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Performance Analysis of LTE in Rural Environments Considering the Combined Effect of Different Download Scheduling Schemes and Transmission Modes

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Abstract: - Long Term Evolution (LTE) is the new standard specified by Third Generation Partnership Project (3GPP) on the way towards the 4G mobile network. The LTE introduces enhance data link mechanisms to support successful implementation of new data services across the network. The incorporated scheduling mechanisms can significantly contribute to this goal. In this paper, we have compared the performance of Best Channel Quality Indicator (Best CQI) and Proportional Fair (PF) which are the two most popular scheduling algorithms used in LTE. The performance was compared in rural environment using Transmit Diversity (TxD) and Open Loop Spatial Multiplexing (OLSM). The results of simulation show that both the Best CQI and PF perform fairly well for transmit diversity. It is due to the fact that variation in channel quality is not so significant in rural environment. On the other hand, throughput and Block Error Rate (BLER) are not improved using OLSM. It was not surprising as the effect of multipath signal is less in rural environment. OLSM can improve throughput only in rich multipath environment.

Keywords: - *Transmit Diversity, Spatial Multiplexing, Best CQI, Proportional Fair, Scheduling.*

I. INTRODUCTION

The 3gpp LTE is designed to meet high speed data & voice support along with multimedia broadcast services. The scheduler in the Medium Access Control (MAC) layer of the eNodeB attempts to make appropriate apportionment of the resources with certain objectives like,

- Required Quality of Service (QoS) for applications.
- Optimized spectral efficiency ensuring high cell throughput under existing channel conditions.
- Fairness among User Equipment's (UEs) and applications.
- Limiting the impact of interference through special handling of cell edge users.
- Load balancing among cells.

There are six downlink channels. They are: Physical Broadcast Channel (PBCH), Physical Control Format Indicator Channel (PFCICH), Physical Downlink Control Channel (PDCCH), Physical Hybrid-ARQ Indicator Channel (PHICH), Physical Downlink Shared Channel (PDSCH) and Physical Multicast Channel (PMCH). In this paper, the Physical Downlink Shared Channel (PDSCH) channel is taken into consideration. This channel can use various Multiple Input Multiple Output (MIMO) techniques, e.g. spatial multiplexing, transmit diversity and beam forming to improve the throughput and data rate. Under this channel, seven transmission modes are defined in Release 8. In this paper, the impact of transmission mode 2 and 3 is demonstrated which represent Transmit Diversity (TxD) and Open Loop Spatial Multiplexing (OLSM) respectively. For the apportionment of downlink resources, the following information is made available with the scheduler for consideration.

- Channel Quality Indicator (CQI) reports from UEs to estimate the channel quality.
- QoS description of the EPS bearers for each UE. This is available in the eNodeB from the downlink data flow.

The throughput of a UE may vary significantly with scheduling algorithm used, distance from eNodeB, multipath environment, multiple antenna techniques and UE speed. The effect of UE speed in the transmission mode performance is already discussed in [1]. The effect of scheduling algorithm, distance and transmission modes 1 and 2 in throughput performance is considered through LTE system level simulations in [2].In this paper, we have focused mainly on the effect of TD and OLSM on Throughput and Block Error Rate (BLER) of LTE specially in rural environment. This report is organized as follows: in section-2 The Downlink Resource scheduling, LTE Transmission Modes are discussed in section-3, section-5 contains the simulation results, and finally conclusion in the section-6.

By analyzing these scheduling algorithms we will easily understand that, which method is useful and cost effective for the rural environment.

II. DOWNLINK RESOURCE SCHEDULING

LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) for downlink transmission. In this case, a time-frequency resource grid is considered using sub-carriers in the frequency axis and symbols in the time axis. A resource element represents one sub-carrier and one symbol resource in the time-frequency resource grid.

Data is allocated to the UEs in terms of Resource Blocks (RB). In time, the length of a RB is one slot which is equal to 0.5 ms (millisecond). With 15 kHz sub-carrier spacing, the number of symbols in one slot is 6 and 7 for normal cyclic prefix and extended cyclic prefix respectively. In frequency, the length of a RB is 180 kHz. The number of sub-carriers in the 180 kHz span is 12 for 15 kHz sub-carrier spacing.

