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Performance Analysis of Channel Models of LTE in Various Transmission Modes

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Abstract— Long Term Evaluation (LTE) is an emerging 4G wireless technology.Multiple-Input Multiple-Output (MIMO) systems are a primary enabler of the high data rate to be achieved by LTE . According to LTE Release 9 there are 7 MIMO configurations from mode 2 to 8. An LTE base station is expected to select and switch among these transmission modes based on channel quality feedback like Channel Quality Indicator (CQI). And the ITU standard multipath channel models proposed by ITU used for the development of 3G 'IMT-2000' group of radio access systems are basically similar in structure to the 3GPP multipath channel models. In this paper we have investigated the effect of different multipath channel models at different SNR levels on the performance achieved through transmission mode 1 to 4. The simulation output shows that the mode 3 and 4 which are open loop and close loop spatial multiplexing respectively using 4 transmitting antenna outperforms all other mode in terms of high throughput at very reasonable BLER.

Index Terms— LTE, Transmission Modes, PedA, PedB, AWGN, CQI, Throughput

1 Introduction

In This Paper we have investigated the effect of ITU Multipath Channel Model proposed by ITU [1] on the performance of LTE Release 9 through LTE link level simulator developed by the Institute of Communications and Radio Frequency Engineering, Vienna University of Technology[2]. The aim of these channel models is to develop standards that help system designers and network planners for system designs and performance verification.

This paper is made for the developing countries, who are migrating towards 4G LTE Technology, so that they can use this as a helping manual. That's why transmission mode 1-4 are simulated in high multipath fading environment and the superiority of the open loop and close loop spatial multiplexing were demonstrated.

The paper is organized in following section. In section two we have presented the over view of LTE transmission modes & CQI Feedback and Multipath Channel Model in Section three. In Release 8, Long Term Evaluation(LTE) [3] was standardized by 3GPP as the successor of the Universal Mobile Telecommunication System (UMTS). The targets for downlink and uplink peak data data rate requirements were set to 100Mbits/sec and 50Mbits/sec, respectively when operating in a 20MHz spectrum allocation [4].

First performance evaluations show that the throughput of the LTE physical layer and MIMO enhanced WCDMA [4] is approximately the same [6-10] . However, LTE has several other benefits of which the most important are explained in the following.

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The LTE downlink transmission scheme is based on Orthogonal Frequency Division Multiple Access (OFDMA) which converts the wide-band frequency selective channel into a set of many flat fading sub-channels. The flat fading sub-channels have the advantage that even in the case of MIMO transmission – optimum receivers can be implemented with reasonable complexity, in contrast to WCDMA systems . OFDMA additionally allows for frequency domain scheduling, typically trying to assign only "good" sub-channels to the individual users . This offers large throughput gains in the downlink due to multi-user diversity [11, 12].

2 Transmission Mode Downlink & CQI Feedback in LTE

2.1 Transmission Mode Downlink

In the downlink, LTE uses technologies such as MIMO, transmit diversity or SISO, Beamforming etc are used to achieve high data rates. In the Release 9 specification [13], up to four antennas are defined in the base station and up to four antennas in the UE [14].

TABLE 1: TRANSMISSION MODES IN LTE RELEASE 9

Transmission Mode (TM)	Description	Comment
1	Single transmit antenna	Single antenna port; port0
2	Transmit diversity	2/4 antennas
3	Open loop spatial multiplexing with cyclic delay diversity(CDD)	2/4 antennas
4	Close loop spatial multiplexing	2/4 antennas
5	Multi-user MIMO	2/4 antennas
6	Close loop spatial multiplexing	1 layer (rank 1), 2/4 anten-

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	using a single transmission layer	**nas**
7	**Beamforming**	**Single antenna port; port 5**
8	**Dule-layer beamforming**	**Dule-layer transmission, antenna ports 7 or 8**

Here we discussed about Transmission Mode 1,2,3,4.

Transmission Mode 1 is Single transmit antenna [14].

Transmission Mode 2 is Transmit diversity which sends the same information via various antennas, whereby each antenna stream uses different coding and different frequency resources. This improves the signal-to-noise ratio and makes transmission more robust. For two antennas, a frequency-based version of the Alamouti codes (space frequency block code, SFBC) is used, while for four antennas, a combination of SFBC and frequency switched transmit diversity (FSTD) is used [14] .

