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Performance Evaluation of Scheduling Algorithms of LTE and LTE-A Mobile Networks using Vienna Simulator

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Abstract

The third-generation partnership architecture specifies Long Term Evolution to give high data speeds of up to 100 Mbit/s and 50 Mbit/s for downlink and uplink transmission, respectively. It can be employed in a variety of bandwidth bands from 1.4 MHz to 20 MHz .The Vienna LTE simulator was used to examine the performance of homogeneous and heterogeneous networks by changing the various physical parameters. There are several distinct qualities that are employed, including throughput, spectrum efficiency, and fairness index. The scheduling mechanism is the process of allocating resources (time and frequency) to users who are simultaneously transmitting different streams. Several scheduling strategies, such as Round Robin, Proportional Fair, and Best CQI, are being looked into. Fractional Frequency Reuse (FFR) is also used to improve performance and reduce edge user disruption. Additionally, eNodeB and femtocells are included in the heterogeneous network, which is easily compared to the homogeneous network.

Keywords

LTE, LTE-A, scheduling algorithms, CQI, Radio Resource Management.

1. Introduction

LTE is a wireless broadband communication protocol for mobile devices and data terminals that is based on the GSM/EDGE and UMTS/HSPA standards. By utilizing a new radio interface and core network enhancements, it improves the capacity and speed compared to those standards. LTE is the upgrading option for operators that have both GSM/UMTS and CDMA2000 networks [1]. Base stations of the same kind, is the opposite of a heterogeneous network. LTE provides a range of benefits and a choice of capacities to satisfy the needs of subscribers. Each block is assigned to the users by a vital mechanism called a scheduler. Each entry in a resource block is referred to as a resource element (RE). Although there are numerous alternative scheduling algorithms, I'll only concentrate on two here: Best Channel Quality Index (CQI) and Round Robin (RR). During round robin scheduling, all user terminals are equally scheduled regardless of the channel quality indication. During the best CQI scheduling, a channel quality indication is sent from the user terminal to the base station as feedback. If the user has a high CQI, the resource block is assigned to the user terminal [2, 3,4]. The 3GPP continued to work on incorporating new features for the second LTE release, also known as release 9, after concluding the first LTE release. Release 9, which was completed in late 2009, featured several significant upgrades, including support for beam-forming in the downlink, network-assisted locating services, and multicast broadcast [5]. LTE-Advanced is investigating Heterogeneous Network (HetNet) installations as a reasonably priced response to the ongoing traffic need. HetNets make use of microcells, distant radio heads, and low-power nodes such Pico cells, femtocells, and relays. The ability to give the ensuing significant performance gain in wireless networks, enhancing spatial spectrum reuse and improving indoor coverage, can be achieved by utilizing network topology, which brings the access network and end users closer together. The addition of additional small cells on top of the microcells, however, creates significant technical challenges [6]. We define heterogeneous networks and go over the primary technical challenges that this style of network architecture presents. We place a lot of focus on the 3GPP's standardization work in regard to better inter-cell interference coordination techniques.

2. Performance Evaluation of LTE homogeneous and LTE-A heterogeneous Network

Due to its high data rate, high capacity, and low latency, LTE is a fascinating and enticing area of research. It was developed by the 3GPP to complement 3G technology and to be the first step towards 4G technology. However, because all cells use the same system bandwidth when employing OFDMA, there is interference between the neighboring cells. Due to its negative effects on the overall functioning of the system, interference will therefore be one of the key issues in such systems. To handle the rising number of mobile broadband data subscribers and bandwidth-intensive services varying for limited radio resources, effective network planning is vital. Operators have overcome this difficulty by developing more effective modulation and coding systems, adding multi-antenna approaches, and increasing capacity with new radio spectrum. However, in the most congested areas and at cell margins, where performance might dramatically deteriorate, these techniques are insufficient on their own. In order to distribute traffic loads, broadly maintain performance and service quality, and most effectively utilize spectrum, operators are now installing tiny cells and tightly integrating them with their macro networks.

Table 1. Network parameter for the whole homogeneous network and the number of users per each cell.

