Throughput Quantification of MIMO based Correlated Rician fading Channel for a LTE downlink system

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ABSTRACT
A MIMO system can offer two types of gains i.e. spatial multiplexing (increase data rate) and diversity gain. However, these benefits of MIMO systems depend crucially on the kind of fading the channels undergo and whether the channel state information (CSI) is known at the transmitter. Most of the researches have been on Rayleigh channels. However in real world propagation environment, the fades are not independent, for instance due to insufficient spacing between antenna elements or due to lack of scatterers. It is possible that the line of sight component (LOS) may exist in addition to scattered components. Then the fading will follow the Rician distribution. This paper envisages the capacity benefits of MIMO under a slow changing and correlated Rician fading environment for the LTE downlink 2x2 configuration. The effect of no of multipath on capacity is also investigated. Here 2 Omni directional transmit antennas at the base station and 2 similar receive antennas at the terminal side are taken. In Long Term Evolution (LTE), MIMO technologies have been broadly used to get better downlink peak rate, cell coverage, as well as average cell throughput. To achieve this goals, LTE adopts two major MIMO technologies i.e. Spatial multiplexing (SM) and transmit diversity (TD). Spatial multiplexing allows transmitting different streams of data simultaneously on the same downlink resource block(s) this increases the data rate of the user. In Transmit Diversity a single stream of data is assigned to the different layers and coded using space frequency block coding (SFBC). SFBC achieves robustness through frequency diversity by using different subcarriers for the repeated data on each antenna. This paper will show the effect of strongest multipath component i.e. Recian factor on capacity and diversity. These all finding will pave the path for comparison between the often studied Rayleigh environment (Non LOS) and the Rician environment (LOS).

Keywords
Spatial Multiplexing, Transmit Diversity, Space-Time Codes, Alamouti Code, LTE, Channel State Information etc.

1. INTRODUCTION
Multiple input multiple output (MIMO) systems which uses multiple transmit and receive antennas are extensively now recognized as the imperative advancement that will allow prospective wireless systems to achieve higher data rates with limited power resource and bandwidth. This increase in data rate (throughput) is only when the channel is rich scattering (Rayleigh fading) and also the fades are mutually independent and identically disseminated. Conventionally, multiple antennas have been used to increase diversity to combat fading.

Wireless technology is the key for all the ambitious communication networks that may allow the transferring and receiving of information anytime and anywhere whether static or in motion. The applications such as wireless phones, wireless Internet access, wireless local area networks (WLAN), automated highways, distance learning, video conferencing, and home audio/visual networks require data rates nearing 1 Gb/s [1]. There are many practical challenges that must be conquered in order to make this dream a reality. One of the toughest challenges faced is the bottleneck presented by the wireless link layer. The wireless channel is a ruthless time-varying propagation environment. A signal transmitted on a wireless channel is subject to interference, propagation path loss, delay spread, Doppler spread, shadowing and fading. While it is possible to increase data rates by increasing the transmission bandwidth or using higher transmit power, both spectrum and transmit power are very constrained in a wireless system. The bandwidth, or spectrum, is prohibitively expensive. Increasing transmit power adds interference to other systems and also reduces the battery life-time of mobile transmitters. The MIMO technology holds the promise of higher data rates with improved spectral competence [2,3,4] it is a step forward in wireless communication system design. The technology offers a number of benefits that help meet the challenges posed by the impairments in the wireless channel and also the resource constraint [4,5,6]. The conventional single-antenna (single–input single-output) wireless systems exploit the time and frequency dimensions, the leverages of MIMO are realized by exploiting the spatial dimension by multiple antennas at the transmitter and receiver. Due to the latent improvement in system performance and advances in digital signal processing, many wireless systems, including the IEEE 802.11n wireless LAN, IEEE 802.16e-based Mobile WiMAX Wave 2 and the Long-Term Evolution (LTE) mobile wireless system, have recently adopted the use of MIMO and multiple antenna technologies. MIMO leverages multipath propagation, a wireless characteristic traditional viewed as a negative [6,7]

