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Downlink Scheduling in Long Term Evolution

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Abstract: This is an investigated research article on resource block scheduling of Long Term Evolution (LTE). LTE is one of the evolutions of the Universal Mobile Telecommunication System (UMTS). It provides internet access to mobile users through smart phone, laptop and other android devices. LTE offers a high speed data and multimedia services. It supports data rates up to 100 Mbps in the downlink and 50 Mbps in the uplink transmission. Our research investigation was aim to the downlink scheduling. We have considered The Best CQI scheduling algorithm and the Round Robin scheduling algorithm. The implementation, analysis and comparison of these scheduling algorithms have been performed through MATLAB simulator. We have analyzed the impact of the scheduling schemes on the throughput and the fairness of both scheduling schemes. Here we have proposed a new scheduling algorithm that achieves a compromise between the throughput and the fairness. Orthogonal Frequency Division Multiplexing (OFDM) has been adopted as the downlink transmission scheme. We have considered the impact of the channel delay on the throughput. In addition, MIMO transceiver systems have been implemented to increase the throughput.

Keywords- Long Term Evolution (LTE), Universal Mobile Telecommunication System (UMTS), Best CQI, Round Robin, Orthogonal Frequency Division Multiplexing (OFDM), SISO , MIMO.

I. Introduction

We are now living in the mobile broadband era. We are concentrated enough to multimedia applications through internet. Live streaming, online gaming, IPTV, mobile TV, etc. become very popular applications today. These applications require higher data rate. The Third-generation Partnership Project (3GPP) started to work on solutions to these challenges and came up with the HSPA. The HSPA is currently used in 3G phones for such applications.

LTE is the evolution of the Third-generation of Universal Mobile Telecommunications System (UMTS). LTE intends to create a new radio-access technology which will provide high data rates, a low latency and a greater spectral efficiency. It provides internet access to mobile users through smart phone, laptop and other android devices. In the coming years LTE mobile broadband technology will be widely used by devices such as notebooks, smart phones, gaming devices and video cameras. The Long Term Evolution provides a high data rate and can operate in different bandwidths ranging from 1.4MHz up to 20MHz. LTE offers a high speed data and multimedia services. It supports data rates up to 100 Mbps in the downlink and 50 Mbps in the uplink transmission. It improves system capacity and coverage also reduces operating costs. Furthermore LTE supports Multiple Input Multiple Output (MIMO) transceiver system. Recently (MIMO) systems have drawn a lot of attention in wireless communication. It accelerates the system to achieve high peak data rates. Moreover LTE operates both in Frequency Division Duplexing (FDD) as well as in Time Division Duplexing (TDD) and can be deployed in different bandwidths. With TDD the uplink and downlink operate in same frequency band whereas with FDD the uplink and downlink operate in different frequency bands.

A scheduler allocates the shared resources (time and frequency) among user terminals. The scheduler is a key element in the Base Station (BS) since it determines to which users the resource blocks should be assigned. Best CQI scheduling and Round Robin scheduling have been selected by their characteristics. The Best CQI scheduling optimizes the user throughput by assigning the resource block to the user with the good channel quality and the Round Robin scheduling is fair in the long term since it equally schedules the Mobile station (MS). In general cell-centre users have a good channel quality compare to the cell-edge users. In order to find a trade-off between the throughput and the fairness a new scheduling algorithm has been proposed. The proposed new scheduling algorithm can be considered as a compromise between the Best CQI scheduling and the Round Robin scheduling.

II. Material and Methodology

The downlink transmissions in LTE technology are grouped in frame. Figure-1 shows the LTE frame structure.

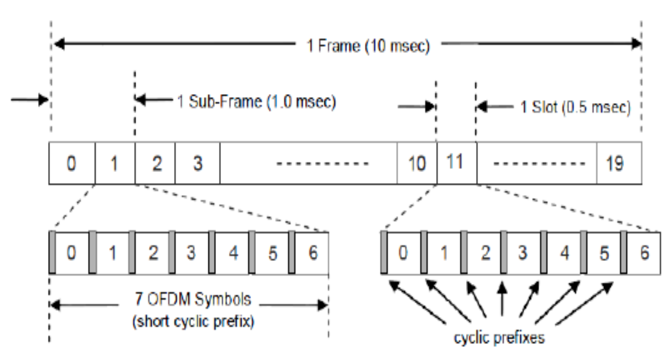

Figure-1: LTE Frame structure

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Each frame length is 10 ms. One radio frame is formed with 10 subframes of 1ms duration. Therefore there are ten subframes in the uplink and ten sub-frames in the downlink. Each sub-frame is divided into two slots of 0.5 ms duration. Each slot counts 6 or 7 OFDM symbols for normal or extended cyclic prefix used.