Parameters	Values
Frequency	2.5 GHZ
Transmitted Power	20watt
Bandwidth	10MHZ
Scheduling Algorithms	Round robin
No of User/Sector(cell)	10

2.1. Performance Metrics

A variety of performance indicators, including throughput, spectral efficiency, and fairness index, are used to analyses the system performance for the proposed model. Additionally, the simulator is used to construct the CDF for the metrics provided.

Throughput depends on the used bandwidth and the value of SINR as shown in the following equation:

$$T_k = B_k log_2(1 + SINR_k/\gamma) \quad (1)$$

$$\gamma = -0.67\ln(5BER) \quad (2)$$

Where, T_k is the average throughput of user k, Threshold is the threshold value of throughput, B_k is the bandwidth allocated per user k and BER is bit error rate threshold (it is taken 0.0001 according to [ref]).[6]

Spectral efficiency the transmission capacity of an air interface, measured in bits per second per Hz bandwidth per cell (bit/s/Hz/cell), which is available to all users inside a radio cell, is known as spectral efficiency, it is calculated according to the following equation:

$$\text{Spectral efficiency}= \sum_{k=1}^{NU} T_k/Total\ BW \text{ (Hz)} \quad (3)$$

Employing various mobile radio technologies, the growth of the downlink average spectral efficiency in a radio cell Launches [6]

Cumulative Distribution Function (CDF) a real-valued random variable X, as shown in the following equation, is the likelihood that X will have a value less than or equal to x.as in the following equation.

$$F_x(x) = P(X \leq x) \quad (4)$$

Fairness Index, the division of the available resources among the consumers is referred to as fairness. The following is how Jain's formula calculates it: [7]

$$\text{Fairness Index} = (\sum_{k=1}^{NU} T_k)^2/NU \sum_{k=1}^{NU} T_k^2 \quad (5)$$

3. Scheduling Algorithms

Making ensuring radio resources are used efficiently and serving customers in accordance with the relevant Quality of Service (QoS) requirements is the responsibility of the Radio Resource Management (RRM) team. The radio resource management performs a variety of tasks depending on the OSI layer, including channel adaptation in layer 2, dynamic scheduling and link adaptation in layer 2, power control and Channel Quality Indicator (CQI) manager in layer 3, and admission control and QoS management in the physical layer [3]. Radio resources are divided up into three categories in LTE: time, frequency, and space. The spatial dimension allows Multi-Input Multiple-Output (MIMO) technologies to be used through multiple antenna ports at the eNB in order to take advantage of the spatial layers and improve performance [8]. It is desirable to employ MIMO with an OFDMA system because the high SNR that OFDMA can attain helps MIMO operate successfully. These scheduling strategies are contrasted in terms of fairness and overall throughput.

3.1. Round Robin (RR)

Users receive resources on a periodic basis from the scheduler without consideration for channel circumstances. It is a straightforward process that delivers the best justice. However, it suggests subpar cell production performance. By giving each user an equal amount of packet transmission time, RR satisfies fairness. Without taking CQI into account, resource blocks are allotted to terminals in turn (one at a time) in Round Robin (RR) scheduling. The stations are therefore evenly scheduled. However, because the technique does not use the reported instantaneous downlink signal-to-noise ratio (SNR) values to determine how many bits to send, throughput performance suffers dramatically [4]. The behavior of the i_{th} user on the k_{th} RB can be converted into the following metric:

$$mj;k=t-Ti \quad (6)$$

Where t denotes the current time and Ti denotes the user's most recent serving time instant. Since each terminal receives the same number of resources, on the surface, it appears to be a fair schedule. However, it ignores the fact that some terminals in poor channel conditions require more resources to operate at the same pace, which makes it blatantly unfair. Because separate terminals have distinct services and varied QoS requirements, this strategy is unworkable for LTE. Figure1. Depicts each of these components.