The eNodeB allocates different RBs to a particular UE in either localized or distributed way. The eNodeB uses DCI format 1, 1A, 1B, 1C, 1D, 2, 2A or 2B on PDCCH to convey the resource allocations on PDSCH for the downlink transmission [1]. The eNodeB uses one of the following three types of resource allocation for a particular UE [3].

- Resource Allocation Type 0
- Resource Allocation Type 1
- Resource Allocation Type 2

The scheduler at eNodeB attempts for appropriate apportionment of the resources among UEs. The Channel Dependent Scheduling can be made in both time and frequency domains. In this case, the scheduling adapts to channel variations and link adaptation is achieved. A user with better channel quality is given more resources as the user can make good use of these resources leading to higher cell throughput. The channel dependent scheduling allows transmitting at fading peaks. The Channel Dependent Scheduling (CDS) requires that sufficient information on uplink and downlink channel conditions is made available with the eNodeB. In order to perform Channel Dependent Scheduling (CDS) in frequency, the information about the radio channel needs to be frequency specific. The eNodeB can configure a more frequency specific information but it requires usage of more resources for this information. Also, the eNodeB can configure the availability of the information more frequently in time so that it can represent the variation of radio channel better but again at the cost of more resources for this information.

The UE reports CQI which helps eNodeB estimate the downlink channel quality. The eNodeB can configure if the CQI report would correspond to the whole downlink bandwidth or a part of it which is called sub-band. CQI reporting for different sub-bands requires more uplink resources. The eNodeB can configure CQI reporting in the following ways [3].

- Wideband Reporting: The CQI reported corresponds to the whole downlink bandwidth
- eNodeB Configured Sub-Band Reporting
- UE Selected Sub-Band Reporting

The channel dependent scheduling leads to higher cell throughput and on the other hand, the scheduling should maintain some fairness among the users in their resource allocations. There is a tradeoff between fairness and cell throughput. The scheduler can exercise various methods as shown below in order to address this tradeoff.

- Best CQI: The CQI value can be expressed as a recommended transport-block size instead of expressing it as a received signal quality. It can be used for the scheduling. Best CQI scheduling algorithm uses these values as a reference for making decision of scheduling.
- Proportional Fair (PF): The scheduler can exercise Proportional Fair (PF) scheduling allocating more resources to a user with relatively better channel quality. This offers high cell throughput as well as fairness satisfactorily. Thus, Proportional Fair (PF) scheduling may be the best option.
- Scheduling for Delay-Limited Capacity: Some applications have very tight latency constraints and so, their QoS require certain guaranteed data rate independent of the fading states. This guaranteed data rate is called delay-limited capacity. The scheduler can allocate resources considering such special requirements.

III. LTE TRANSMISSION MODES

PDSCH is configured with one of the following transmission modes according to Release 8 [4]. The choice of transmission mode may depend on the instantaneous radio channel conditions and the transmission mode may be adapted semi-statically.

- Transmission Mode 1: Using a single antenna at eNodeB
- Transmission Mode 2: Transmit Diversity
- Transmission Mode 3: SU-MIMO Spatial Multiplexing: Open-Loop
- Transmission Mode 4: SU-MIMO Spatial Multiplexing: Closed-Loop
- Transmission Mode 5: MU-MIMO Spatial Multiplexing
- Transmission Mode 6: Beam forming using Closed-Loop Rank-1 Precoding: It can also be seen as a special case of SU-MIMO Spatial Multiplexing.
- Transmission Mode 7:Beam forming using UE-Specific Reference Signals

The following sections briefly describe the transmission modes which are simulated for evaluation purpose.

3.1 Transmit Diversity (TxD)

In TxD Figure 1(a), Space Time Block Codes (STBC) are used to provide improvement against the channel deteriorating effects.Alamouti STBC is considered to be the simplest space-time block codes. It is well known that Alamouti codes [5] can achieve full diversity and full code rate simultaneously. But for MIMO Systems having more than two transmit antennas diversity and orthogonality can only be achieved at the cost of slower date rates. Therefore we cannot achieve high data rates beyond a certain value and powerful coding schemes are required to achieve higher data rates as the SNR (Signal to Noise Ratio) $\rightarrow \infty$. Another issue with TxD is that it is single rank i.e. it does not support multi stream transmission [6].