Foschini and Gans in 1998 showed from their theoretical study that there is a linear growth of capacity with the number of antennas [4,8]. Many other studies have reported diversity gains. [9]–[12]. These all studies assume Rayleigh fading condition. The assumption of only Rayleigh fading is debatable as in real world; the line-of-sight (LOS) component may exist along with the scattered components. In practice, however, the deficient antenna spacing and the lack of scatterers reduce the capacity as well as the performance of the space-time processing due to increased channel correlation. This motivates the need to estimate the performance of a MIMO system with spatially correlated fading channel with Ricean factor K, as well as to characterize the impact of these factors on the performance of the system for two major MIMO technologies i.e. Spatial multiplexing (SM) and transmit diversity (TD).

2. SPATIAL MULTIPLEXING (SM) AND TRANSMIT DIVERSITY (TD)
Spatial multiplexing (SM): For an antenna system containing M_T transmitting antenna and M_R receiving antennas the system

offers a linear i.e. min (M_R, M_T) increase in the transmission rate (or capacity) for the same bandwidth and with no additional power expenditure. For illustration if we have two transmit and two receive antennas the bit stream is split into two half-rate bit streams, modulated and transmitted simultaneously from both the antennas. The receiver, having complete knowledge of the channel, recovers these individual bit streams and combines them so as to recover the original bit stream. Since the receiver has knowledge of the channel it provides receive diversity, but the system has no transmit diversity since the bit streams are completely different from each other in that they carry totally different data. Thus spatial multiplexing increases the transmission rates proportionally with the number of transmit-receive antenna pairs. [4, 13]

Transmit diversity *(TD):* In this case we introduce controlled redundancies at the transmitter, which can be then exploited by appropriate signal processing techniques at the receiver. Generally this technique requires complete channel information at the transmitter to make this possible. But with the advent of space-time coding schemes like Alamouti's scheme [6], it became possible to implement transmit diversity *without* knowledge of the channel. This was one of the fundamental reasons why the MIMO industry began to rise. Space-time codes for MIMO exploit both transmit as well as receive diversity schemes, yielding a high quality of reception at the base station and the number of users [13]

3. SYSTEM PARAMETERS

The configuration used is 2x2 MIMO Transmit Diversity and 2x2 MIMO Spatial Multiplexing. The measured parameters are Swept Throughput vs. SNR measurements for LTE downlink correlation based channel environments with Rician component (K=6).

Other system parameters are summarized in table 1.

System	:	SU – 3GPP LTE Downlink Channel
Rayleigh spectrum shape	:	Classical 6dB.
XPER	:	-9dB
Antenna Type	:	Omni Antenna
Distance between Transmitting Antennas	:	2λ
Distance between Receiving Antennas	:	2 λ
Mobile Station Velocity	:	3 km/hr
MS Direction in Degree	:	120
Frequency	:	2GHz
Bandwidth	:	10 MHz

Table 1

We have chosen to work with at most 12 paths between the Base Station (BS) and the Mobile Station (MS) / User equipment (UE). Table 2 shows the path parameters

Path index	Path power in dB	Path delay ns	Path AoA	Path AoD
1.	-3.0	0	-2.3	6.6
2.	-5.0	5	-2.3	6.6
3.	-7.0	10	-2.3	6.6
4.	-4.3	28	42.6	14.1
5.	-6.5	290	42.6	14.1
6.	-8.3	295	42.6	14.1
7.	-5.7	205	-49.5	50.8
8.	-7.9	210	-49.5	50.8
9.	-9.7	215	-49.5	50.8
10.	-7.3	660	24.7	38.4
11.	-9.5	665	24.7	38.4
12.	-11.3	670	24.7	38.4

Table 2

Fig 1, 2 and the definitions given explains the various angle parameters used in the simulation studies.