3.2. Proportional Fair (PF)

A user with a somewhat better channel state will receive more resources thanks to this approach. While scheduling users, this algorithm aims to maintain user equity while also taking the channel state into account. As a result, the highest level of fairness and cell throughput are provided. Each data flow is assigned a scheduling priority that is inversely correlated with the predicted number of resources it will consume. This offers high cell Throughput and acceptable fairness. Therefore, scheduling with proportional fairness (PF) may be the best option. With its proportional fair scheduler, fairness and overall system throughput are balanced. The eNodeB received feedback on the current Channel quality condition (CQI) in terms of the needed data rate $R_{k,n(t)}$ for each user k in accordance with how the PF algorithm operates

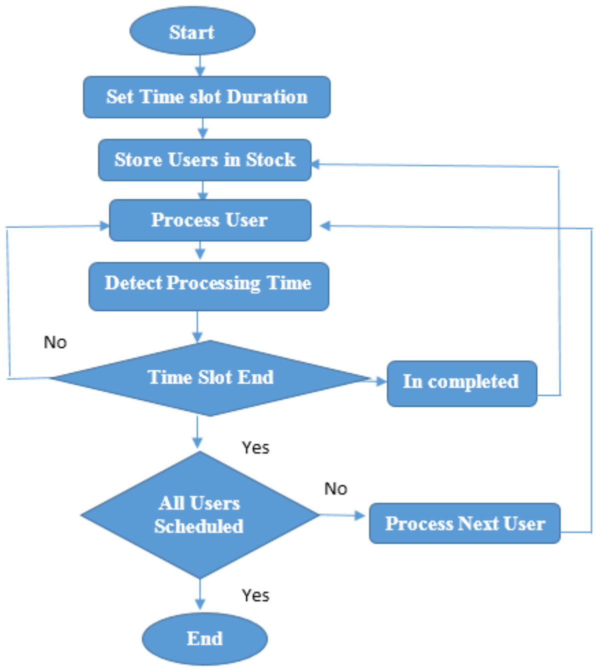

Figure 1. Flow chart for Round Robin.

Then, it logs the moving average throughput $T_{k,n(t)}$ of each UE k on each PRB n over a window in time of length t_c. The proportional fair scheduler gives preference to the PRB n that satisfy the maximum in time slot t and UE K* in the t_{th} time slot [4]. Figure 2. Shows each of these elements.

3.3. Best Channel Quality Indicator (CQI)

This scheduling method allocates resource blocks to the user with the best radio link conditions. The resource blocks that belonged to the user with the greatest CQI have the highest CQI on that RB. The BS must receive input from the MS regarding the Channel Quality Indication (CQI) in order to carry out the Best CQI. Channel Quality Indicator (CQI) is a signal that terminals send to the base station (BS) for scheduling. The downlink pilot is essentially a reference signal that the BS transmits to terminals. These reference signals are used by the UEs to determine the CQI. When the CQI number is higher, the channel condition is better. [4]. While users who suffer deep declines are not scheduled at all, those who experience a fading peak are more likely to be scheduled continuously. Every TTI awards the user with the highest SNR the best CQI. The most effective CQI scheduler must maximize system throughput while fully neglecting fairness. The received SNR of the RB signal at the tth TTI, the k_{th} user's then$_{th}$, can be represented as follows:

$$S_{K,n(t)}=(S_{K,n(t)}\ H_{k,n(t)})/(NOB/N) \qquad (7)$$

Where SK,n(t), Hk,n(t) , and the channel gain on the nth sub-carrier at the tth TTI, respectively, N is the number of sub-

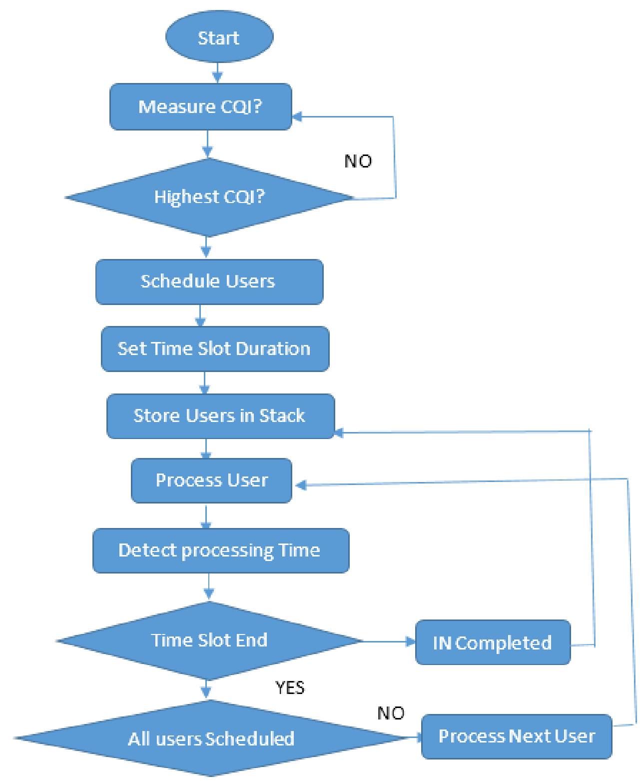

Figure 2. Flow chart for Proportional Fair.