Transmission Mode 3 is Open loop spatial multiplexing with CDD which supports spatial multiplexing of two to four layers that are multiplexed to two to four antennas, respectively, in order to achieve higher data rates. It requires less UE feedback regarding the channel situation (no precoding matrix indicator is included), and is used when channel information is missing or when the channel rapidly changes, e.g. for UEs moving with high velocity [14].

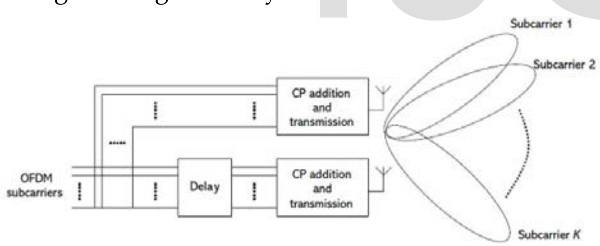

Fig 1: Transmission Mode (TM) 3, Spatial multiplexing with CDD

Transmission Mode 4 is closed loop spatial multiplexing with up to four layers that are multiplexed to up to four antennas, respectively, in order to achieve higher data rates. To permit channel estimation at the receiver, the base station transmits cell-specific reference signals (RS), distributed over various resource elements (RE) and over various timeslots[13].

TABLE 2 : CODEBOOK INDICES FOR SPATIAL MULTIPLEXING WITH TWO ANTENNAS [13]

Spatial multiplexing LTE		
Codebook index	Number of layers υ	
	1	2
0	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\j & -j\end{bmatrix}$
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	-

n the UE and sent to the eNodeB in the form of so-called CQIs (Channel Quality Indicator). The quality of the measured signal depends not only on the channel, the noise and the interference level but also on the quality of the receiver, e.g. on the noise figure of the analog front end and performance of the digital signal processing modules. That means a receiver with better front end or more powerful signal processing algorithms delivers a higher CQI. The signal quality measurements are done using reference symbols. In Figure 2 [15] the whole signal generation chain of the LTEs physical layer with Turbo coding and modulation modules can be seen, which are parts of the link adaptation system.

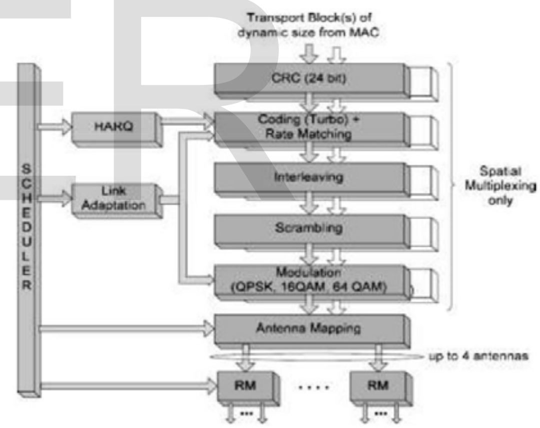

Fig 2: Signal generation chain in LTE

In the LTE physical layer, resources are managed with the so-called RM Modules (Resource Management), which assign incoming data blocks to resource blocks. One resource block consists of 12 sub-carriers and one time slot. The resource management in LTE can be seen in Figure 3 [15] CQI values are used also to select the optimum resource block i.e. the optimum sub-carrier and the optimum time slot.

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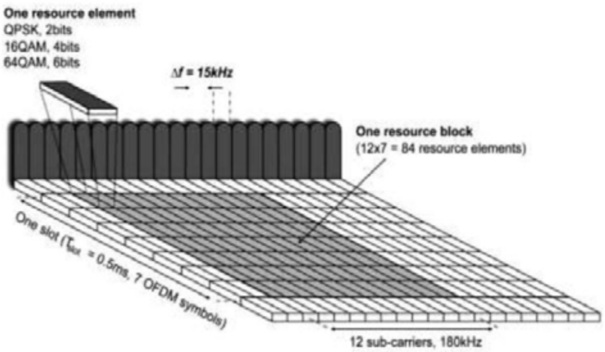

Fig 3: Two dimensional resource management in LTE

3 ITU MULTIPATH CHANNEL MODEL

Instead of defining propagation models for all possible environments, ITU proposed a set of test environments in[1] that adequately span the all possible operating environments and user mobility. In our work we used Pedestrian A, Pedestrian B & Additive White Gaussian Noise(AWGN) Channel.

