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A Quantitative Analysis of Some Key LTE Radio Performance Metrics

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Abstract: This paper provides analyses of the performance of radio parameters necessary for efficient Long term evolution (LTE) radio planning: through numerous simulations in different transmission modes and network scenario. It mainly highlights the throughput, Block Error Rate (BLER) with respect to Signal-to-Noise Ratio (SNR) along with changed UE mobility on the physical layer and in network context covering different simulation environments.

Keywords: Transmission mode, BLER, SNR, CQI, Throughput

1. Introduction

LTE is a fourth generation technology which is expected to be the mobile broadband platform for services in innovation for the foreseeable future. It is a 3rd Generation Partnership Project (3GPP) standard designed to have wider channels up to 20MHz with packet optimized radio access technology. It has many promising features for example high scalability, Frequency Division Duplex (FDD) and Time Division Duplex (TDD) duplexing mode. To meet the user's expectations, LTE aims at better spectral flexibility, higher data rates, low latency, improved coverage and better battery lifetime. To achieve these targets, mainly three enabling technologies are employed namely; Orthogonal Frequency Division Multiple Access (OFDMA), Single Carrier Frequency Division Multiple Access (SC-FDMA) and Multiple Input Multiple Output (MIMO). LTE employs OFDMA in the downlink direction and SC-FDMA in the uplink data transmissions [1-3].To substantially enhance the air interface, MIMO employs multiple transmit and receive antennas, for higher data rates and fight against multi path fading.

The main objective of the paper is to analyze the performance of radio parameters necessary for efficient LTE radio planning. Through numerous simulations in different transmission modes and network scenario, it mainly aims to highlight the throughput, BLER with respect to SNR along with changed UE mobility on the physical layer and in network context.

The remainder of this paper is organized as follows: Section 2 highlights about related works, section 3 contains the brief overview of transmission modes. Afterwards, link and system level simulation results and their analyses have been given in section 4; while section 5 covers the UE mobility and the throughput results.

2. Related Works

Related works using link level results include: SNR to Channel Quality Indicator (CQI) mapping for different MIMO settings [4], limiting downlink Hybrid Automatic Repeat Request (HARQ) retransmission in poor link [5]. Radio network planning for Dhaka city- coverage and capacity analysis approach has been suitably presented in [6-7]. A LTE coverage prediction scenario with Kolkata city is presented in [8]. Similar approach with Dhaka city using Link and System Level simulator [9] has been made in [13]; but that analysis didn't cover the UE mobility with near and far field region and its relationship with different performance metric considering different transmission modes. Again, none of those had the clear motive to thoroughly investigate these stated LTE radio parameters in different transmission modes and environments running simulations with numerous different settings. So, this has been chosen as the focus of this paper along with integrating the UE

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mobility case which is expected to improve the network planning issue of LTE and LTE-Advanced considerably.

3. Transmission Modes

Suitable transmission mode can be adapted semi-statically according to various channel conditions during dynamic resource scheduling. Physical Downlink Shared Channel (PDSCH) channel employs different transmission modes utilizing multiple antennas in both transmitting and receiving sides. Till now nine transmission modes have been released while only first four have been implemented [2], [13-14]. These nine transmission modes are: single antenna: port 0, transmit diversity, open loop spatial multiplexing (OLSM), closed loop spatial multiplexing (CLSM), MU-MIMO, closed loop rank-1 precoding, single antenna: port 5, dual layer transmission: port 7, 8 and up to 8 layer transmission: port 7-14. Among these transmission modes, single antenna, transmit diversity and spatial multiplexing will likely be the point of interest based on the implementations [14].

A. SISO

SISO is used in transmission mode 1. It uses single antenna at the eNodeB. It has got the lowest data rate compared to other transmission modes.

B. Transmit Diversity

Transmit Diversity (TxD) is used in transmission mode 2. Transmit diversity increases the SNR at the receiver instead of directly increasing the data rate.

C. Spatial Multiplexing

Spatial multiplexing allows multiple antennas to transmit multiple independent streams. So it is sometimes referred to as the true MIMO technique.

- OLSM is used in transmission mode 3. It makes use of the spatial dimension of the propagation channel and transmits multiple data streams on the same resource blocks.
- CLSM is used in transmission mode 4. In this case, the UE estimates the radio channel and selects the most desirable entry from a predefined codebook. Then the UE sends a feedback to the eNodeB and hence, it is termed as closed-loop.

4. Simulation Results and Performance Analysis

For efficient deployment of LTE, performance analyses of different radio parameters are worth investigating. Simulations are necessary to test and optimize algorithms and procedures. These have to be carried out on both the physical layer and in the network context. LTE physical layer is important for conveying both data and control information between an eNodeB and UE. To enable reproducibility and to increase credibility of our results, simulation of the physical layer is done using a link level simulator [9-10] and in the network using a system level simulator [9], [11-14].