Carriers, B is the bandwidth, and No is the power spectral density of the AWGN. Each user's immediate data rate is identified, and the BS provides services to each user at that rate. The following equation yields the immediate service rate on the nth sub-carrier at the t_{th} TTI:

$$R_{k,n(t)} = B/N\log 2(1+SNR) \qquad (8)$$

Where B is the total bandwidth, N is the number of subcarriers, and $R_{k,n(t)}$ is the Kth user transmission rate during the t_{th} time slot [4] These components are all displayed in Figure3.

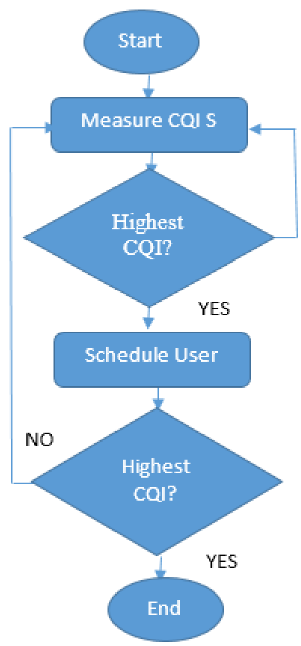

Figure 3. Flow chart for Best CQI.

3.4. Fractional Frequency Reuse (FFR).

FFR is a type of frequency reuse technique, in which the cell is divided into an inner region with some users and an outer region with other users and the assigned frequency is distributed between them [9].

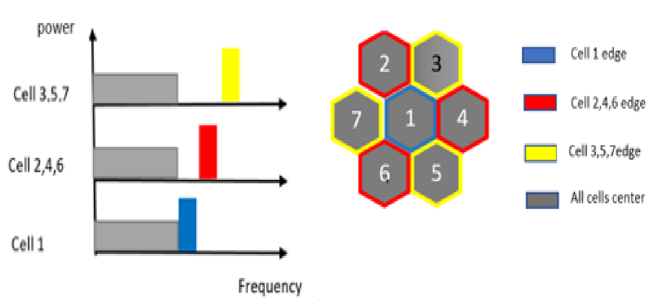

Figure 4. FFR Method.

4. The Vienna Simulator

Simulations are required to test and improve algorithms and processes during the development and standardization of LTE as well as during the installation process of equipment makers. This needs to be done at both the network (system level) and physical layer (link level) levels: simulations at the link level Link level simulations enable the study of methods for channel estimation, tracking, and prediction, synchronization, MIMO gains, adaptive modulation and coding (AMC), and feedback [10]. Additionally, link level analyses typically include receiver structures (typically ignoring inter-cell interference and the impact of scheduling, as these significantly increase simulation complexity and runtime) [5], channel encoding and decoding modeling, physical layer modeling necessary for system level simulations, and similar analyses In system level simulations, network-related issues including resource scheduling and allocation [4], handling many users, managing mobility, regulating admissions, limiting interference, and optimizing network planning are given additional focus. A few more thorough evaluations of LTE performance include fairness, multi-user diversity, and DoF. System-level simulations look at a network's overall performance. A huge number of eNodeBs are utilized in an LTE network to cover an area where numerous mobile terminals are positioned and/or moving. Due to the vast number of computational resources required, it is simply not practical to do physical layer simulations of all radio links between terminals and base stations for system level evaluations.

4.1. The link measurement model

The link measurement model, which is required for resource allocation and link adaptation, takes into account the connection quality reported in the UE measurement reports. The provided link quality parameter is evaluated for each subcarrier. The Signal to Interference and Noise Ratio (SINR) is used by the UE to calculate the feedback (PMI, RI, and CQI), which is used for link adaptation at the ENodeB. The scheduling algorithm allocates resources to users based on this feedback to enhance the system's performance (for instance, in terms of throughput) [6]. Based on the receiver SINR and the transmission characteristics (such modulation and coding), which are based on the link measurement model, the link performance model estimates the BLER of the link.