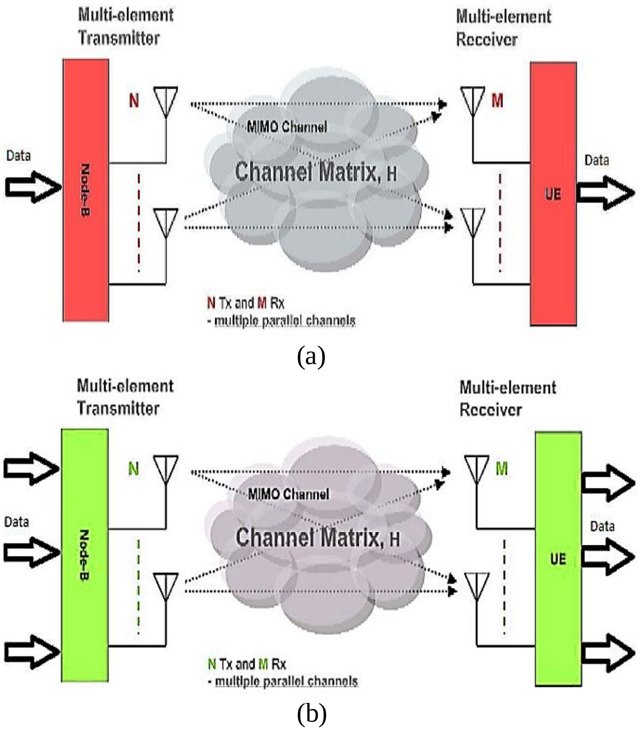


Figure-1: (a) Block diagram of a MIMO transmission using Transmit Diversity (b) Block diagram of a MIMO transmission using OLSM

3.2 Spatial Multiplexing(SM)

SM provides extra gain as compared to TxD [7]. Independent data streams are transmitted from the NT transmit antennas in spatial multiplexing. There are two classes of spatial multiplexing, they are open and closed loop spatial multiplexing. OLSM is discussed in Figure 1(b). OLSM transmits the independent data streams without deploying any feedback algorithm. High data rate is achieved as compared to TxD as multiple independent streams are transmitted. This endorses high BLER. To compensate this BLER Closed Loop Spatial Multiplexing (CLSM) is used. In CLSM, essential amount of CSI is used as feedback which enables us to achieve high throughput with lower BLER. But the CLSM is not considered in this paper.

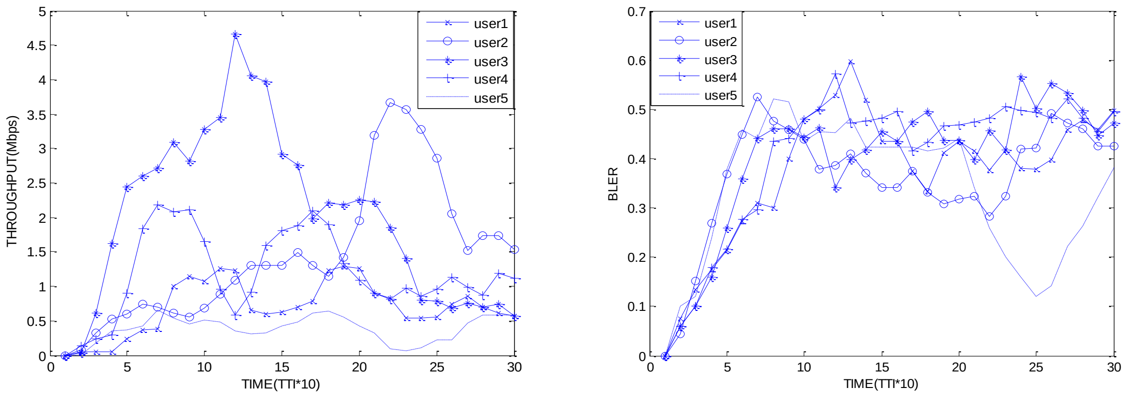
IV. SIMULATION RESULTS

LTE system level simulator [8] was used with parameters shown in the table-1. Five UEs are placed randomly in one sector of a cell. Performance with Best CQI and Proportional Fair scheduling has been observed for five UEs at various distances from the eNodeB. The throughput has been determined for transmission modes 2 and 3 for rural propagation model.