A. Link Level

The analysis with link level simulations was carried out using parameters stated in Table I. The focus was to analyze throughput and BLER values with the change of SNR. Number of subframes was 1000 to visualize the effect.

Results of throughput vs SNR were obtained and shown in Fig. 1. Again, the results of BLER vs SNR are presented in Fig. 2. With different transmission modes: SISO, TxD 2×1, TxD 4×2 and OLSM 4x2 simulation of both throughput and BLER were performed taking Pedestrian B (PedB) and Flat Rayleigh channel using CQI value 7 [13].

TABLE I. : Basic Settings Used For Link Level Simulator

Parameter	Settings
Bandwidth	1.4MHz
Retransmissions	0 and 3
Channel type	Flat Rayleigh, PedB
Filtering	Block Fading
Receiver	Soft Sphere Decoder
Simulation length	1000 subframes
Transmit modes	SISO, TxD (2x1 and 4x2) and OLSM (4x2)

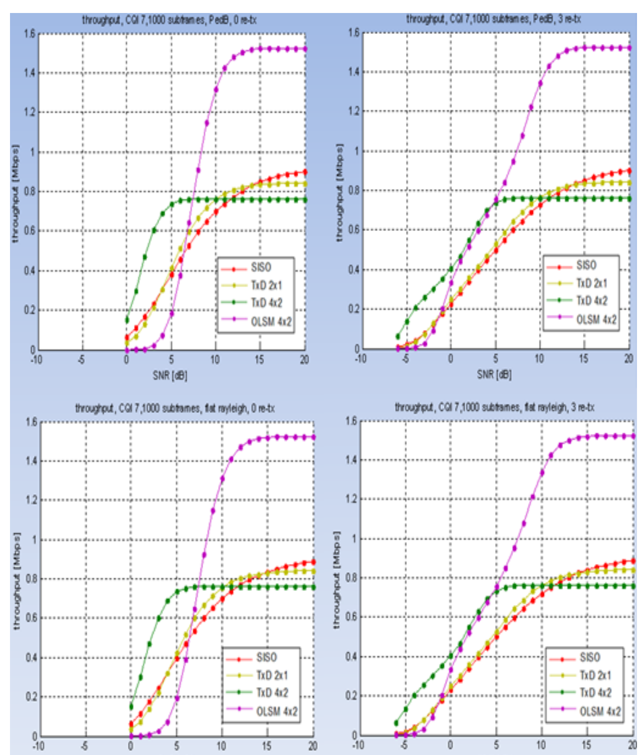

Figure 1. Throughput vs SNR for 1000 Subframes with 0 and 3 re-tx: PedB channel (top) & flat rayleigh channel (bottom)

1) *Throughput analysis:* From Fig. 1, if SNR requirement is fixed at 15dB, the maximum throughput is found as 1.52Mbps achieved with OLSM 4x2 and the least throughput is about 0.78Mbps obtained with TxD 4x2.

2) *BLER analysis:* BLER is defined as the ratio of the number of erroneous blocks received to the total number of blocks sent. An erroneous block is defined as a Transport Block, the cyclic redundancy check (CRC) of which is wrong. A 0% BLER is not always necessary or practical, due to the extra time it takes to resend blocks with errors. In LTE, adaptive modulation and coding has to ensure a BLER value smaller than 10 % [10]. As per Fig. 2, if BLER value is limited at 10^{-1} (10% of the max.); at least a SNR of about 4 dB is required to reach this target BLER. It is achieved through TxD 4x2. This means less signal power is needed with this transmission mode-TxD 4x2 for minimum possible BLER. The same BLER can also be achieved with a maximum SNR of 14dB given by SISO and this implies that more signal power has to be given using that scheme. So, SISO is supposedly not a good choice for BLER sensitive environment because of its higher power requirement.