3.1 ITU Pedestrian A & Pedestrian B Channel

For Pedestrian models the base stations with low antennas height are situated outdoors while the pedestrian user are located inside buildings or in open areas. Fading can follow Rayleigh or Rician distribution depending upon the location of the user. The number of taps in case of Pedestrian-A model is 3 while Pedestrian-B has 6 taps. The average powers and the relative delays for the taps of multipath channels based on ITU recommendations are given in figure 4 [1].

Tap No	Pedestrian-A Relative Delay (ns)	Pedestrian-A Average Power(dB)	Pedestrian-B Relative Delay (ns)	Pedestrian-B Average Power(dB)	Doppler Spectrum
1	0	0	0	0	Classical
2	110	-9.7	200	-0.9	Classical
3	190	-19.2	800	-4.9	Classical
4	410	-22.8	1200	-8	Classical
5	NA	NA	2300	-7.8	Classical
6	NA	NA	3700	-23.9	Classical

Fig.4. Average Powers and Relative Delays of ITU multipath Pedestrian-A and Pedestrian-B cases

3.2 AWGN Noise Channel

AWGN is a noise that affects the transmitted signal when it passes through the channel. It contains a uniform continuous frequency spectrum over a particular frequency band.

4 SIMULATION

4.1 Simulation Result

In LTE we have seen the variation in Throughput with the change of Transmission mode & CQI. Ideally it seems like the picture below for all channels (PedA, PedB, AWGN)

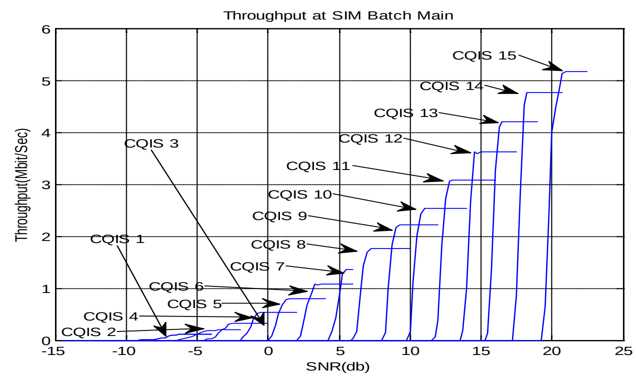

Fig 5: Ideal variation in throughput with the change of CQI

Here SUMIMO (Single User Multiple Input Multiple Output),MUMIMO (Multiple User Multiple Input Multiple Output),SUSISO(Single User Single Input Single Output) are used as parameters.

But practically, the variation doesn't happen in this way. The throughput varies differently for each types of transmission mode. Every transmission mode follows a definite rate to vary the parameter (Throughput). We can observe the variation rate through the table below:

TABLE 3 : VARIATION RATE OF TRANSMISSION MODE WITH THE CHANGE OF CQI

CQI	Transmission Mode (Transmission mode, nTx, nRx)	Peak throughput (Mbit/Sec) for all Channels [PedA,PedB,AWGN]
1	1	0.1
	221	0.1
	242	0.1
	342	0.2
	442	0.2
2	1	0.25
	221	0.25
	242	0.2
	342	0.35
	442	0.35
3	1	0.35
	221	0.35
	242	0.35
	342	0.75
	442	0.75
4	1	0.55
	221	0.5
	242	0.5
	342	1
	442	1
5	1	0.8
	221	0.75
	242	0.7

	342	1.4
	442	1.5
6	1	1.1
	221	1.01
	242	1
	342	2
	442	2
7	1	1.4
	221	1.3
	242	1.4
	342	2.4
	442	2.4
8	1	1.8
	221	1.8
	242	1.6
	342	3.2
	442	3.2
9	1	2.2
	221	2.1
	242	2
	342	4
	442	4
10	1	2.6
	221	2.4
	242	2.3
	342	4.6
	442	4.6
11	1	3.1
	221	2.9
	242	2.8
	342	5.6
	442	5.6
12	1	3.6
	221	3.4
	242	3.3
	342	6.5
	442	6.5
13	1	4
	221	4
	242	3.8
	342	7.6
	442	7.6
14	1	4.8
	221	4.5
	242	3.5
	342	8.9
	442	8.9
15	1	4.1
	221	4.8
	242	2.4
	342	8.8
	442	8.8