Table 1: Simulation Parameters

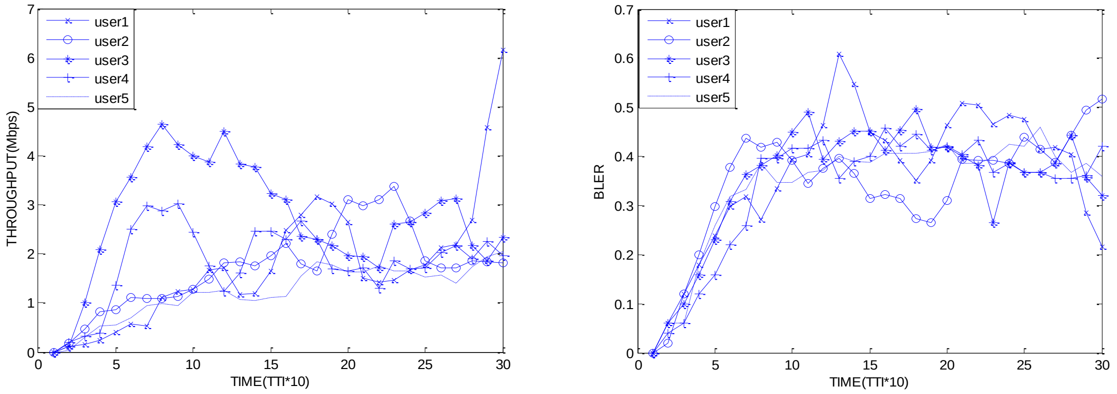
Parameters	***Assumptions***
Transmission bandwidth	2.0GHz
Inter-site distance	5MHz
Thermal noise density	500m
Receiver noise figure	9dB
Simulation length	5000 TTI
UE speeds of interest	5km/hr
UEs position	5UEs/sector, located in target sector only.
BS antenna pattern	$A(\theta) = -\min[12(\frac{\theta}{65^\circ})^2, 20dB]$, $-180 \le \theta \le 180$
BS antenna gain	15 DBi [1]
Scheduler	Best CQI, Round Robin,Proportional Fair
Thermal noise density	-174dBm/Hz
TXmode	1, 2
nTX x nRX antennas	2 x 2
eNodeB TX power	43dBm
Subcarrier averaging algorithm	EESM
Uplink delay	3TTIs
Macroscopic path loss model	Rural, given as, $L=128.1+37.6\log_{10}(R)$

The results are presented as graphs for all three scheduling algorithms i.e. Best CQI, Proportional Fair and Round Robin for three different transmission modes. For each scheduling algorithms, we have observed the THROUGHPUT and BLER for the 5 users.



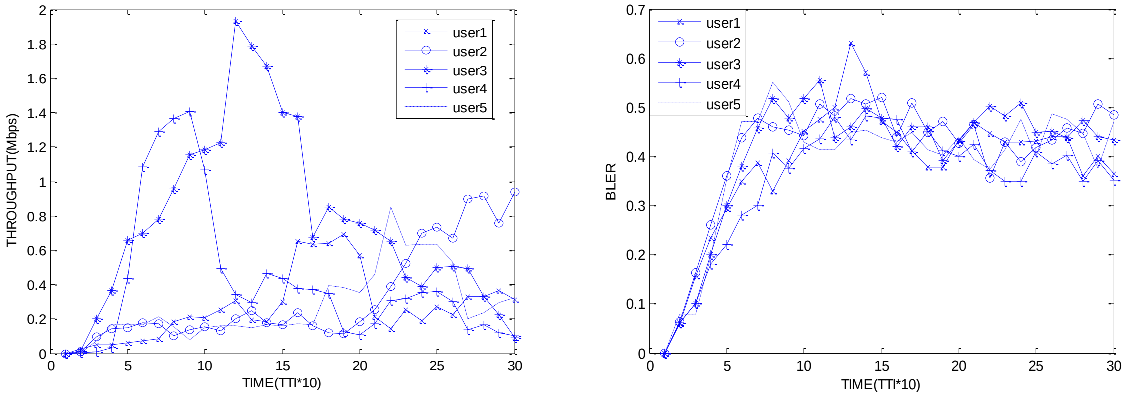
(a) (b)

Figure-2: (a) THROUGHPUTgraphs of 5 users of Best CQI in transmission mode 1(5MHz Bandwidth)
(b) BLER graphs of 5 users of Best CQI in transmission mode 1(5MHz Bandwidth).



