COMPARATIVE STUDY ON THE PERFORMANCE OF ROUND ROBIN AND PROPORTIONAL FAIR DOWNLINK RESOURCE SCHEDULERS AT DDIFFERENT STATE OF USER MOBILITY IN LTE

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APPROVAL

This Thesis titled **"Comparative study on the Performance of Round Robin and Proportional Fair Downlink Resource Schedulers at Different State of User Mobility in LTE "** submitted By Md. Roknuzzaman, Md. Rezwanul Bari and Naeim Khan to the Department of Information and Communication Engineering (ICE), Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Electronics and Telecommunication Engineering and approved as to its style and contents. The presentation was held on January, 2019.

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DECLARATION

We hereby declare that this paper is our own work and effort under the supervision of **Prof. Dr. A.K.M. Fazlul Haque, Professor, Department of Information and Communication Engineering and Associate Dean, Faculty of Engineering,** Daffodil International University, Dhaka. It has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged.

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ABSTRACT

In this paper, a comparative study has been carried out between the two most popular Downlink Resource Scheduling techniques in LTE based on user end mobility. Round Robin and Proportional Fair techniques have been considered for the analysis. The study has been performed via simulation using Vienna LTE-A Downlink System Level Simulator v2.0 Q3 2018 in a Heterogeneous Network scenario. The performances of the schedulers are evaluated for both stationary and moving users according to average UE (User End) throughput and average UE spectral efficiency. It is found that Round Robin technique performs better in lower velocities and Proportional Fair technique performs better in higher velocities. Keeping the feature in mind, a switching system combining both the techniques has been proposed.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Long-Term Evolution (LTE) is a 4^{th} generation telecommunication standard which is used for transferring data at a data rate of 50 Mb/s upstream and 100 Mb/s downstream over cellular network. In the downlink, it uses orthogonal frequency division multiple access (OFDMA) in the downlink. Some responsibility is done a node named eNodeB which is present in between the core network and the user end. This eNodeB is responsible for all Radio Resource Management (RRM) functions. Data is transmitted and received as digital signal which represents a bit stream. This bit stream is created by the physical layer. The LTE physical layer is a highly efficient means of conveying both data and control information between an enhanced base station (eNodeB) and mobile user equipment (UE). It employs some advanced technologies that are new to cellular applications. These include Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) data transmission. In addition, the LTE physical layer uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier – Frequency Division Multiple Access (SC-FDMA) on the uplink (UL). OFDMA allows data to be directed to or from multiple users on a subcarrier-by-subcarrier basis for a specified number of symbol periods [4]. To provide high speed data is the main goal of LTE. A maximum data rate of 326.4 Mbps can be achieved in the downlink for a 20 MHz channel and a maximum data rate of 86.4 Mbps can be achieved in the uplink for the same channel [1] LTE downlink transmission scheme is based on Orthogonal Frequency Division Multiple Access (OFDMA), while the uplink transmission is based on Single Carrier Frequency Division Multiple Access (SC-FDMA). The main drawback of OFDMA over SC–FDMA is its high Peak to Average Power Ratio (PAPR) [2]. The PHY of LTE transfers information to and from the MAC layer using transport blocks that convey data for at most two sub-frames [3] For transmitting data PHY of LTE uses Downlink and Uplink Channels [2]. To transmit the downlink user data physical downlink shared channel (PDSCH) is used. It is used for all type of data users and also for (PBCH) paging broadcast channel. For the data signal and control signal physical uplink shared channel (PUSCH) is used. This channel is used to carry uplink users information data [4]. The downlink transmitter in the physical layer starts with the grouped resource data which are in the form of transport blocks. PDSCH is used to transmit the Downlink Shared Channel (DL-SCH). The DL-SCH is the transport channel used for transmitting downlink data (a transport block). One or two coded transport blocks (code words) can be transmitted simultaneously on the PDSCH depending on the pre-coding scheme used [2]. According to [5] the processing steps of transmitting downlink data in PDSCH are:

- Transport block CRC attachment
- Modulation using OFDM
- Scrambling, Modulation
- Code Block Concatenation
- Layer Mapping
- Rate Matching
- Mapping to Resource Elements
- Channel coding
- Attachment of CRC and segmentation of Code block

In wireless system, scheduling is one of the important thing. A scheduler is very necessary element in base station (BS) because it allocates the resource block (RB) to different user ends (UE).To produce high speed data services to mobile consumers, Scheduling in wireless networks has hidden substantial contemplation [6]. A scheduler considers traffic volume, quality of service (QOS), channel condition etc. A LTE scheduler performs different types of functions for efficient scheduling which is link adaptation, rate control, packet scheduler, resource assignment, power control etc. There are different types of schedulers such as Max CQI, Round Robin, Proportional Fair etc. These schedulers perform well based on their specific metric. Among all the resource scheduler Round Robin and Proportional Fair are the most popular scheduling techniques. In Round Robin, it mainly shared in an equal manner. The scheduler provides resources cyclically to the users without considering channel conditions into account [7]. It’s a simple procedure giving the best fairness. Round Robin meets the fairness by providing an equal share of packet transmission time to each user which is called time quantum. Proportional fair is a Downlink scheduler best suited for best traffic effort. Main purpose of Proportional Fair scheduler is to balance between throughput and fairness among all the UEs. Proportional Fair gives an averaged scheduled rate. It considers resource fairness as well as maximizing cell throughput. We are proposing a switching technique between Proportional Fair and Round Robin scheduling technique and perform a simulation of both and observe the impact of user mobility in the performance of downlink. We will also observe and compare the bit error rate between the two techniques when they are implemented separately and combined.

1.2 Literature Review

There are many analysis done regarding LTE and its downlink resource scheduling techniques in many journals in the past. Some of those journals or papers gave a comparison and some of them gave a clear indication of what is better and what not. Among those journal or articles or papers one is L.Kanchan, et al. has done an analysis on the topic of LTE. In this paper they have done the analysis of transmissions of downlink and uplink in LTE. They have measured some parameters like Bit Error Rate and Throughput. They have also considered the parameter of Frame Error Rate. They analyzed with this parameters and achieved higher performance by changing those parameters when it is compared with the methods which existed that time.

There is another paper which was written by Temito O. Takpor and Francis E.Idacha and in this paper there was an analysis about the LTE physical layer. They have analyzed the physical uplink and downlink shared channels. They showed the performance of transceiver of LTE in those Physical downlink and uplink channels. They have done simulation and simulation is configured with different measurement parameters. They used the parameters like throughput and Bit Error Rate. The shown the graphs on respect to this parameters. In this paper they got the results they expected by using those measurement in the physical uplink and downlink channel of LTE. They did not came up with any decision or any specific solution which would be better than the existing system.

There is another paper written by Abdullah Bin Shams, et al., in this paper they analyzed the performance of LTE. They focused on the resource schedulers of LTE on the aspect of Downlink and they considered the user mobility effect on those schedulers. The analysis is done by simulation and they have considered some parameters like average UE (User End) Throughput and Spectral Efficiency. They have focused on two popular downlink resource scheduling techniques which are Proportional Fair and Round Robin. They showed in there analysis that how Proportional Fair performs compared to Round Robin. They also given a comparative analysis result where they came up with a decision that Proportional Fair Performs better in low mobility of users where Round Robin does not give as good performance as Proportional Fair in low mobility of UE (User End). But in high mobility Round Robin

Performance way better than Proportional Fair on the basis of average throughput and spectral efficiency. And From there analysis we have found that Proportional Fair performs better than Round Robin till the UE mobility is less than 30 mile/hour. And we have done this analysis on the basis of user mobility to understand the real scenario. Parameters like spectral efficiency and average throughput parameters are also used in our paper. But the main focus was mobility and performance of these two schedulers against the mobility of UE (User End) and how the average throughput and spectral efficiency increased or decreased as the mobility increased or decreased. Our result shows slight difference in the performance comparison of Proportional Fair and Round Robin. We have analyzed that Proportional Fair could not outperform Round even when the user mobility is more than 15 mile/hour. In our result we have found that for stationary mode proportional fair is gives clearly better performance than Round Robin on the basis of average UE throughput and spectral efficiency and it continues like this till the user reaches to its velocity of 15 mile/hour maximum. After that point if velocity exceed one more mile than the performance of Proportional Fair Decreases Drastically where Round Robin keeps on giving its average performance which is far better than Proportional Fair on that point. So we have also given a future work of a switching scheme which will use both the schedulers and switch them according to the state of velocity of user which will ensure the high performance of schedulers on any state of user mobility. When the user is in stationary state and till it reaches the 15 km/hr velocity the switching scheme will run Proportional Fair and when the velocity is more than 15 km/hr.

1.3 Motivation

Initially Proportional Fair was developed for stationary users only. So it performs very well in term of stationary user. But in term of user mobility the performance degrades consistently which causes data packet loss. On the other hand Round Robin is a scheduling technique that performs remarkably better than PF in term of user mobility. Our main concern is to minimize the data packet loss by switching to Round Robin Scheduling technique while the user is moving at a velocity greater than 30 km/hr. Under 30 km/hr. Proportional fair is still a good decision to go with because it outperforms the average performance of Round Robin under this condition.