4.2. The link performance model

An AWGN-equivalent SINR (GAWGN) is obtained for the link performance model using Mutual In-formation Effective Signal to Interference and Noise Ratio Mapping (MIESM). GAWGN is transferred to BLER using AWGN link performance curves in a subsequent phase [10,11]. The Vienna LTE simulators demonstrate homogeneous and heterogeneous networks in this part, with macro-and femto-cells carrying 10 users each.

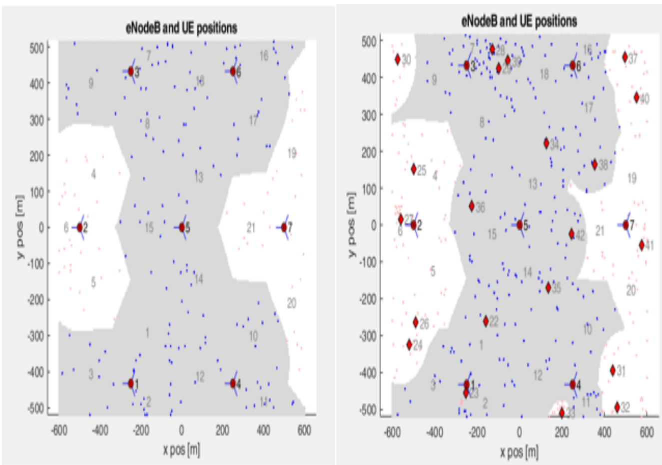

Figure 5. Homogenous and Heterogenous networks

Aggregate results GUI. Plots show the throughput ECDF for the average UE throughput (upper-left), spectral efficiency (upper-right), wideband (lower-left) SINR and the mapping between the wideband SINR and the average throughput for each UE.

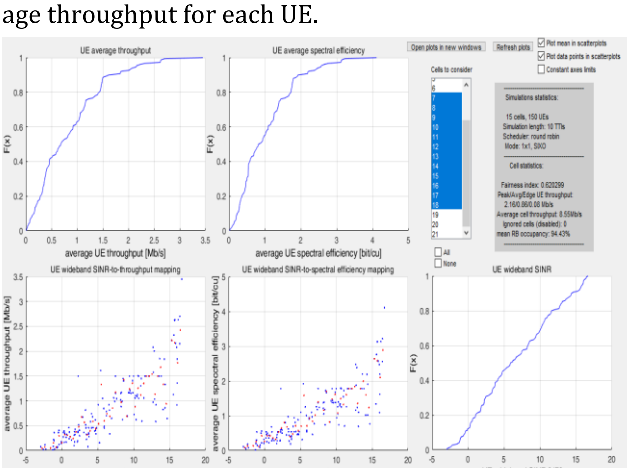

Figure 6. LTE-GUI-aggregate results.

5. Simulation Results

MATLAB Vienna LTE System Level Simulator, is used to describe the Performance of a whole Network. The simulator will be used to measure different performance metrics such as throughput, spectral efficiency, fairness index, etc.

5.1. Performance Evaluation of LTE

This section describes the simulations results to evaluate performance and discusses the results obtained from experiments conducted using the LTE simulator developed.

Table 2. Result of physical parameters of the whole network.

Users/Metrics	Throughput	Fairness	Spectral efficiency
All users	1.84 Mbps	0.798775	2.19 bit/cu
Center user	2.05 Mbps	0.798775	2.44 bit/cu
Edge user	1.98 Mbps	0.798775	2.36 bit/cu

By using the physical parameter in Table1, changing the scheduling algorithms, the value of throughput and fairness at different scheduling algorithms in LTE will be as shown in the following table.

Table 3.Comparison between three scheduling algorithms in LTE network.