(a) (b)

Figure-3: (a) THROUGHPUT graphs of 5 users of Best CQI in transmission mode 2(5MHz Bandwidth) (b) BLER graphs of 5 users of Best CQI in transmission mode 2(5MHz Bandwidth).

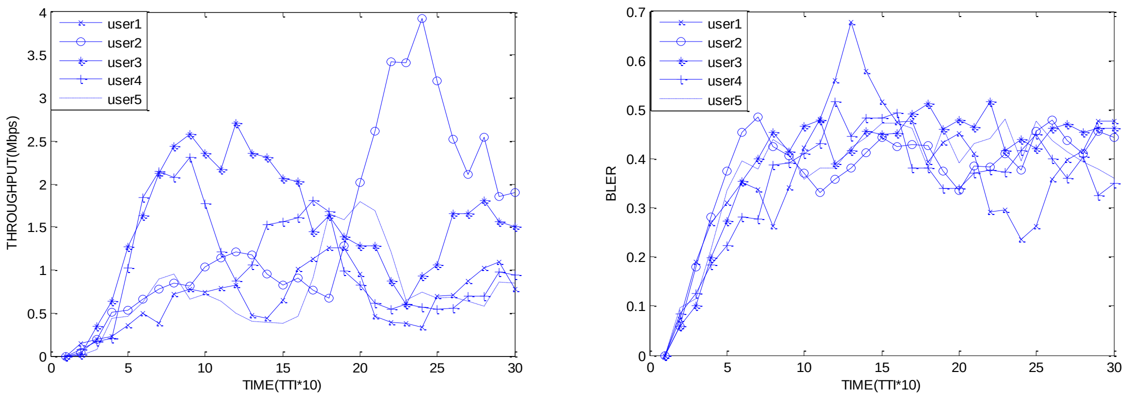


(a) (b)

Figure-4: (a) THROUGHPUT graphs of 5 users of Best CQI in transmission mode 3(5MHz Bandwidth) (b) BLER graphs of 5 users of Best CQI in transmission mode 3(5MHz Bandwidth).

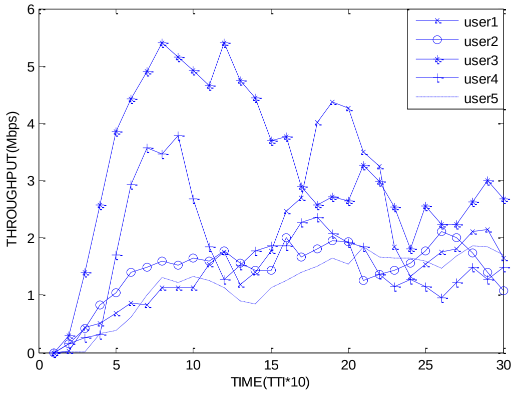
From the figure 2(a), 3(a) and 4(a) we can easily observe that, at transmission mode 2, i.e. using transmit diversity we are getting slightly higher throughput than transmission mode 1(where the transmission mode 1 is SISO or Single Input Single Output) but significantly higher than transmit mode 3(where the transmission mode 3 is OLSM or Open Loop Spatial Multiplexing).

From the figure 2(b), 3(b) and 4(b) we can easily observe that, the BLER is not much affected by the different transmission modes (here we used transmission mode 1, 2 and 3).