CHAPTER 2

NETWORK ARCHITECTURE

LTE tries to take mobile communication technology with versatile innovation to the next step all the way through the acknowledgment of transmission capacities of higher rate, superior range proficiency, more extensive inclusion. It also deals with the complete interworking with different access and backend frameworks. LTE/SAE proposes to do such an excess of utilizing an all-IP architecture with very much characterized interworking with circuit-switched system. Moreover, the advanced 3GPP framework presented a hybrid portable system design supporting radio access advancements and a few mobility components. We start this section by presenting the LTE network reference model and characterize its different utilitarian elements and its interconnection conceivable outcomes.

2.1 Architecture and Components

Architecture of an LTE network depends on useful deterioration standards, where the highlights of the requirements are deteriorated into practical substances with no explicit usage suspicions about physical system elements. That's why 3GPP indicated the Evolved Packet Core (EPC), which was organized to help the E-UTRAN through a decrease in the quantity of components, easy functionality, better redundancy and above all, taking into account that associations and hand over to other settled line and wireless access technologies, by which the increased capacity to sustain a consistent mobility experience is given to the service providers.

2.2 Architecture Reference Model

In Figure2.1 the reference model of an LTE network is shown. It is a logical view of the system architecture of the network. This model separates the working physical elements in the core architecture and the focus of the reference is fixed between the practical entities over which interoperability is accomplished.

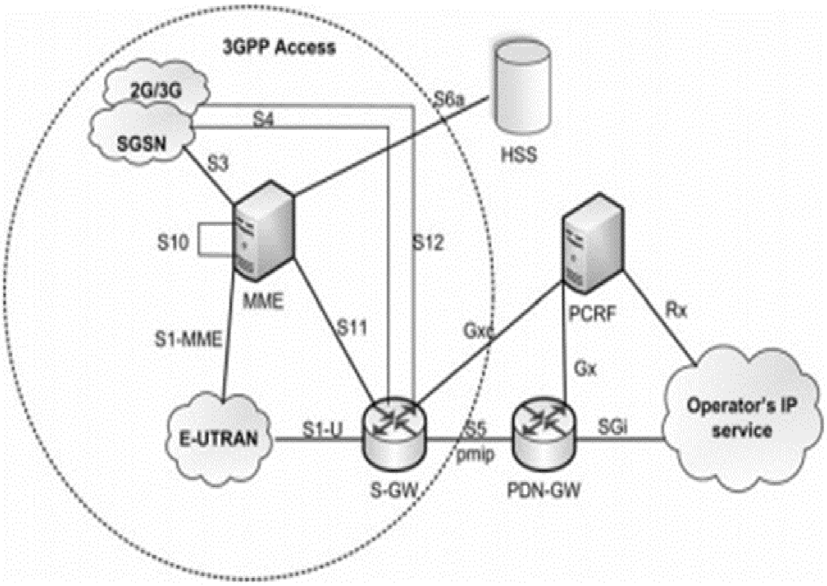


Figure 2.1: LTE reference model

The whole model has two particular segments. One is the access network and another one is core network. The first part is called Developed E-UTRAN. And the second one that means core network is an all-IP center system. This system is completely Packet Switched (PS). EPC is the center system of the model. System unpredictability along with inertness are lessened because the number of hops is less in the plane of information and signaling. For mobile IP, the intension is to improve the non-3GPPP access with the help of EPC. Non-Access Stratum (NAS) plane is an optional layer of deliberation to enhance the security of the important data. In order to make the system more secure, a presentation is done by this NAS which includes figuring and also respectability assurance.

2.3 Functional Description of LTE Network

We feature in this segment the useful depiction of the most essential piece of the LTE network architecture which is isolated into radio access network and core network.

2.3.1 Evolved Universal Terrestrial Radio Access Network (E-UTRAN)

For mobile network Long Term evolution (LTE) has a redesign way which is the air interface called the E-UTRAN. The radio access standards like HSDPA, UMTS etc. technologies are substituted by this completely new improved system of air interface. E-UTRAN gives higher rates of information and lower idleness and for packet data it is upgraded. For Downlink radio access (OFDMA) is utilized and for the uplink SC-FDMA is utilized. The solitary node which interfaces with the client hardware is compromised by the E-UTRAN which is used in the architecture of Long Term Evolution. This improvement is done to diminish the dormancy of the tasks of all the radio interfaces. X2 interface is used to associate eNODEBs with one another and S1 interface is used to associate with the core PS networks (see Fig2.2).

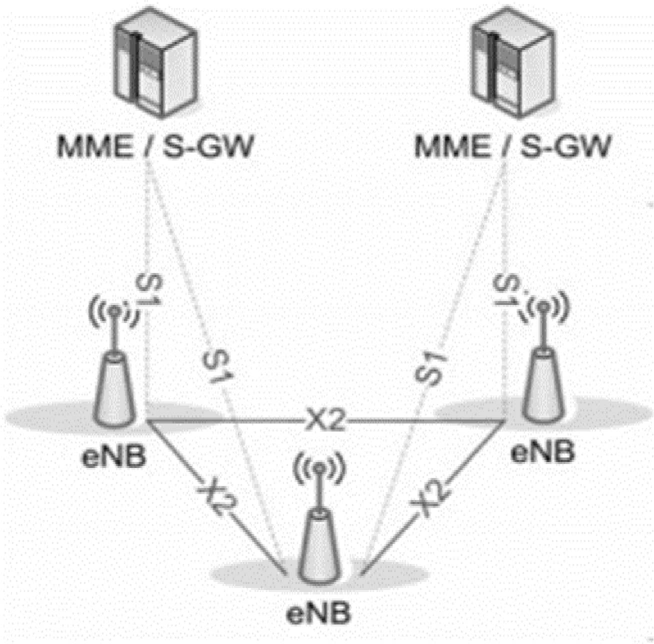


Figure 2.2: E-UTRAN architecture

A general convention design of E-UTRAN (Figure 2.3) parts the radio interface into three layers: a physical layer or Layer 1, the data link layer or Layer 2, and the network layer or Layer 3. This various leveled stratification gives an entire vision of the radio interface, from both the usefulness related with each of the organized layer to the convention stream between them.

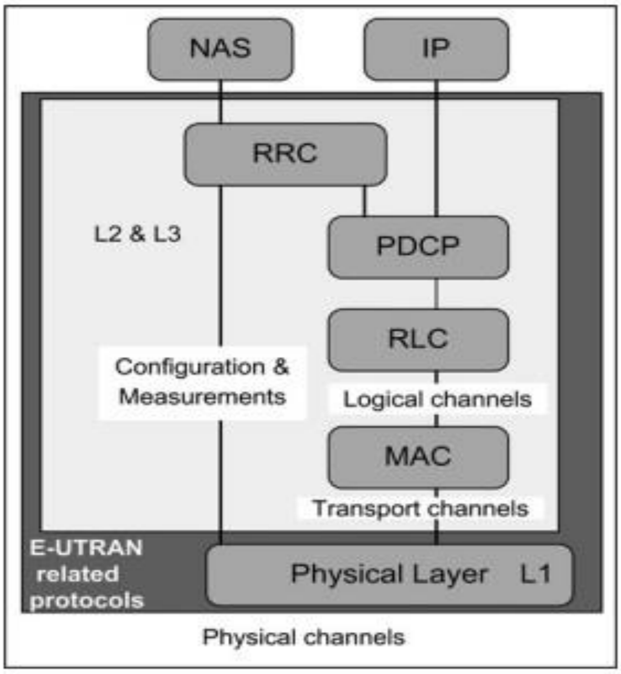


Figure 2.3: Physical Channels

To transmit data consistently through the channels administrations are needed to be set and this is the reason for the convention stack. And the data they convey are the characterizing parameters of those channels. Also sensible channels like this needed to guide through transport channels and the manner by which and with what trademark the data inside each channel transmission is done over the interface of the radio is the characteristic. This characteristic implies that there is at least one transport design related to each transport channel. Every one of them characterized by the encoding, interleaving bit rate, and mapping onto the physical channel. Each layer is characterized by the services provided to the higher layers or entities and the functions that support them [1] as follows:

- **Physical layer**: Conveys all data from the MAC transport channels over the air interface. Deals with the connection adjustment (AMC), control, cell seek (for beginning synchronization and handover purposes), and different estimations (inside the LTE framework and between frameworks) for the RRC layer.
- **MAC**: The MAC sub-layer offers a lot of legitimate channels to the RLC sub-layer that it multiplexes into the physical layer transport channels. It likewise deals with the HARQ error correction, handles the prioritization of the legitimate channels for a similar UE and the dynamic planning between UEs, and so on.