Metrics	Round Robin	Prop Fair	Best CQI
Peak/Avg/Edge UE throughput	2.09/0.81/0.11 Mbps	5.04/1.46/ 0.21 Mbps	12.29/2.25/0. 00 Mbps
Avg.Cell throughput	8.07Mbps	14.61Mbps	22.53 Mbps
Fairness index	0.603615	0.469402	0.22697

Table 3 displays the optimal CQI scheduler with the highest system throughput and the least amount of fairness. Round robin cycles the same number of resources to each user without taking into account their equipment input. By allocating time to the user who has the best current channel realization in comparison to its own average, the proportional fair stresses multiuser variety. Also, the following graphs show the average throughput of different three scheduling at homogenous network.

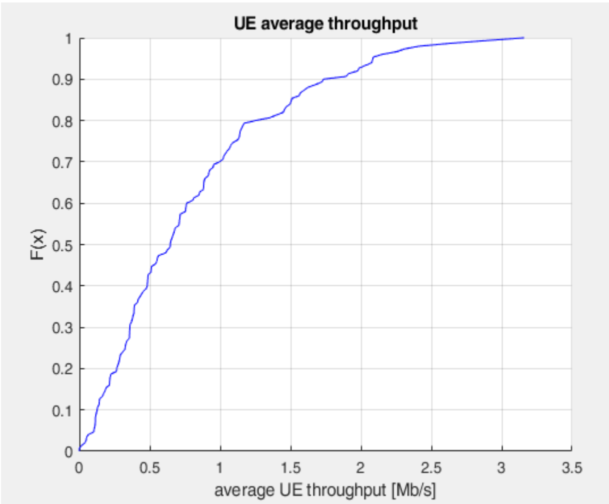

Figure 7. Average throughput in RR

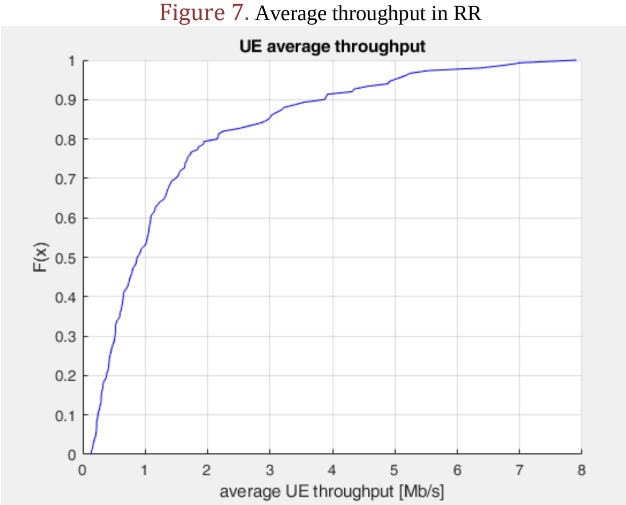

Figure 8. Average throughput in Prop Fair.

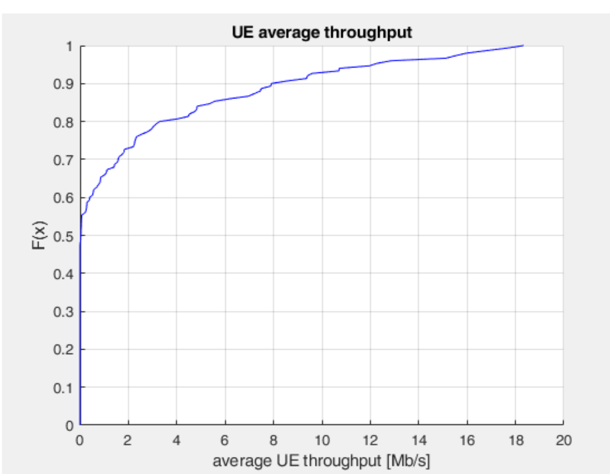

Figure 9. Average throughput in Best CQI.

5.2. Performance Evaluation of LTE-A

By using the physical parameter in Table1, by addition Transmitted power of femtocell (0.2watt) and number of users at each cell (10 users) and calculate the value of throughput and fairness at different scheduling algorithms in LTE-A will be as shown in the following table.

Table 4.Comparison between three scheduling algorithms in LTE-A network.