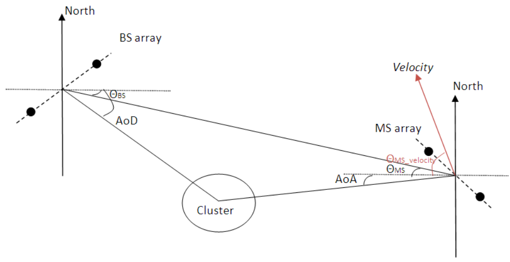

Figure 1
Angle Parameters between Transmitter & Receiver

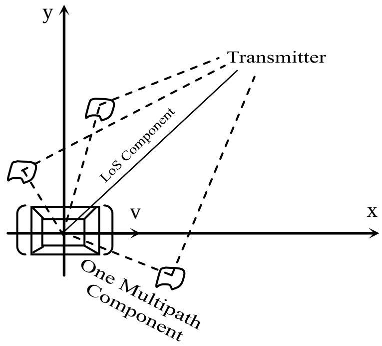

Figure 2
LOS Component and Multipath Components between Transmitter & Receiver

The antenna position is defined based on Cartesian coordinates, where y-axis points to the geographical north and the x-axis is parallel to the ground.

Path AoA specifies the mean of the angles of an incident path's power at the UE/Mobile station array. The angle of arrival is defined with reference to x-axis, in the range of (-180^o, 180^o).

Path AoD specifies the mean of the angles of an departing path's power is transmitted by the BS array. The angle of departure is defined with reference to x-axis, in the range of (-180^o, 180^o).

Θ_{MS} specifies the line-of-sight angle of arrival.

MS Direction specifies the mobile station direction of travel.

Θ_{BS} specifies the line-of-sight angle of departure.

The definitions used are:

(i) BLER (Block error rate)

$$\frac{\sum_{SubframeStart}^{SubframeStop}(1-\mathrm{CRCParity})}{\sum_{SubframeStart}^{SubframeStop}(1)}$$

(ii) Throughput (averaged throughput (bps) over specified sub frames)

$$\sum_{SubframeStart}^{SubframeStop}\left(TBS\times CRCParity\times 1000\right)$$

(iii) Throughput Fraction (the fraction (%) of averaged throughput to the maximum possible throughput)

$$\frac{\sum_{SubframeStart}^{SubframeStop} TBS\times CRCParity}{\sum_{SubframeStart}^{SubframeStop} TBS}$$

TBS- Transport Block Size of subframe.
CRCPARITY- CRC result of received transport block bits.

4. RESULTS & DISCUSSIONS

Type A: Spatial Multiplexing Mode (SM)
We have taken the line of sight component i.e. Rician factor K = 6. We have chosen four, eight and twelve multipath for our simulation.

Results of 4 Multipath (Table: 3)

SNR	BLER	THROUGHPUT	THROUGHPUT FRACTION
10	0.986	181440	1.4
12	0.796	2.644×10^{6}	20.4
14	0.5	6.48×10^{6}	50
16	0.247	9.759×10^{6}	75.3
18	0.1	11.66×10^{6}	90

Table 3

Results of 8 Multipath (Table: 4)

SNR	BLER	THROUGHPUT	THROUGHPUT FRACTION
10	0.683	4.108×10^{6}	31.7
12	0.405	7.711×10^{6}	59.5
14	0.077	11.96×10^{6}	92.3
16	3×10^{-3}	12.92×10^{6}	99.7
18	0	12.96×10^{6}	100

Table 4

Results of 12 Multipath (Table: 5)

SNR	BLER	THROUGHPUT	THROUGHPUT FRACTION
10	0.923	997920	7.7
12	0.499	6.493×10^{6}	50.1
14	0.187	10.54×10^{6}	81.3
16	7×10^{-9}	12.87×10^{6}	99.3
18	0	12.96×10^{6}	100

Table 5

Fig 3 Shows the graph between throughput fraction and SNR for the data given in table 3, 4, 5.