- **RLC**: It transports the PDCP's PDUs. It can work in three unique modes relying upon the unwavering quality gave. Contingent upon this mode it can give ARQ error correction, division/connection of PDUs, reordering for in sequence conveyance, copy location, and so forth.
- **PDCP**: For the RRC layer it furnishes transport of its information with figuring and honesty assurance and for the IP layer transport of the IP parcels, with ROHC header compression, figuring, and relying upon the RLC mode in-arrangement conveyance, copy recognition, and retransmission of its own SDUs at the time of handover.
- **RRC**: Between others it deals with the communicated framework data identified with the Non-Access Stratum messages transportation, handover, foundation, paging and arrival of the connection of RRC, administration of the authorization key, UE estimations identified with between inter –system (inter- RAT) mobility, QoS, and so forth.

2.3.2 System Architecture Evolution (SAE)

The Evolved Packet Core is the fundamental part of the System Architecture Evolution engineering which comprises the functional [1] components below:

- **Serving Gateway**: The Serving Gateway forwards and routs client information packets and it additionally going about as the versatility grapple for the client plane at the time of eNodeB handovers and as the stay for versatility among LTE and other 3GPP advances (ending S4 interface and transferring the traffic between 2G/3G frameworks and PDN-GW) . For inactive state UEs, the S-GW ends the downlink information way and triggers paging at the point when downlink information touches base for the UE. It oversees and stores UE settings, e.g., parameters of the IP carrier administration and system inner directing data. It likewise performs replication of the client traffic if there should be an occurrence of legitimate capture attempt.
- **Packet Data Network Gateway**: The availability of the UE to outside packet information is given by Packet Data Network Gateway by acting as the purpose of section and exit of traffic in the case of the UE. More than one PDN-GW for getting to numerous packet information systems availability may have concurrent with a UE. The

Packet Data Network Gateway performs arrangement implementation, parcel sifting for every client, charging support, and legitimate block attempt. Going about as the grapple for versatility among LTE and other advances is another key factor of Packet Data Network Gateway, for example, 3GPP2 and WiMAX etc.

- **Mobility Management Entity**: The arrangement of LTE is done by MME as it is the key control node of LTE. It is do following of UE in inactive mode and paging strategy which includes retransmissions. The carrier enactment and deactivation process are associated with it. Additionally it is in charge of picking the S-GW at the underlying append for a UE. It is also in charge when intra-LTE handover is taking place including node migration of Core Network. It also validates the client. It is likewise in charge of age and distribution of brief characters to UEs. It checks the approval of the UE to camp on the specialist co-op's Public Land Mobile Network (PLMN) and authorizes UE meandering confinements. The MME is the end point in the system for signaling/respectability assurance for NAS flagging and handles the security key administration. Legitimate capture attempt of signaling is additionally upheld by the MME. MME additionally with the S3 interface gets to the system ending at MME and also gives the control plane capacity to versatility among LTE and other like 2G/3G. At long last, additionally the S6a interface ended by MME which was toward the home HSS. Which was the cause for roaming UEs.

2.4 Protocol Architecture

In LTE, the radio interface is characterized through its protocols where it can be defined by two fundamental groupings according to the two final purpose protocols:

- User Plane Protocol
- Control Plane Protocol

The first one carries user data through the access stratum and the second one is in charge of controlling the connections between the UE and the system and the radio access bearers. Despite the fact that division of the control plane and the client plane was possibly a standout amongst the most essential issues of LTE configuration, full autonomy of the layers isn't feasible because, without interaction between the user plane and the control plane, administrators are not able to control QoS, the source/destination of media traffic, and when the media begins and stops.

2.4.1 User Plane

The E-UTRAN included in the stack of plane protocol of user and a conventional system of an interface named S1 is demonstrated in figure 2.4. MAC, RLC, and PDCP protocols are used by the radio access. The S1 interface has a user plane part which is based on the GPRS Tunneling Protocol [1]. GTP ensures the delivery a mechanism of tunneling, of the IP packets are forwarded to the eNodeB which is destined to the UE which is currently located. An outer IP packet is an encapsulated form of the original IP packet which is encapsulated by GTP addressed to the specific eNodeB. Various Layer 1/Layer 2 technologies operate the S1 interface.

Figure 2.4 shows additionally a precedent TCP/IP-based application, for example, web perusing. The corresponding peer entities work in the UE and at the server which is hosting the web application. Peer protocol entities of the server are drawn in the Serving Gateway (S-GW); howsoever, generally they are located somewhere in the Internet. The user plane acts as via for the transportation process of all the data sent and received by the UE. It creates user plane traffic which is processed at various progressive dimensions or hierarchical levels. The levels are from eNodeB to core network. Additionally, the attachment of the user plane is the control traffic.

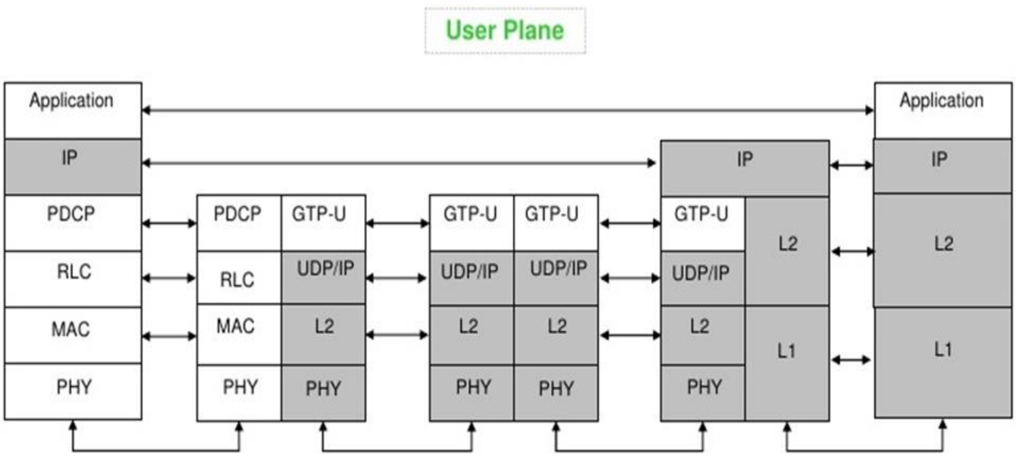


Figure 2.4: User plane end-to-end protocol stack

When it comes to the edge of the network microwave transmission becomes a more flexible and cost-effective substitution, particularly in terms of capacity extending [1].

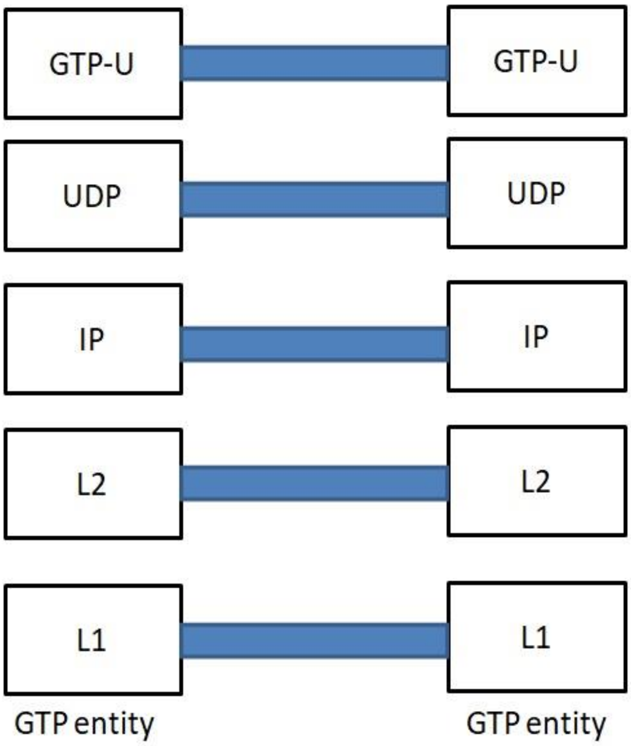


Figure 2.5: GTP Stack

2.4.2 Control Plane

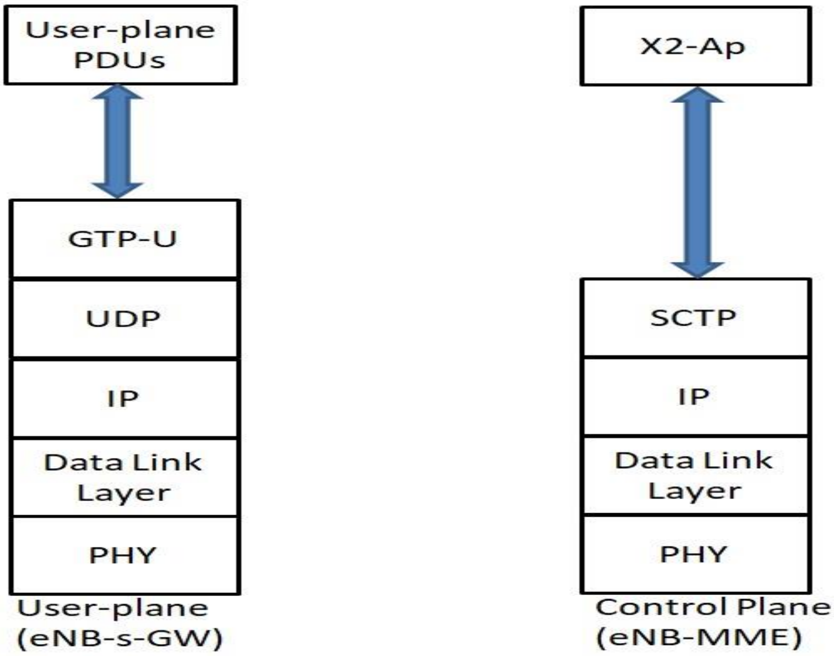
The radio access bearers and the connection between the UE and the network is controlled by the control plane protocol function. The connections of E-UTRAN network access, all the attributes of access connection of an established network, the route of an established network in order to support mobility of user, network resources assignment to meet the demands of changing user are controlled by the functions of control plane. Thus the protocols of control plane support the user plane functions too.

