_{2I} \end{bmatrix} = \begin{bmatrix} h_{1,1R} & h_{1,2R} & -h_{1,1I} & h_{1,2I} \\
                     h_{2,1R} & h_{2,2R} & -h_{2,1I} & h_{2,2I} \\
                     h_{1,1I} & h_{1,2I} & h_{1,1R} & h_{1,2R} \\
                     h_{2,1I} & h_{2,2I} & h_{2,1R} & h_{2,2R} \end{bmatrix} \begin{bmatrix} x_{1R} \\ x_{2R} \\ x_{1I} \\ x_{2I} \end{bmatrix} + \begin{bmatrix} b_{1R} \\ b_{2R} \\ b_{1I} \\ b_{2I} \end{bmatrix} \] (6)

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transmissions modes specified by the 3GPP are as follow:
The different configuration of UE request for PDSCH. The different
configuration of LTE has configured particular transmission modes to the
transmission (PDSCH) is used to downlink transmission data for users.
Antenna port, as shown in the following equation:

\[ \mathbf{x} = (\mathbf{H}^H \mathbf{H})^{-1} \mathbf{H}^H \mathbf{y} \]  \hspace{1cm} (7)

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 [7].

IV. PRECODING FOR TRANSMIT DIVERSITY

The concept of transmit diversity is to send the same
information via various antenna, whereby each antenna uses
different coding and different frequency resources. Since the
transmit diversity can be still provided by using STBC. The
best STBC scheme varies with SNR. S. M. Alamouti
proposed a simple two branch diversity scheme [8]. 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 rank i.e. it does not
support multi stream transmission [8] [13].

An Alamouti scheme is used for precoding, which
defines the relationship between input and output, for two
antenna port, as shown in the following equation:

\[
\begin{bmatrix}
    y^{(0)}(2l) \\
    y^{(1)}(2l) \\
    y^{(0)}(2l + 1) \\
    y^{(1)}(2l + 1)
\end{bmatrix} = \frac{1}{2} \begin{bmatrix}
    1 & 0 & j & 0 \\
    0 & -1 & 0 & j \\
    0 & 1 & 0 & j \\
    1 & 0 & -j & 0
\end{bmatrix} \begin{bmatrix}
    Re\{x^0(l)\} \\
    Re\{x^1(l)\} \\
    Im\{x^0(l)\} \\
    Im\{x^1(l)\}
\end{bmatrix} \hspace{1cm} (8)
\]

In downlink LTE, Physical Downlink Shared Channel
(PDSCH) is used to downlink transmission data for users.
LTE has configured particular transmission modes to the
configuration of PDSCH [12]. These transmissions modes
are chosen from the UE request for PDSCH. The different
transmissions modes specified by the 3GPP are as follow
[9]:
- Transmission mode 1: using a single antenna port
  at eNodeB; Port 0.
- Transmission mode 2: Transmit diversity (TxD)
- Transmission mode 3: SU-MIMO Open loop
  Spatial Multiplexing
- Transmission mode 4: SU-MIMO Close loop
  Spatial Multiplexing
- Transmission mode 5: MU-MIMO Spatial
  Multiplexing
- Transmission mode 6: Closed-loop Rank=1
  precoding.
- Transmission mode 7: Single antenna port; port 5.

V. SIMULATION RESULT AND DISCUSS

For simulating the radio link performance of MIMO
transmit diversity and SISO transmission mode for
downlink LTE system, different parameters have been
chosen as shown in Table I. To performs and compare the
MIMO TxD and SISO scheme, we have choose these
different transmissions modes settings: SUSISO (111),
SUMIMO transmit diversity (222 221 and 242). Each
transmission mode is normalized and describe as shown on
[9]. The MIMO channels are a multi-path channel which
uses the profile of ITU-Vehicular A with a speed of
30Km/h. the performance of downlink LTE system are
simulated for CQI 9.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier frequency</td>
<td>2.1 GHz</td>
</tr>
<tr>
<td>Channel type</td>
<td>ITU-Vehicular-A</td>
</tr>
<tr>
<td>ITU-Pedestrian-A</td>
<td></td>
</tr>
<tr>
<td>Number of Base station</td>
<td>1</td>
</tr>
<tr>
<td>Bandwidth (MHz)</td>
<td>1.4</td>
</tr>
<tr>
<td>Transmission mode</td>
<td>SISO, MIMO TxD</td>
</tr>
<tr>
<td>Number of subframe</td>
<td>1000</td>
</tr>
<tr>
<td>Data modulation</td>
<td>16QAM(CQI 9)</td>
</tr>
<tr>
<td>Channel Estimation</td>
<td>Perfect Channel Estimation</td>
</tr>
<tr>
<td>Cyclic Prefix (CP) length</td>
<td>4.7 usec</td>
</tr>
</tbody>
</table>

In first time, to observe the effect of channel encoder, we
simulate and plot the downlink LTE system for SISO and
MIMO precoding for both coded and uncoded transmission.
The Bit Error Rate (BER) and Throughput (Mbps) vs. SNR
(dB) result is shown in Fig. 3 and 4, respectively.

Fig. 3. BER for Coded and Uncoded transmission in downlink LTE
system, SISO and MIMO Transmit Diversity (2Tx/ 2Rx), CQI=9,
Vehicular-A channel, Bandwidth=1.4 MHz

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Fig. 4. Throughput for Coded and Uncoded transmission in downlink LTE system, SISO and MIMO Transmit Diversity (2Tx/2Rx), CQI=9, Vehicular-A channel, Bandwidth=1.4 Mhz

The Fig. 3 show the Bit Error Rate for coded and uncoded transmission in both SISO and MIMO transmit diversity. The effect of coded transmission is also observed and a considerable gain almost 4 dB is achieved at BER=10^{-2} when we use the channel encoder for both SISO and MIMO transmission. For transmit diversity, we see a performance enhancement almost 10 dB at a BER=10^{-2} compared with a single transmit antenna. This is explained by the exploitation of spatial diversity to improve the system performance. The system throughput is show in Fig. 4 and it is also observed that MIMO transmit diversity outperform the SISO transmission. But, for both SISO and MIMO transmission, in case of high SNR, the uncoded system outperforms the coded transmission and a gain almost 1.5 Mbps is achieved.

REFERENCES