The downlink physical resource is represented as a time-frequency resource grid consisting of multiple resource blocks (RB). A resource block is divided in multiple resource elements (RE). A scheduler is a key element in the BS that assigns the time and frequency resources to different users in the cell. Thus a RB is the smallest element that can be assigned by the scheduler. Our research is focused on the Round Robin scheduling and on the Best CQI scheduling. The Best CQI scheduling assigns the resource blocks to the user with the highest CQI on that RB. To perform this scheduling the MS must feedback the Channel Quality Indication (CQI) to the BS. In Round Robin (RR) scheduling the terminals are assigned the resource blocks in turn (one after another) without taking the CQI into account. Thus the terminals are equally scheduled.

The Round Robin scheduling and Best CQI scheduling have been simulated in a MATLAB-based Downlink Link Level Simulator. The performance of these scheduling algorithms in terms of throughput is analyzed. Furthermore the throughput results are compared to the channel capacity. We have considered simple AWGN channel model. The impact of the channel delay on the throughput has been investigated here. The throughput of a MIMO (2x2) and MIMO (4x4) systems have also been taken into consideration.

A link level simulation can emulate all the features of transmission between base station and mobile terminal. MATLAB-based downlink physical layer simulator may carry out single-downlink in single-cell multi-user and multi-cell multi-user simulations. Figure 2 depicts an overview of different possible simulation scenarios in LTE downlink physical layer simulator. But our focus is on single-downlink in single cell multi-user fashion and all simulation scenarios have been performed for duration of 100 TTI (Transmission Time Interval) whereas selected bandwidth will be 20 MHz.

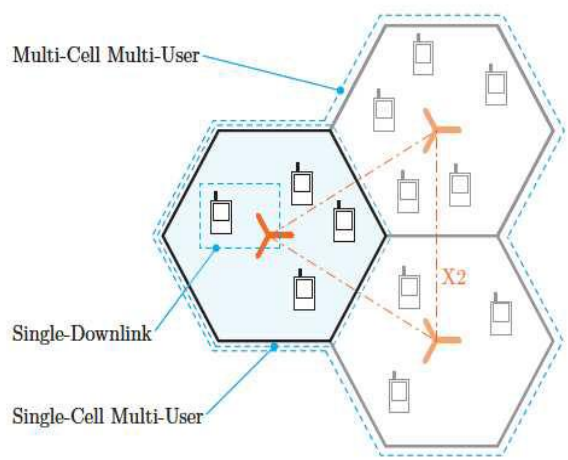

Figure-2: Different simulation scenarios in the LTE simulator.

Multiple Input Multiple Output (MIMO) technique supports multiple antennas at the transmitter and at the receiver. A communication system is designed in MIMO fashion to achieve spatial diversity and spatial multiplexing. It allows the system to increase the capacity by transmitting different streams of data simultaneously in parallel from different antennas. Spatial diversity can be used to increase the robustness of the communication system in fading channels by transmitting multiple replicas of the transmitted signal from different antennas. Thus MIMO can be used to improve the cell capacity and link reliability. Claude Shannon showed that the maximum error-free bit for an Additive White Gaussian Noise (AWGN) channel is given by:

$$\frac{C}{B} = \log_2\left(1+\frac{S}{N}\right)$$

Where C is the channel capacity in bps, B is the channel bandwidth in Hz and S/N is the signal-to-noise power ratio at the input to the digital receiver. The system capacity is defined as the Shannon capacity adjusted by the inherent system losses. The system capacity of an AWGN channel is given by:

$$C = FB\log_2\left(1+\frac{S}{N}\right)$$

Here, B is the bandwidth occupied by the data sub-carrier, and F is the correction factor.

MIMO can be used to increase the signal-to-noise power ratio. In a system with N_t transmit antennas and N_r receive antennas, the received SNR can be increased in proportion to N_t x N_r. In this way the channel capacity becomes:

$$C = FB\log_2\left(1+\left(\frac{N_r}{\min_{N_t,N_r}}\right)\cdot\frac{S}{N}\right)$$

The Best CQI scheduling strategy assigns resource blocks to the user with the best radio link conditions. In order to perform scheduling, terminals send Channel Quality Indicator (CQI) to the base station (BS). Basically in the downlink, the BS transmits reference signal (downlink pilot) to terminals. These reference signals are used by terminals for the measurements of the CQI. A higher CQI value means better channel condition. Best CQI scheduling can increase the cell capacity at the expense of the fairness.