In the control plane, the NAS protocol controlled The MME and UE is controlled by the NAS protocol which is used in the control plane to control attachment of network, bearers set up, authentication and mobility management. The MME and UE ciphers all the NAS messages. In the eNodeB, handover decisions are made by the Radio Resource Control (RRC) layer. It is done based on measurements of neighbor cell which are sent by the UE, pages over the air for the UEs, information of broadcasts system, controls measurement of UE reporting. Channel

Quality Information is such type of UE reporting to active UEs, allocation of temporary identifier in cell-level. At the time of hand over UE context is also transferred from the eNodeB to another. RRC messages integrity protection is also performed by it.

2.4.3 X2 Interface in User and Control Planes

This interface is defined between the corresponding eNodeBs. It provides PDUs of user plane but it is non-guaranteed. In the Fig. 2.6a the protocol stack is shown. Between two neighbor eNodeBs X2-CP (X2 Control Plane) is defined. In the Fig. 2.6b control plane protocol stack is shown. Transport Network Layer is based on a protocol named Stream Control Transmission Protocol (SCTP).The X2-Application Protocol is the signaling protocol for application layer. In order to carry PDUs, a GTP-U and IP transport based layer named transport network layer is used.

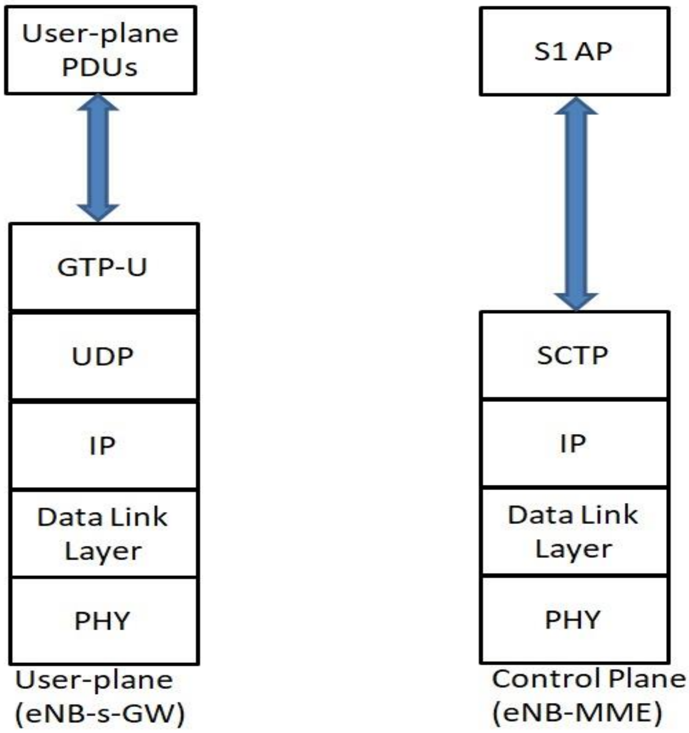


(a) **(b)**

Figure 2.6: (a) X2 interface in user plane, (b) X2 interface in control plane

2.4.4 S1 Interface in User and Control Planes

Not similarly as X2 interface, S1 interface is defined between s-GW and eNodeBs. It provides delivery of PDUs of user plane between the S-GW and the eNodeBs but it is non-guaranteed. In the Fig. 2.7a the protocol stack of user plane shown. In Fig. 2.7b the protocol stack of control plane of the S1 is shown. In order to carry PDUs between S-GW and eNodeBs, a GTP-U and IP transport based layer named transport network layer is used. The definition of S1 control plane interface can be determined between the s-GW and eNodeBs.



(a) (b)

Figure 2.7: (a) S1 interface in user plane, (b) S1 interface in control plane

2.5 Radio Resource Management

Radio resources needs to be used efficiently and a mechanisms that allow E-UTRAN to access radio resources-related necessities needs to be given and this is the reason for using Radio Resource Management. Specifically, RRM in E-UTRAN gives means to manage radio resources considering single-and multi-cell perspectives. The RRM functions are described to by the following aspects.

2.5.1 Connection Mobility Control (CMC)

Two things of the radio resources management which are the connection with idle and mobility which a concern for Connection Mobility Control. In idle or stationary mode, re selection algorithms of the cell are controlled and it is controlled by parameters set up which are values of hysteresis and threshold that help to identify which cell is the best or it helps to decide if a new cell should be selected by the User Ends. E-UTRAN also broadcasts parameters that configure the UE measurement which is configured by the parameters are broadcasted by E-UTRAN and it also broadcasts reporting procedures. The mobility of radio connections has a mobility which needs to be supported in connected mode [1]. Measurements of enodeB and User End may determine the handover process. By taking inputs like traffic distribution, cell load and transport hardware resources we also can determine handover process. In the enodeB Connection Mobility Control.

2.5.2 Dynamic Resource Allocation (DRA) – Packet Scheduling (PS)

Allocation and de-allocation of resources is done by Packet Scheduling to user and control plane packets. There are several sub-tasks involves into DRA, including the radio bearers selection whose packets are to be scheduled and also managing the required resources.PS usually considers the Quality of Service requirements connected with the channel quality information for User Ends, the radio bearers, interference situation, buffer status, etc. Resource blocks which are available or the block sets of resources preferences may also be considered by the DRA because of inter-cell interference coordination considerations. The eNodeB is where the DRA is situated.

2.5.3 Load Balancing (LB)

The traffic load is needed to be distributed with proper balance and the unbalanced needs to be managed which is done by the Load Balancing over multiple cells. The purpose of Load Balancing (LB) is to influence the load distribution in such a manner that radio resources remain high utilization of the radio resources need to be done which depends on the load distribution which is influenced by Load Balancing. Also the in-progress sessions need to be maintained such a way that QoS is maintained properly as much as possible and call dropping probabilities are cut down to low. Traffic is needed to be reallocated the cells where it is highly loaded to the cells which are unused and it is done by handover or reselection of the cells which is done by the Load Balancing algorithms. The eNodeB is where the LB is situated.

CHAPTER 3

DOWNLINK RADIO RESOURCE in LTE NETWORKS

3.1 LTE Signal

LTE is getting to be pertinent to associations outside real market of cellular network. It gives considerably higher transmission rate than 3rdGeneration communication technology. In order to demodulate an LTE signal, at first a clear understanding of the structure is required.

The intension of LTE is to transmit data with a very low latency. Frames of 10ms are organized to create an LTE signal.

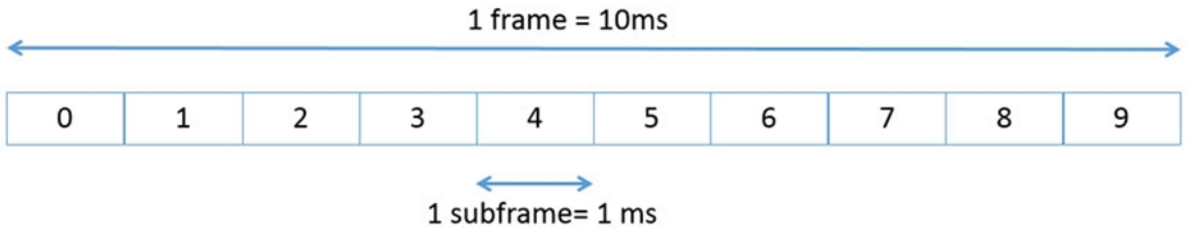


Figure 3.1: LTE frame and sub frame structure.

It uses OFDM modulation. It also uses MIMO for various functional work. An LTE frame outline is made out of ten sub-frames of 1ms. Each sub-frame includes 14 OFDM symbols. Sub-frames are normally portrayed as a 2 Dimensional grid of time and frequencies which are called resource grid. Figure 3.2 demonstrates the resource grid. From 72 to 1200 subcarriers fit in the grid. Cells on the grid are called resource component. A resource block consists of a 12-by-7 set of resource components.