Metrics	Round Robin	Prop Fair	Best CQI
Peak/Avg/Edge UE throughput	2.82/1.29/0.01 Mbps	7.08/2.53/0.16 Mbps	10.24/2.87/0.00 Mbps
Avg.Cell throughput	12.93Mbps	25.33Mbps	28.69 Mbps
Fairness index	0.632591	0.519761	0.337689

Also, the following graphs show the average throughput of different three scheduling at heterogeneous.

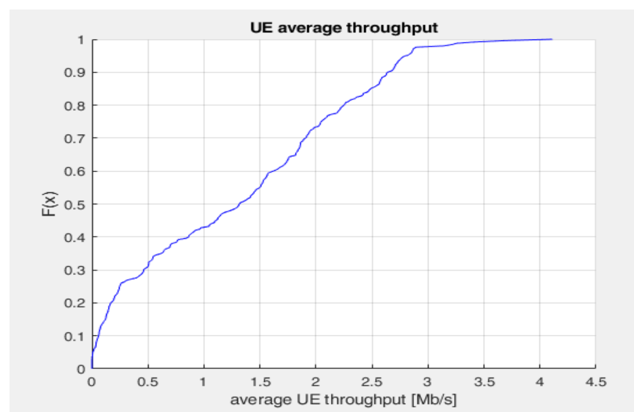

Figure 10. Average throughput in RR

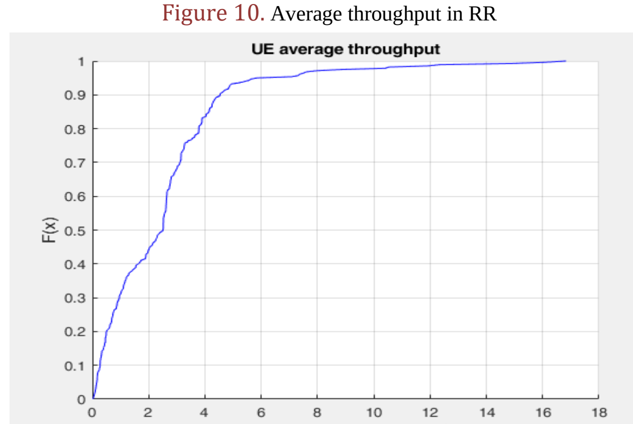

Figure 11. Average throughput in Prop Fair

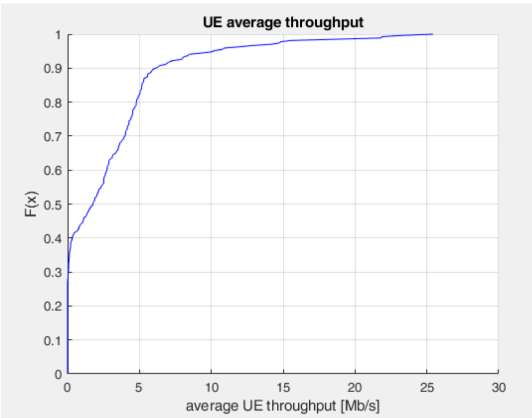

Figure 12. Average throughput in Best CQI.

6. Conclusion

The primary objective of this research was to examine the LTE downlink scheduling methods. To comprehend these scheduling methods, a general understanding of LTE must be explored. Numerous supporting technologies that are part of the LTE standard help to increase the system's capacity and coverage. OFDM, which enables the division of the total bandwidth into a variety of time-frequency resource portions, is one of the enabling technologies used in the downlink transmission. The scheduler is a vital part of the base station that aids in allocating time-frequency resources to consumers. The effectiveness of the two approaches is thoroughly compared, with the Best CQI scheduling the users with good channel quality and so enhancing system performance. After carefully analyzing the effects of throughput and fairness, I have proposed a revolutionary scheduling approach. A sub-frame has two openings in each slot. According to the new scheduling mechanism, the sub-frame with the highest CQI value fills the first slot of each sub-frame, and the second slot is scheduled sequentially. The novel scheduling technique thus strikes a compromise between throughput and fairness. These scheduling strategies have been put into practice using the Vienna LTE System Level Simulator for MATLAB. As part of the throughput study, different transmission technologies and scheduling methods are taken into consideration. In comparison to the Round Robin Scheduler and the Best CQI, the new scheduler operates more effectively and fairly. To boost throughput, several antenna transmission methods are used.

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