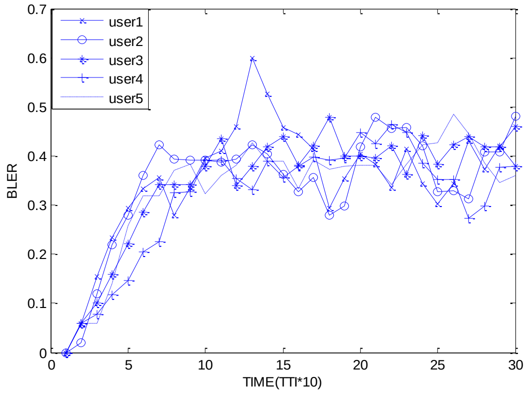


(a) (b)

Figure-5: (a) THROUGHPUT graphs of 5 users of Proportional Fair in transmission mode 1(5MHz Bandwidth) (b) BLER graphs of 5 users of Proportional Fair in transmission mode 1(5MHz Bandwidth).

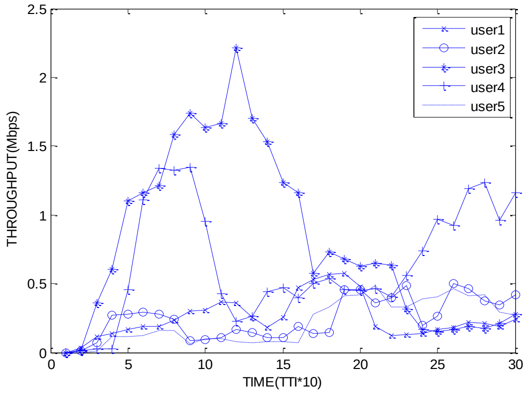


(a)

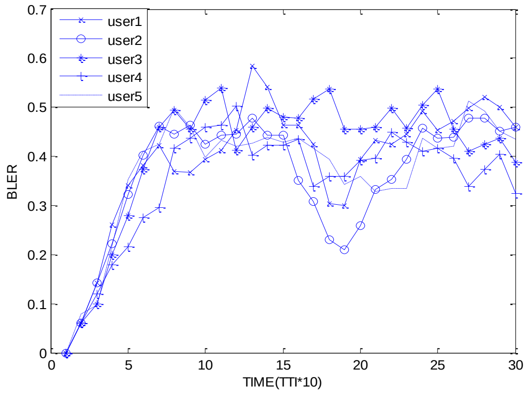


(b)

Figure-6: (a) THROUGHPUT graphs of 5 users of Proportional Fair in transmission mode 2(5MHz Bandwidth) (b) BLER graphs of 5 users of Proportional Fair in transmission mode 2(5MHz Bandwidth).



(a)



(b)

Figure-7: (a) THROUGHPUT graphs of 5 users of Proportional Fair in transmission mode 3(5MHz Bandwidth) (b) BLER graphs of 5 users of Proportional Fair in transmission mode 3(5MHz Bandwidth).

From the figure 5(a), 6(a) and 7(a) we observed that, at transmission mode 2, i.e. using transmits diversity we are getting significantly higher throughput than transmission mode 1(where transmission mode 1 is SISO). Using the transmission mode 3 or Open Loop Spatial Multiplexing (OLSM) the throughput gets decreased in comparison with the other two transmission modes. Finally, it is observed that the BLER is not heavily affected by the different transmission modes.

From the figure 5(b), 6(b) and 7(b) we can easily see that, there is a significant change in the BLER. BLER is affected by the different transmission modes. According to theory, the BLER is decreasing from transmission mode 1(SISO) to transmission mode 3(OLSM).

V. CONCLUSION

From the simulation results we get fairly good Throughput and BLER for both Best CQI and Proportional Fair schedulers in three different modes. But the analysis of the simulation graphs show that Proportional Fair scheduler has highest throughput values in transmission mode 2. At low BLER values Proportional Fair scheduler performed more efficiently than other scheduler algorithms. On the other way, the OLSM failed to show any significant improvement in Throughput. It is due to the fact that OLSM takes advantages of multipath environment. In rural environment the multipath environment is not so rich, that's why OLSM is not effective here. We also observed the Throughput and BLER of Round Robin, but did not get any expected results. The Round Robin shows drastically lower Throughput and specially the higher BLER from transmission mode 1 to transmission mode 3 which is undesirable. If we want just high Throughput then the Best CQI schedulers will be a good choice for the system. But if high Throughput and lower BLER is a major consideration in the service requirement of the system then the Proportional Fair idea will be a better choice. It is also worth noting that the difference in the throughput results of the Best CQI and Empirical is not low and cannot be used to justify the argument for Proportional Fair as a better algorithm.

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