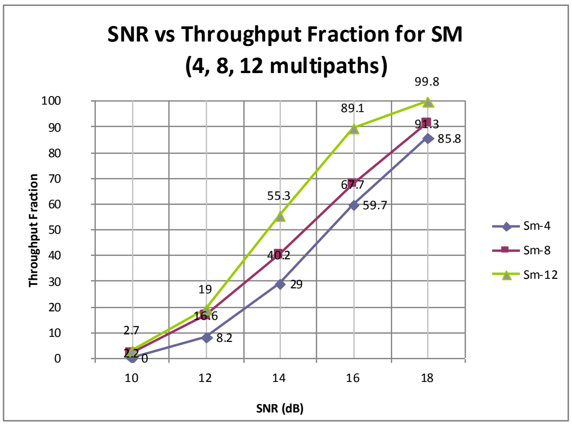

Figure 3
Variation of SNR with Throughput Fraction for Spatial Multiplexing Mode

Type B: Transmit Diversity Mode (TD)
Here too we have taken the line of sight component i.e. Rician factor K = 6 and have taken four, eight and twelve multipath for our simulation.

Results of 4 Multipath (Table: 6)

SNR	BLER	THROUGHPUT	THROUGHPUT FRACTION
2	0.465	6.934×10^{6}	53.5
4	0.258	9.616×10^{6}	74.2
6	0.065	12.12×10^{6}	93.5
8	0.021	12.69×10^{6}	97.9
10	0	12.96×10^{6}	100

Table 6

Results of 8 Multipath (Table: 7)

SNR	BLER	THROUGHPUT	THROUGHPUT FRACTION
2	0.32	8.813×10^{6}	68
4	0.107	11.57×10^{6}	89.3
6	0	12.96×10^{6}	100
8	0	12.96×10^{6}	100
10	0	12.96×10^{6}	100

Table 7

Results of 12 Multipath (Table: 8)

SNR	BLER	THROUGHPUT	THROUGHPUT FRACTION
2	0.41	7.646×10^{6}	59
4	0.152	10.99×10^{6}	89.8
6	0.012	12.8×10^{6}	98.8
8	0	12.96×10^{6}	100
10	0	12.96×10^{6}	100

Table 8

Fig 4 Shows the graph between throughput fraction and SNR for the data given in table 6,7,8.

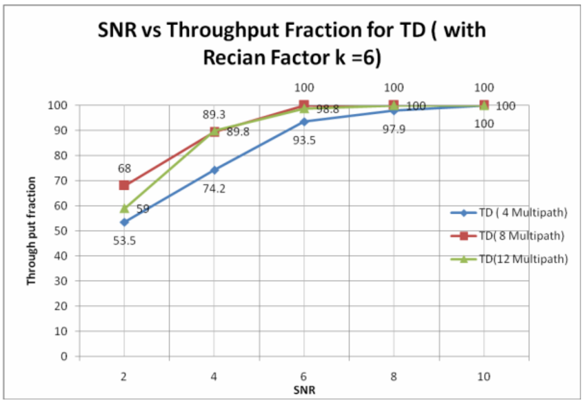

Figure 4
Variation of SNR with Throughput Fraction for Transmit Diversity Mode

5. CONCLUSION

We have separately investigated the effect of Rician fading and no of multipath on the capacity of multi-input and multi-output (MIMO) systems. The variation of Block Error Rate, Throughput and Throughput Fraction with SNR, keeping the no of multipath constant (4, 8 & 12 multipath) are quantitatively reported and discussed. Studies have shown that in certain realistic propagation environments, the number of significant multipath components can be small [14] i.e. 5 to 18 for wireless local loop [15], 6 to 12 for rural and suburban cellular telephony [16], and 9 to 18 for indoor factory applications [17].

In general it is observed that the Throughput fraction increases with the no of multipath, but the effect is more prominent for the Spatial Multiplexing mode (SM). We observed that the presence of a rich multipath environment can improve the performance of MIMO systems even in the presence of stronger LOS component.

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