The variation rate & characteristics' can easily be visualized through the figures given below :

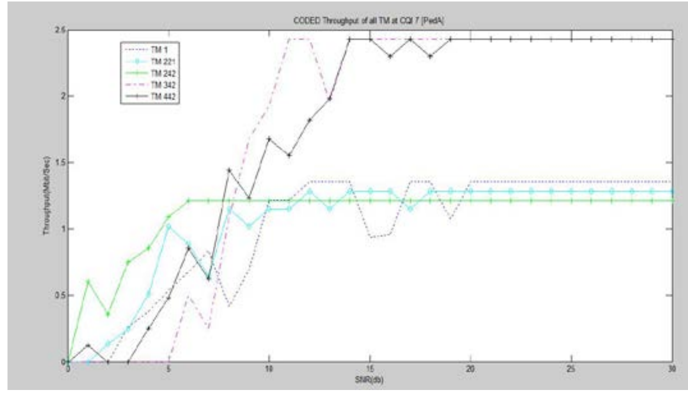

Fig 6: Throughput of all Transmission Modes at CQI 7 (PedA)

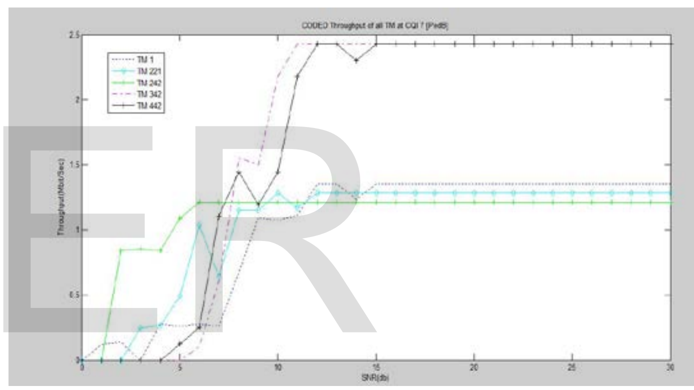

Fig 7: Throughput of all Transmission Modes at CQI 7 (PedB)

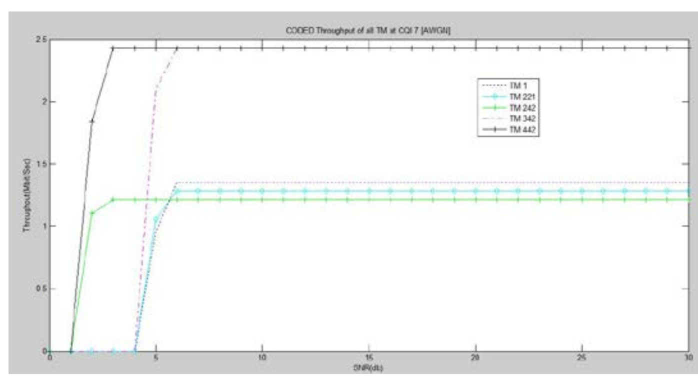

Fig 8: Throughput of all Transmission Modes at CQI 7 (AWGN)

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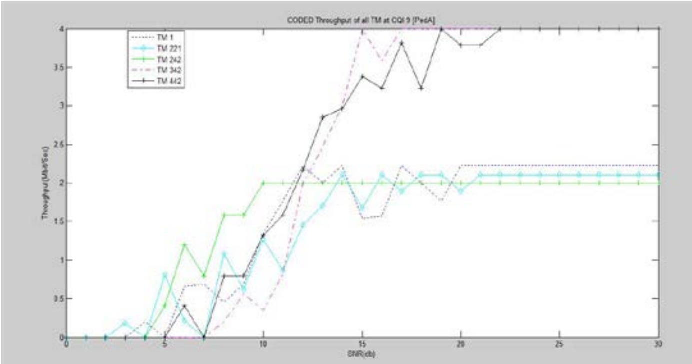

Fig 9: Throughput of all Transmission Modes at CQI 9 (PedA)