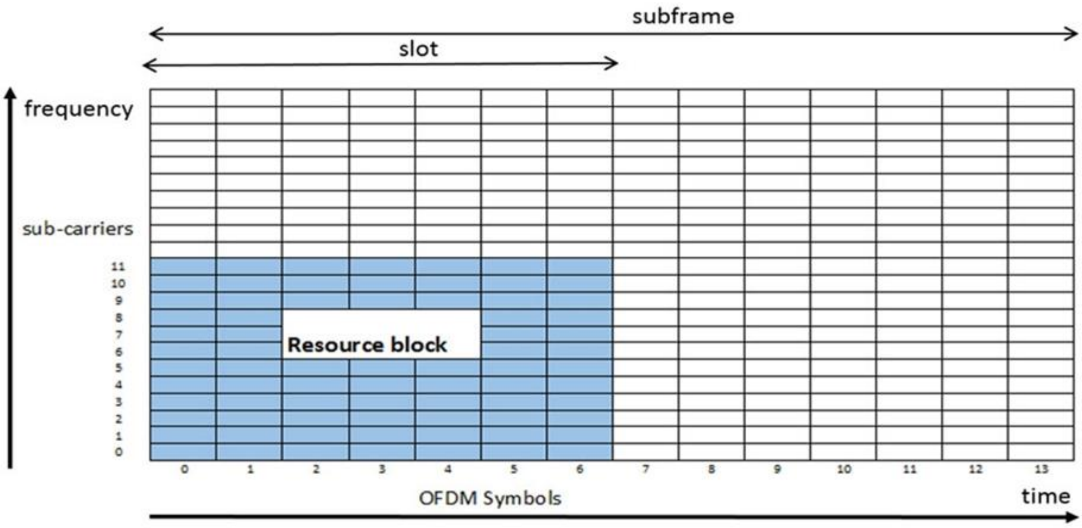


Figure 3.2: Empty resource grid and one resource block.

At the point when a LTE device, for example, a telephone is on, it initially needs to be identified and interfaced with LTE. LTE can be conveyed with data transmissions going from 1.4MHz to 20MHz (relating to the 72 to 1200 subcarriers referenced previously). The LTE standard in this manner puts all the data required for the telephone to interface with the system in the narrowest bandwidth, which is inside the center of 72 subcarriers. This information [8] includes:

- Primary synchronization signs (PSS) and optional synchronization signals (SSS), which help decide the frame timing and cell distinguishing proof. These signs happen after each five sub-frames.
- The broadcast channel (BCH), which conveys the Master Information Block (MIB). The MIB incorporates data, for example, the genuine cell transmission capacity (somewhere in the range of 1.4MHz and 20 MHZ). The BCH happen each 10 sub-frames.

Each sub-frame incorporates 14 OFDM symbols. The initial few symbols portray the control region. They are saved for control data, with payload information going into the rest of the symbols. The quantity of control symbols fluctuates from sub-frame to sub-frame, and is signaled by the Physical Control Format Indicator Channel (PCFICH).

The network includes [8] three additional channels:

- Physical Hybrid Indicator Channel (PHICH), which conveys acknowledgments for information recently sent to the base station
- Physical Downlink Control Channel (PDCCH), which conveys information of the allocated part of the grid to a specific user and the modulation and coding scheme used.
- Physical Downlink Shared Channel (PDSCH), by which traffic data is carried.

3.2 System Model

A downlink data scheduler architecture with various shared channels for several User Ends is shown in Fig. 3.3.M User Ends in a cell are served by an eNodeB at a given time. The transmission regulated centrally by the eNodeB in both communication ways. In the eNodeB, all data packets from higher layers determined for the User Ends where they are classified into SDFs and each SDFs with various Quality of Service (QoS) requirements. One bearer is associated with each SDF which can be deliberated as a link establishment between the User Ends and the Packet Data Network gateway (PDN-GW).Generally, bearers are two kinds and one is non-guaranteed bit rate (non-GBR) which is an IP connectivity bearer and another is guaranteed bit rate (GBR) which is a fixed bearer. Various bearer level Quality of Service (QoS) parameters are associated with guaranteed bit rate (GBR) and Non-ensured bit rate (non-GRB) and it is called QoS Class Identifier (QCI).The data packets are attributed OFDMA by a slot allocator when higher layer data packet have been grouped into SDFs and scheduled by the MAC layer. In OFDMA frame structure, a slot is the initial resource unit as it is a unit of sub-channel symbol. One can consider that the data region (frame) is a two-dimensional allocation which can be visualized as a rectangle [1].

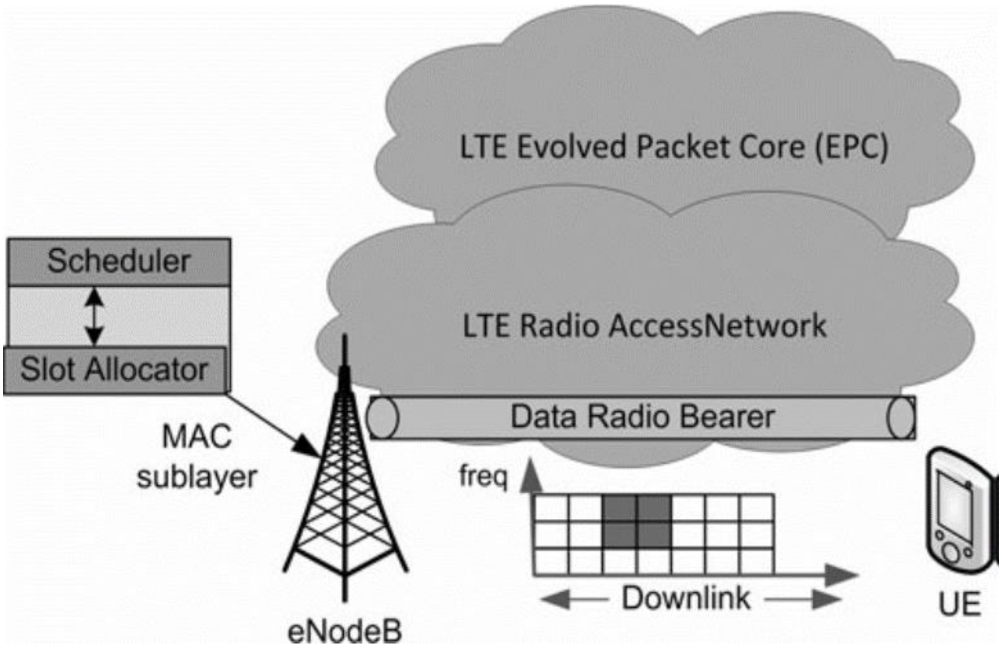


Figure.3.3: Downlink system model for LTE

In downlink, allocation of OFDMA slots to data is done by the segmentation of the data into blocks. The segmentation process takes place after the modulation process and it is done in such a way that the blocks fit into one OFDMA slot. In this way, an OFDMA frame which is divided into K sub channels and T symbols where the K sub channels are in the frequency domain and the T symbols are in the time domain. There are T × K slots in each OFDMA frame and according to its application requirements one or more this slots are allocated for each User End. A broad range of data rates which can be supported in this model is one of the advantage of this system model and it also very compatible for the LTE system. For understandability, the slot on the Kth sub channel at the tth symbol is denoted as (kth, tth) slot. QoS Class Identifier (QCI) of the total frame is completely known at the eNodeB via messages from User Ends (UEs).In this manner, M User Ends (UEs) simultaneously served by the eNodeB and for various SDFs, various SDFs receive packets in queue of each of the user end. Slots can be scheduled and assigned effectively by slot allocator which is in the eNodeB. Also slots of OFDMA on downlink is also where the allocation of power is done by SDFs characteristics and the conditions of wireless channels [1].

A HetNet consists of femto cells and macro cell. The eNodeBs and the positions of the UEs are shown in the Fig 3.4

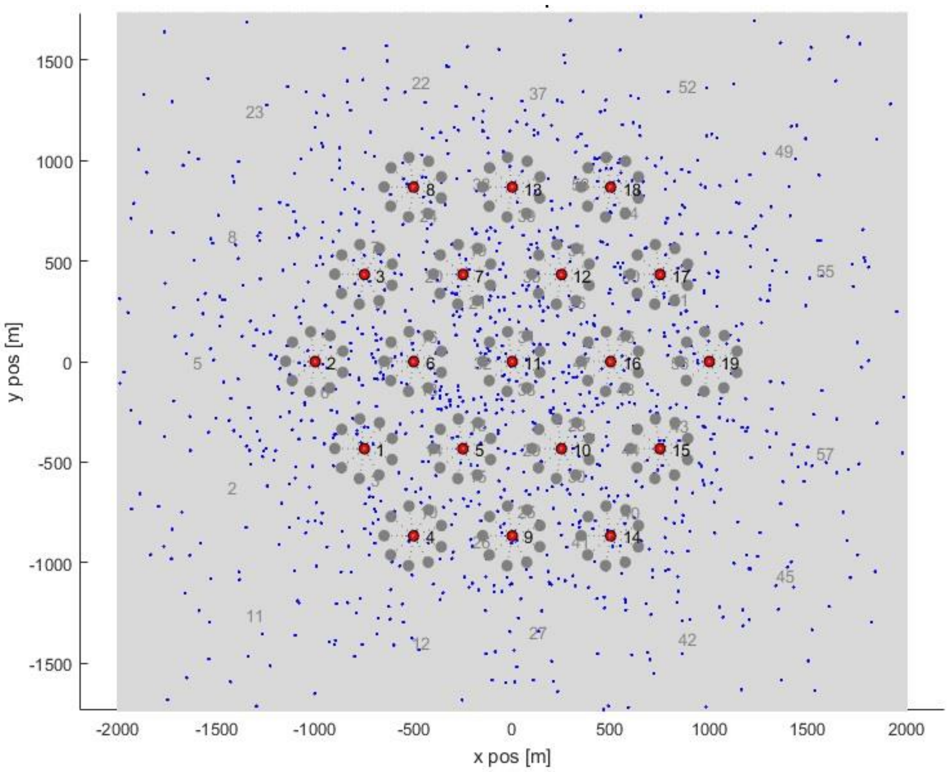


Figure.3.4: Deployment of HetNet with macro cells and femto cells.