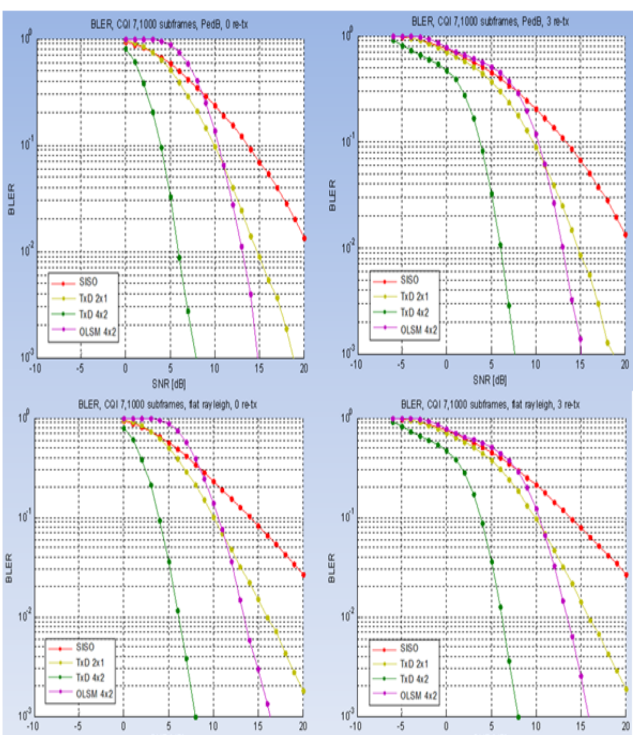

Figure 2. BLER vs SNR for 1000 Subframes with 0 and 3 re-tx: PedB channel (top) & flat rayleigh channel (bottom)

B. System Level

To determine the level at which predicted link level gains impact network performance, system level simulations were performed [9], [12] and results shown in Fig. 3-7. Parameters set for the simulator were 21 cells which form the region of interest shown in Fig 3. A simulation length of 50 TTIs was used. Scheduler: Proportional fair, 2 transmitting and 2 receiving antennas, and MIMO Transmit mode was CLSM.

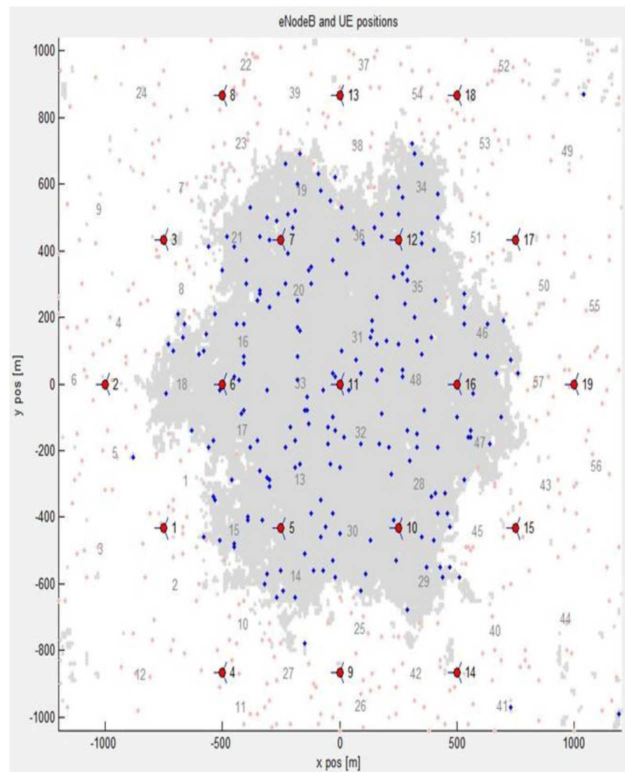

Figure 3. Region of Interest, eNodeB-UE Distribution for 30 UEs/cell

From Fig. 4(a), in order to ensure 50% cumulative probability required UE average throughput is around 2.2 Mbps. Fig. 4(b) shows the UE wideband SINR to throughput mapping. From this plot required SINR value is around 5 dB to maintain throughput level of 2.2 Mbps.

In the same way, from Fig. 5(a), in order to keep 50% cumulative probability required UE average spectral efficiency is around 3.8 bits/c.u. Fig. 5(b) shows the UE wideband SINR to spectral efficiency mapping. From this plot required SINR value is around 7 dB to maintain the spectral efficiency of 3.8 bits/c.u. In this case, SINR level for required spectral efficiency exceeds that of average throughput. To sum it up, an aggregate SINR level of 7 dB is required for 50% cumulative probability considering both UE average throughput and spectral efficiency.

But SINR if lifted to 7 dB will result into slightly higher UE average throughput of 2.3 Mbps. The aggregate SINR level can be verified from the Empirical Cumulative Distribution Function (ECDF) vs SINR plot of Figure 6. Table II shows average throughput and spectral efficiency results varying consecutively number of UEs/cell from 10 to 30. From here a spectral efficiency of 3.73bit/cu, 4.00bit/cu, 3.79bit/cu, 3.74bit/cu and 3.94bit/cu were also attained for 10UEs -30 UEs respectively.