In Round Robin scheduling strategy the terminals are assigned the shared resources in turn. Thus every user is equally scheduled without taking the CQI into account. The principal advantage of Round Robin scheduling is the guaranty of fairness for all users. Since Round Robin doesn’t take the channel quality information into account, it will result in low user throughput.

The new scheduling algorithm will result in an acceptable throughput and provides some fairness between users. We propose a new scheduling algorithm that assigns the RB to the user that maximizes the CQI in the first slot period of each sub-frame whereas in the second slot period the scheduler assigns the RB in turn to each user. Implementing such an algorithm a compromise between the fairness and the throughput could be achieved.

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III. Results and Tables

First of all the Best CQI scheduling strategy for single user in different transmission systems has been investigated. The simulated throughput with reference to SNR for different transmission schemes i.e. SISO, MIMO (2x2), and MIMO (4x4) has been plotted.

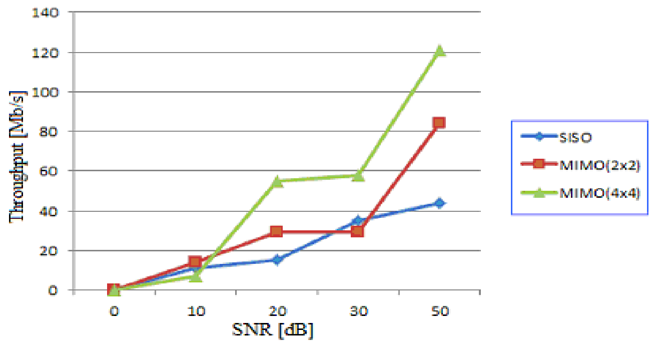

Figure-3: SNR versus Throughput for single user in different transmission schemes involving Best CQI algorithm.

Figure-3 shows the SNR and the user throughput for SISO and MIMO systems when downlink algorithm is Best CQI. From this figure the user throughput of a MIMO (2x2) system is higher than the throughput of a SISO system and lower than the throughput of a MIMO (4x4) system. Moreover the throughput increases with the SNR. Here we can reach a maximum throughput of 121 Mbps.

Secondly we have simulated different transmission systems for Round Robin scheduling algorithm. This scenario is also intended to simulate single user transmission system showing the user throughput for different SNR values. The simulated throughput with reference to SNR for different transmission schemes i.e. SISO, MIMO (2x2), and MIMO (4x4) has been plotted. We have set CQI fixed at 7 in this simulation. As the Round Robin scheduler does not adapt the AMC mode according to the CQI-feedback the CQI is assigned fixed at 7 while performing the simulation with Round Robin as scheduling algorithm.

Figure-4 exhibits the relation between the SNR and the user throughput for different antenna schemes. The throughput of a SISO system is lower than the throughput of a MIMO (2x2) and the throughput of a MIMO (2x2) system is lower than the throughput of a MIMO (4x4) system.

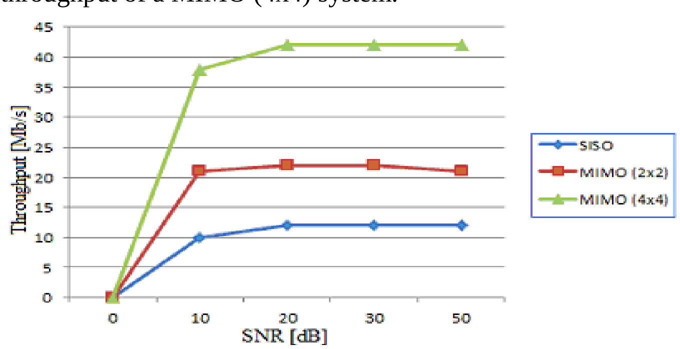

Figure-4: SNR versus Throughput for single user in different transmission schemes involving Round Robin algorithm.

It is clear from the figure that the throughput of a MIMO (4x4) system is two times higher than the throughput of a MIMO (2x2) system and the throughput of a MIMO (2x2) system is also two times higher than the throughput of a SISO system. Here we became able to achieve a maximum throughput of 42 Mbps.

In this stage we have simulated a single user throughput for different antenna arrangement involving new proposed scheduling algorithm. We have plotted here the simulated throughput for different SNR values comparing different transmission plan i.e. SISO, MIMO (2x2), and MIMO (4x4).