3.3 Resource in LTE

Data is divided into frames and frames are divided into sub-frames of 1ms in LTE, where a frame length is of 10ms in the time domain. Each sub-frame contains 14 OFDM signals. The OFDM signals are weather QPSK or QAM symbols. These QPSK or QAM symbols contains cyclic prefix and Fast Fourier Transform.

3.3.1 LTE Frame Structure

There are two different modes in LTE, Frequency Division Mode (FDD) Type 1 and Time Division Mode (TDD) Type 2. LTE frame structure differs according to the two modes:

- Frame 0 and 5 (always downlink in TDD).
- Frame 1 and 6 is always used for synchronization in TDD.
- For Uplink and Downlink, frame allocation is settable in TDD.

Both the technologies FDD and TDD operate under 1-ms sub-frame and time slot definition of 0.5 us with the same sampling rate. For TDD the first 3 (0-2) configurations can be viewed as 5ms allocation due to repetition. The figure below represents a relationship between rates and LTE frame structure.

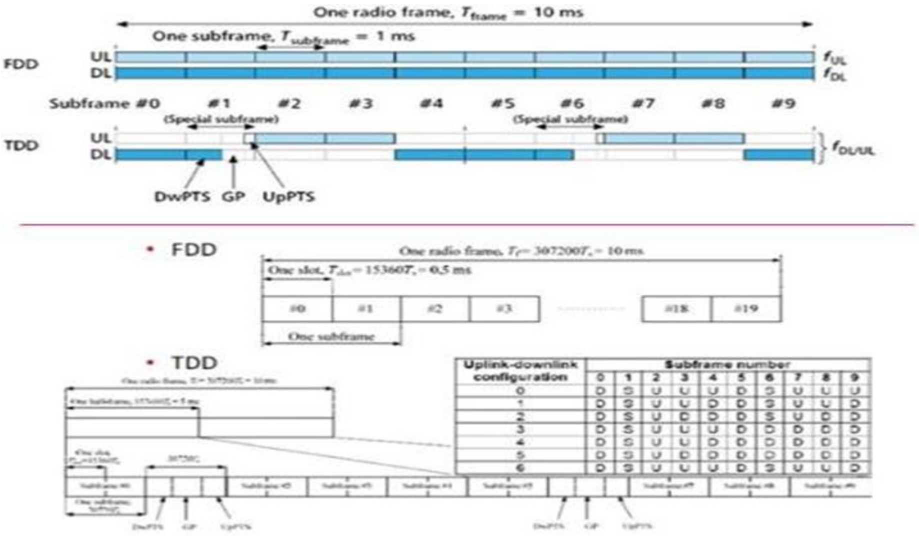


Figure 3.5: Relation between rates and frame structure.

3.3.2 LTE Resource Block Architecture

Physical resource block (PRB) is the main block of LTE. A scheduling function base station (eNodeB) handles all of the allocation of LTE physical resource blocks (PRBs).

- Every frame is of 10ms which consists of 10 sub-frames
- Each subframe is of 1ms and contains 2 slots
- Every slot is of 0.5ms in time domain. Depending on the bandwidth allocation and resource availability one slot can contain N resource blocks where 6<N<110.
- One resource block is of 0.5ms and each contains 12 subcarriers for each OFDM symbol in frequency domain.

- There are 7 symbols in normal cyclic prefix per time slot or 6 symbols in long cyclic prefix for LTE.

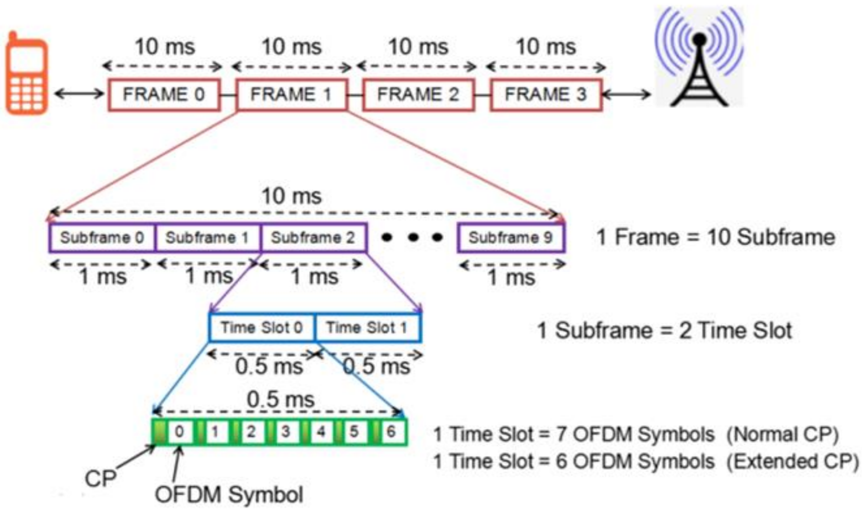


Figure 3.6: Resource Block

CHAPTER 4

DIFFERENT RESOURCE SCHEDULING ALGORITHMS

One of the most important goals of LTE booking is to fulfill Quality of Service (QoS) necessities of all users by attempting to reach, in the meantime, an ideal exchange off among usage and fairness. This objective is very challenging in the presence of real-time applications. These applications are characterized by the strict constraints on packet delay and also by jitter. In LTE system, the concept of scheduling according to channel-sensitivity has been introduced. It takes advantage of the independency fast fading across the users. In the case of many users measuring a different channel quality, it actually finds a user with good or relatively good condition of the channel within the given time. In LTE, the decision of scheduling is highly depends on the channel quality.

4.1 Proportional Fair (PF)

For non-real-time traffic Proportional Fair algorithm is a very suitable scheduling technique. It distributes radio resources considering both the experienced CQ (Channel Quality) and the throughput of past user. The purpose of this algorithm is to maximize the throughput of the total network and also guarantee fairness among flows. It is the most popular scheduling technique nowadays.

$$j = \frac{\mu i(t)}{\bar{\mu}i}$$

Where, $\mu i(t)$ defines , at time t, the data rate of the corresponding channel state of the user i and $\bar{\mu}i$ is the mean of the data rate.

4.2 Maximum Largest Weighted Delay First

Maximum Largest Weighted Delay First (M-LWDF) algorithm was designed to support multiple real-time data users simultaneously in CDMA-HDR systems. With different types of QoS (Quality of service) requirements, it supports multiple data users. Variations of instantaneous channel and video service delays are supported by this algorithm. This scheduling technique tries to balance the packets weighted delays and to use the information of the channel state efficiently.

4.3 Best CQI Scheduling Algorithm

This scheduling technique allots resource blocks to the user with the best channel quality. To schedule, terminals transmit Channel Quality Indicator (CQI) to the base station (BS). Generally in downlink, BS transmits downlink pilot to the terminals. These are called reference signals which are utilized by UEs for measuring the CQI. The higher The CQI the better the channel condition. This scheduling technique increases cell capacity with unfairness.

4.4 Round Robin (RR) Scheduling Algorithms

Round Robin is a scheduling algorithm that lets users take turns in utilizing the shared resources. In this technique, the instantaneous conditions of channel do not matter. So, it offers outstanding fairness to the users while radio resource management. But it decreases throughput performance of the system. Round Robin scheduling technique can be implemented on into two ways, one is the Time Domain Round Robin (TDRR) and another one is Time and Frequency Domain Round Robin (TFDRR). In TDRR, the user who reaches first is served with the whole spectrum of frequency for a specific period of time, then these resource blocks are turn back and allotted to the next user for the next time period. After that the user who was previously served, is lined up at the end of the queue so that it can be served with resources in the next process. The algorithm continues this process again and again. In TFDRR, multiple users can be scheduled during one TTI in the order of a cycle. Round Robin scheduling guaranties fairness for all the users. This is the principal advantage of this scheduling technique. It is easy to implement, which is the reason of its being used by many systems and in LTE also.