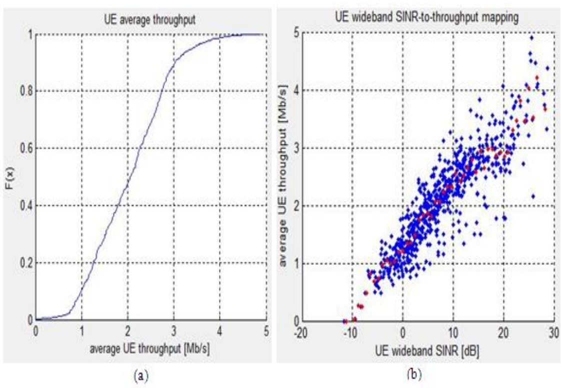

Figure 4. UE Wideband SINR to Throughput Mapping

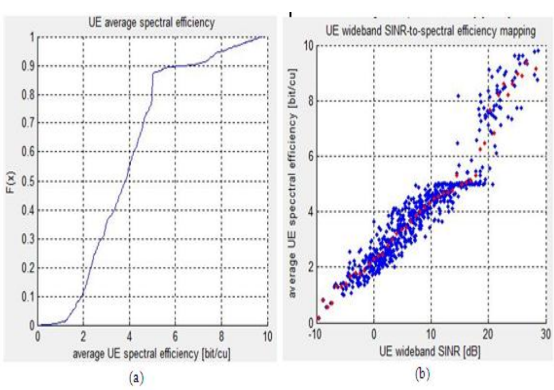

Figure 5. UE Wideband SINR to Spectral Efficiency Mapping

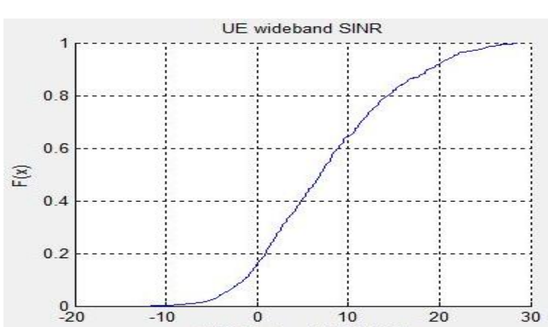

Figure 6. Aggregate SINR Level: ECDF vs SINR

TABLE II. AVERAGE THROUGHPUT & SPECTRAL EFFICIENCY WITH DIFFERENT UES PER CELL

UE/Cell	Average Throughput (Mb/s)	Average Spectral Efficiency (bits/c.u.)
10	5.87	3.73
15	4.27	4.00
20	3.00	3.79
25	2.45	3.74
30	2.05	3.94

5. UE MOBILITY AND THROUGHPUT RESULTS

UE with slow (1.25 m/s) and fast (25 m/s) speed were taken into consideration involving both near and far field region for comparison of the transmission modes. The performance measure in terms of throughput is shown in Fig. 7(a) for slow UE and Fig. 7(b) for faster UE speed 20 times higher than the earlier one.

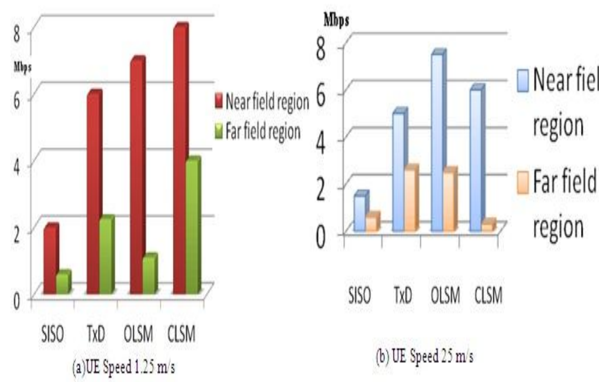

Figure 7. Throughput with Changed Speed for Transmission Modes

- For low speed-1.25 m/s case, OLSM and CLSM has comparatively better throughput in near field region. But for far field region TxD has better throughput compared to OLSM while CLSM still dominates the overall comparison.
- For higher speeds-25 m/s case, OLSM tops the chart in near field region while CLSM has the second highest throughput.
- While throughput for TxD is quite close to that of CLSM in near field region, it tops the chart for far-field region for faster UEs. But for far-field case, throughput for OLSM is quite close to that of TxD while CLSM has the least throughput.
- CLSM imposes a heavy burden on uplink since it requires the most feedback information among the transmission modes of LTE. So, considering the

complexity CLSM is less likely to be chosen as transmission mode.

- Though OLSM has better performance in near-field region, TxD serves quite well in far-field region which is also one of the most significant performance parameters.

6. Conclusion

It is evident from the simulated results that the highest throughput is achieved with MIMO scheme: OLSM 4x2 mode, while the suitable BLER is achieved with the TxD 4x2 Mode. Besides these, effects on throughput; spectrum efficiency for different UE/cell, BLER and aggregate UE parameters involving throughput and CDF were also analyzed with different case-studies. In addition to that, UE mobility and throughput performance with near and distantly located UEs involving all transmission modes add significant insight to the content of the paper. In a nutshell, this paper should help guiding the LTE radio network planning work with more precision. Besides that, the performed analysis on LTE network might appear as handy for future LTE-Advanced network through comparative studies and optimization.

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