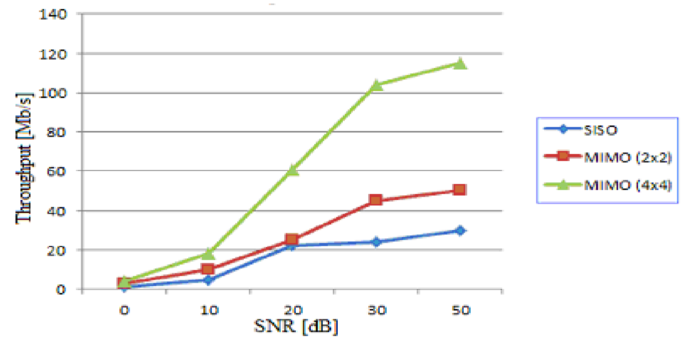

Figure-5: SNR versus Throughput for single user in different transmission schemes involving new scheduling algorithm.

Figure-5 depicts the user throughput for different transmission schemes. We observe that the throughput of a SISO system is lower than the throughput of a MIMO (2x2) and the user throughput of a MIMO (2x2) system is lower than the throughput of a MIMO (4x4) system. Thus in other words, the higher the transmission schemes, the higher the throughput. To be more precise the throughput of a MIMO (4x4) system is two times higher than the throughput of a MIMO (2x2) system and the throughput of a MIMO (2x2) system is also two times higher than the throughput of a SISO system. The throughput increases with the SNR. Here we became able to achieve a maximum throughput of 115 Mbps

This scenario simulates the signal-to-noise ratio power values versus throughput for multiple users. Here the MIMO (2x2) transmission system is simulated and Best CQI scheduling algorithm is implemented.

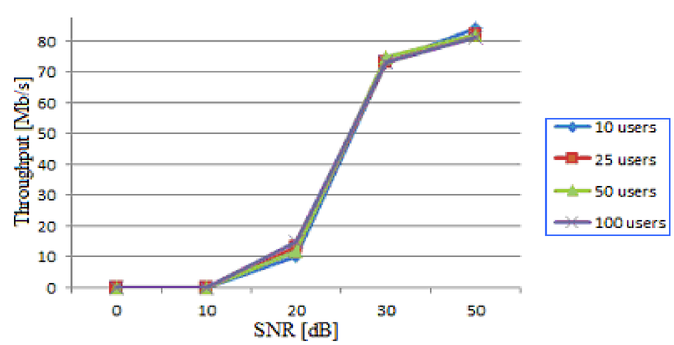

Figure-6: SNR versus Throughput for multiple users in MIMO (2x2) system involving Best CQI algorithm.

Figure-6 represents the SNR versus the throughput for a MIMO system with Best CQI scheduling algorithm. Here the throughput is almost 0 for the SNR values up to 10 dB. This due to the reported channel condition is very bad for every user which could result in a low throughput (almost zero). From 10 dB, it can be seen that the cell throughput increases with the SNR. The maximum cell throughput in this scenario is 84 Mbps. That is 2 times higher than SISO system.

Again multiple users are simulated for a MIMO (2x2) transmission system with Round Robin scheduling algorithm.

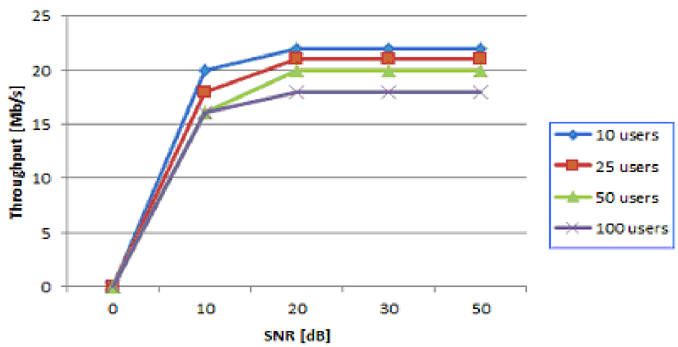

Figure-7: SNR versus Throughput for multiple users in MIMO (2x2) system involving Round Robin algorithm.

Figure-7 depicts the SNR versus the throughput for a MIMO (2x2) system. It is clear that the cell throughput for different set of users (10 users, 25 users, 50 users and 100 users) is almost the same. For the case of 10 users each user can be scheduled 10 times. When we have 20 users, each user can be scheduled 5 times in a Round Robin fashion. For 50 users, each user can be scheduled 2 times in turns and if we have 100 users, each user can be scheduled one time. That is why the cell throughput for the different set of users is almost the same.
Here again multiple users are simulated for a MIMO (2x2) transmission system and the SNR values versus throughput for different set of users have been plotted. Here only a MIMO (2x2) system is considered. But the scheduling algorithm implemented is the proposed new scheduling algorithm.