CHAPTER 5

USER MOBILITY

In worldwide among the all cellular network including 4G cellular network, mobility must remain in communication networks. In telecommunication, it is most important to maintain a stable connection when users are in mobility. The principle aim of LTE in communication is to give quick and also consistent handoff from one cell to another cell or from source to destination. One of the important component in LTE is eNodeB which is considered as a base station. eNodeBs manage the consistent communication among all the user ends when the user ends are in a flat network.

LTE introduced a service which is 3GPP standards. The 3GPP mainly manage the handoff and user mobility. A continuous handoff process of any connection is enabled by 3GPP. Different type of system of LTE support a secure and consistent handoff for delay-tolerant full-mobility applications such as VOIP or voice over IP. For quick handoff by using this service also increasing the battery life of the users.

5.1 Mobility Management

When user is moving at one place to another place to communicate, the two important component are required to enable for identifying a user end in a network and there need some system to give an incoming data packets to a user end. The procedure of tracking and locate a user ends present position in a network is known as a location management. For keeping up a progression session while the user ends move from one eNodeB to another eNodeB in the coverage region, a flawlessly transition mechanism or handover, this progression session must be required. All the mechanisms to maintain this things is called handoff management. Mobility management is established by both the location management and handoff management.

5.2 Location Management

Location management includes two procedures. Location registration is the first procedures and it also known as location update where current location network periodically informed by UE. Location registration conducts the network to verify the UE and UEs location profile which is updated by it in a database. At least one primary location is need inside the network where the databases are typically set. In a location there have two or more base stations in a coverage region. There need to inform the user devices location in the network for that reason a location update is utilized. There is required to register user device from its previous location to new location for allowing to transfer the incoming calls. When the location update system is perfectly determined the user device location in the network then it able to transfer and route correctly the incoming call into new location. A paging inquiry is required to the user cells in the network for that when an incoming calls occurred then the user devices have to inform its current location. The above procedures is called paging which is related with location management. It is also important to maintain a low cost for sending consecutive paging message so that there must be reduced the paging area size [9]. Generally a paging area consists of a set of user cells. Two types of costs are considered to calculate the size of a paging area which is paging cost and location update cost. Most of the location management system is using this type of technique to reduce the above costs.

CHAPTER 6

PROPOSED SWITCHING SCHEME

Our switching scheme is based on the scheduling techniques. There are many scheduling techniques for LTE system. Among these techniques, Proportional Fair (PF) and Round Robin (RR) are two most popular schedulers used in LTE. Proportional Fair and Round Robin are better in their own different situations. The switching scheme is based on their separate characteristics working together to create a high performance for the UE's at downlink data transfer in different velocity.

6.1 Proportional Fair Performance

A lot of research work has concentrated on the execution of different scheduling schemes and their outcomes show PF to rule over different schedulers as far as accomplishing a harmony between high UE throughput and better fairness. But in case of mobility of UE's the performance of PF decreases consistently. So it is a big drawback of PF as it is out performed tremendously by RR when user is not in stationary state or above the velocity of 30 km/hr to be precise. On the basis of parameters like average cell edge throughput and spectral efficiency PF outperforms RR in stationary state or sate of user velocity which is less than 30 km/hr.

6.2 Round Robin Performance

Round Robin (RR) scheduling technique is one of the most popular scheduling techniques for its simplicity as it does not represent the state of channel of UE. All the UEs are treated equally on the basis of priorities under a BS. Round Robin scheduler technique outperforms PF when the UEs are above 30 km/hr velocity on the basis of parameters like average cell edge throughput and spectral efficiency. A low throughput is given by RR at cell edge in high velocity which maintains a seamless network connection. This characteristic of RR prevents call drops.

6.3 Proposed Scheme

Initially Proportional Fair was developed for stationary users only. So it performs very well in term of stationary user. But in term of user mobility the performance degrades consistently. On the other hand Round Robin is a scheduling technique that performs remarkably better than PF in term of user mobility and at the edge of cell. In this paper we are proposing a combined scheduling technique using both PF and RR to achieve better performance not only in stationary mode but also in any state of user mobility. In this proposed scheme when the user is in stationary mode the PF scheduler will be active and it will stay active until the UE reaches to a velocity of 30mile/hour. If the UE velocity further increases and reaches to 31 km/hr velocity than switching will take place. This switching will convert the scheduling technique to Round Robin (RR). This way proportional fare will take place when the UE velocity V≤30 km/hr and Round Robin (RR) will take place when UE velocity V>30 km/hr.

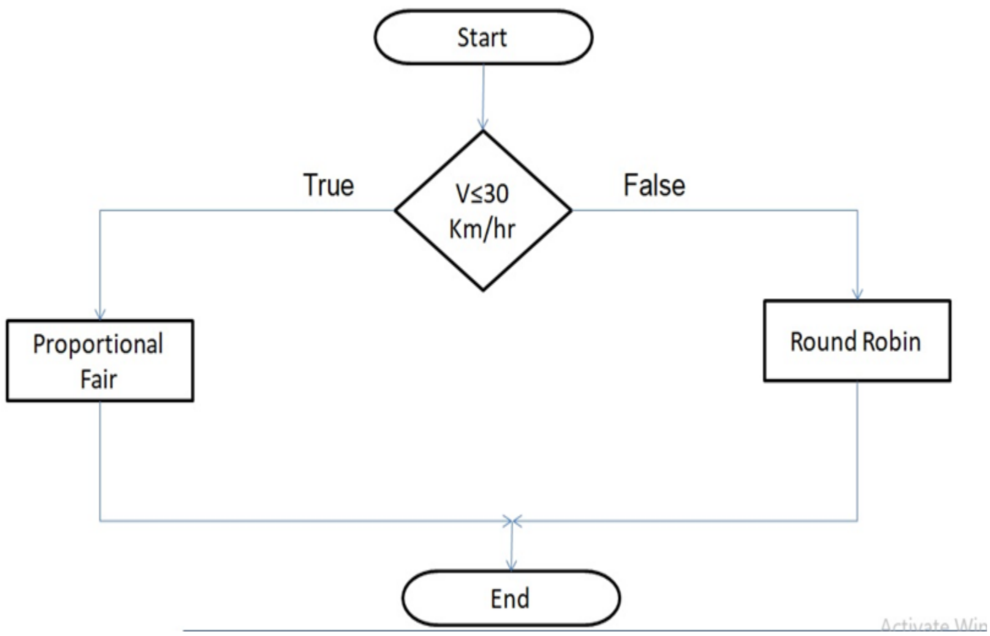


Figure 6.1: Methodology of proposed scheme.

Figure 6.2 shows the performance comparison of PF and RR on the basis of average UE throughput against UE velocity.

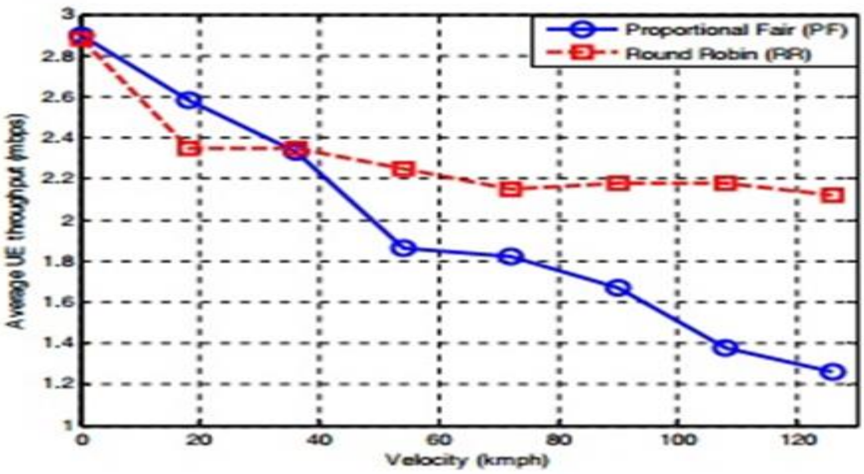


Figure 6.2: Average UE throughput vs. UE velocity under PF and RR scheduler [10]

So by our proposed switching technique we are using proportional fair scheduler when the velocity is less than or equal to 30mile/hour which gives high average UE throughput. And when the UE velocity is more than 30 km/hr than the scheduler technique will switch to RR scheduler which will give high average UE throughput for higher mobility of UEs. This proposed scheme will give consistent uncompromising average UE throughput for any state of user mobility.

Figure 6.3 shows the performance comparison of PF and RR on the basis of spectral efficiency against UE velocity.