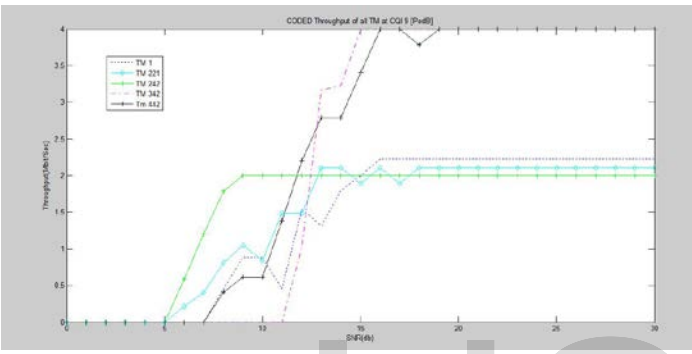

Fig 10: Throughput of all Transmission Modes at CQI 9 (PedB)

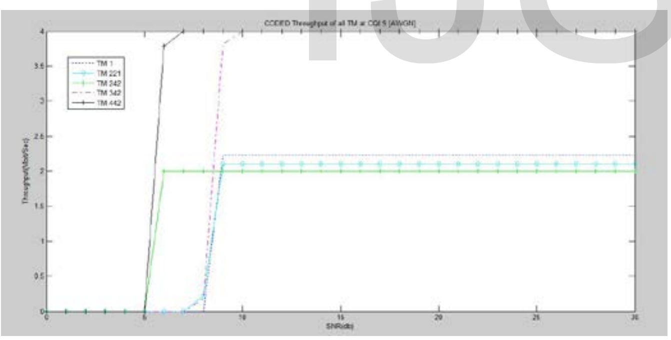

Fig 11: Throughput of all Transmission Modes at CQI 9 (AWGN)

4.2 Simulation Comparison

From the above figures we have seen that, AWGN Channel gives flat signal and not "frequency-selective" [16] as well. And Pedestrian A channel takes more DB to be stable than Pedestrian B channel. It can be realized through the picture given below:

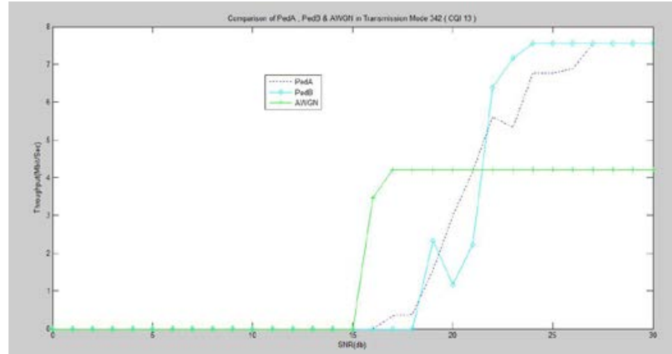

Fig 12: Comparison of PedA, PedB & AWGN in TM 342

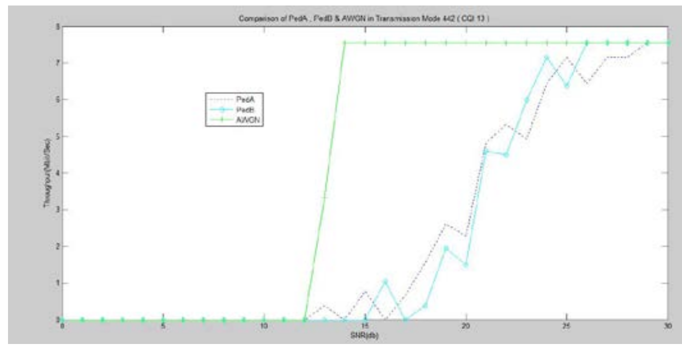

Fig 13: Comparison of PedA, PedB & AWGN in TM 442

That's why Pedestrian B Channel is effective for the developing countries,who are migrating towards 4G LTE Technology

5 Conclusion

The analysis done by ITU-R showed that evolution of 3G systems to future generation networks will require technology changes on large scale while new quality of service (QoS) requirements will require increased transmission bandwidth. So LTE channel models require more bandwidth as compared to UMTS channel models to account that fact that channel impulses are associated to the delay resolution of the receiver. The LTE channel models developed by 3GPP are 52 based on the existing 3GPP channel models and ITU channel models. The extended ITU models for LTE were given the name of Extended Pedestrian-A (EPA), Extended Vehicular-A (EVA) and Extended TU (ETU). These channel models are classified on the basis of low, medium and high delay spread where low delay spreads are used to model indoor environments with small cell sizes while medium and high delay spreads are used to model urban environments with large cells.

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