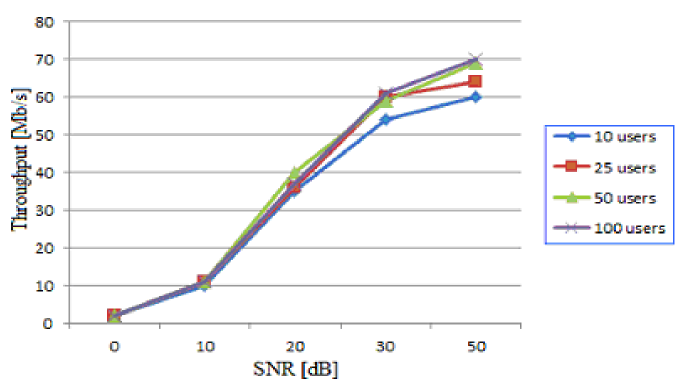

Figure-8: SNR versus Throughput for multiple users in MIMO (2x2) system involving new scheduling algorithm.

Figure-8 shows the SNR versus the throughput for a MIMO (2x2) system. We can observe that the cell throughput for different sets of users (10 users, 25 users, 50 users and 100 users) increases with the SNR. The maximum cell throughput is 70 Mbps.

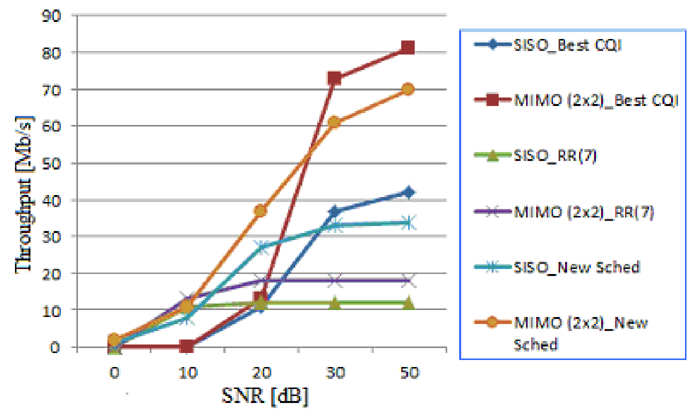

Figure-9: SNR versus Throughput for multiple users (100) comparing different scheduling algorithms.

Figure-9 displays the throughputs for different scheduling schemes. Furthermore SISO and MIMO systems are considered. The total number of users in the cell is fixed to 100. We compare the cell throughput for the different scheduling algorithms namely: Best CQI, the proposed new scheduling and Round Robin. We can observe that the cell throughput of the Best CQI scheduling is the highest in this example. The throughput of the proposed new scheduling algorithm is higher than the throughput of Round Robin. Furthermore it is clear that MIMO systems increase the throughput.

IV. **Conclusion**

Here we have try to represent the overview of Long Term Evolution of UMTS. LTE provides high peak data rates, improves the system capacity and coverage. It also efficiently supports packet data transmission, etc. OFDM has been adopted as the downlink transmission scheme of LTE. In fact LTE is the future of mobile broadband.
Investigation on the LTE downlink scheduling algorithms was our research goal. The scheduler is a very important element of the base station. It assigns the resource blocks to different users. We have worked on Best CQI and Round Robin scheduling algorithms. We have investigated the impact of the scheduling schemes on throughput and fairness. The Best CQI scheduling maximizes the throughput by scheduling the user with the good channel quality and the Round Robin scheduling is fair since it equally schedules the terminals.
We have proposed here a new scheduling algorithm that assigns the resource blocks to the user with the highest CQI in the first slot period of each sub-frame whereas in the second slot period the scheduler assigns the resource blocks in turn to each user. The new scheduling algorithm can be seen as compromise between throughput and fairness. We have carried out a comparative laboratory analysis among the different scheduling

algorithms based on their throughputs for different antenna transmission systems and different number of users. We are concluded that the throughput of the Best CQI scheduling is the highest whereas Round Robin is the lowest. The new scheduling algorithm has a better throughput performance than the Round Robin scheduling algorithm. Moreover the new scheduling algorithm is fairer than the Best CQI.

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