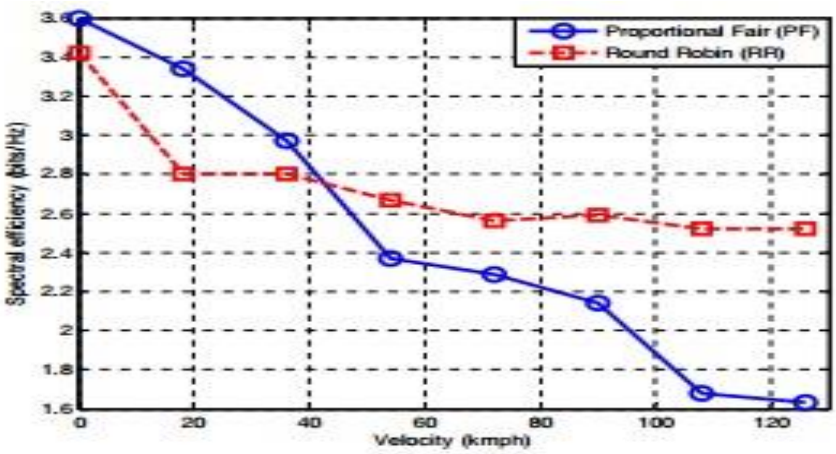


Figure 6.3: Spectral efficiency vs. UE velocity under PF and RR scheduler [10]

In the case of spectral efficiency our proposed scheme again gives consistent and uncompromising performance. As proportional fair scheduler gives better spectral efficiency than RR when UE velocity is less than 30mile/hour and Round Robin scheduler gives better performance than PF when UE is more than 30mile/hour. So our proposed scheme is giving best suited scheduler for any state of user mobility which will give high spectral efficiency consistently.

CHAPTER 7

RESULTS AND DISCUSSION

Our simulation is divided into 3 different scenario according to velocity. The simulation parameters are shown in table in 7.1

Table -7.1: Simulation Parameters

Simulation Parameters	
Channel Model	winner+
Frequency	900MHz
Bandwidth	10MHz
No. of Tx	1
No of Rx	4
Transmission Mode	Transmit Diversity (TxD)
BS height	20m
Receiver height	1.5m
Antenna gain	15dBi
BS Transmitter Power	45dBm
Femto cell transmitter power	10watts
Simulation Time	10TTI

7.1 For Stationary Users

Proportional Fair scheduling technique was developed for stationary users and so it's throughput for stationary users is very high. It prioritizes users by the CQI (Channel Quality Indicator). As a result when users start moving, the average UE throughput decreases because the feedback of CQI is low. Also at the cell edge, CQI feedback is low and that's why the cell edge throughput becomes zero in some scenario. The simulation statistics are shown in Figure 7.1 while the velocity of users was assumed to be zero. The average UE throughput and average spectral efficiency for Proportional Fair are shown in Figure 7.2.

```
----------------------------------------
Simulations statistics:

57 cells, 1140 UEs
Simulation length: 2 TTIs
Scheduler: prop fair Sun
Mode: 1x4, CLSM
----------------------------------------
Cell statistics:

Fairness index: 0.3943
Peak/Avg/Edge UE throughput:
20.16/6.23/0.00 Mb/s
Average cell throughput: 124.68Mb/s
Ignored cells (disabled): 0
mean RB occupancy: 100.00%
----------------------------------------
```

Figure 7.1: Simulation Statistics of PF.

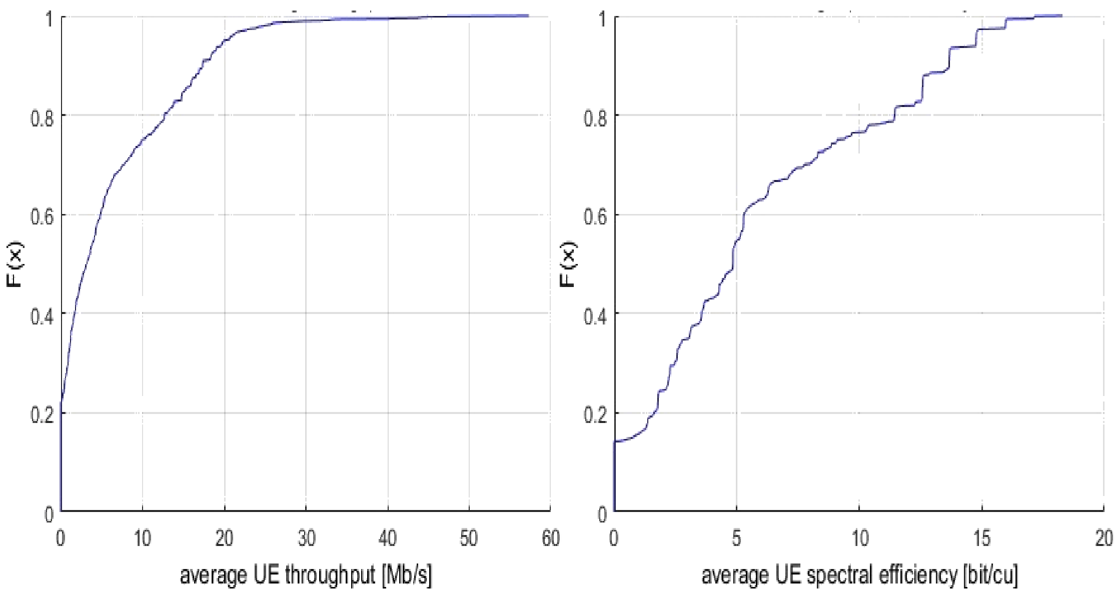


Figure 7.2: Average UE throughput and Average UE spectral efficiency of PF

The average UE throughput and average spectral efficiency for Round Robin are shown in Figure 7.2. In this scenario, Round Robin shows better fairness index though the average throughput was lower than that of Proportional Fair. The simulation statistics for Round Robin are shown in Figure 7.3.

```
----------------------------------------
Simulations statistics:

57 cells, 1140 UEs
Simulation length: 2 TTIs
Scheduler: round robin
Mode: 1x4, CLSM
----------------------------------------
Cell statistics:

Fairness index: 0.589177
Peak/Avg/Edge UE throughput:
8.13/2.89/0.46 Mb/s
Average cell throughput: 57.71Mb/s
Ignored cells (disabled): 0
mean RB occupancy: 100.00%
----------------------------------------
```

Figure 7.3: Simulation Statistics of RR.

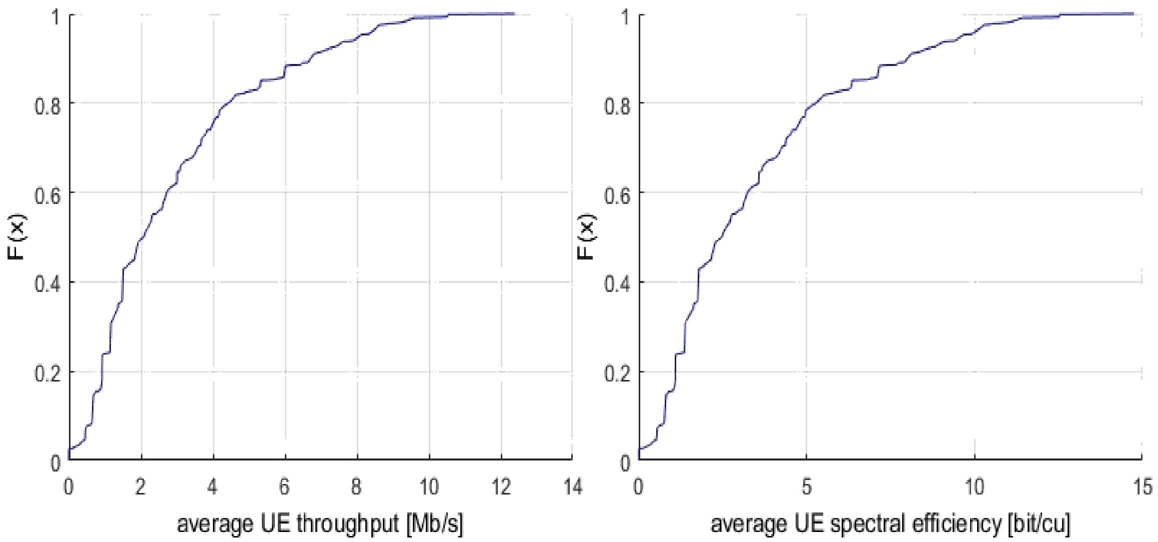


Figure 7.4: Average UE throughput and Average UE spectral efficiency of RR

7.2 For users moving at a velocity of 6 m/s

Round Robin gradually outperforms Proportional Fair with the increase of user mobility. Round Robin gives better cell edge throughput than Proportional Fair. The simulation statistics for Proportional Fair and Round Robin are shown in Figure 7.5 and Figure 7.6 respectively.

```
------------------------------------------
Simulations statistics:

57 cells, 1140 UEs
Simulation length: 10 TTIs
Scheduler: prop fair Sun
Mode: 1x4, CLSM
------------------------------------------
Cell statistics:

Fairness index: 0.685689
Peak/Avg/Edge UE throughput:
6.01/2.47/0.69 Mb/s
Average cell throughput: 49.40Mb/s
Ignored cells (disabled): 0
mean RB occupancy: 100.00%
------------------------------------------
```

Figure 7.5: Simulation Statistics of PF.

```
------------------------------------------
Simulations statistics:

57 cells, 1140 UEs
Simulation length: 10 TTIs
Scheduler: round robin
Mode: 1x4, CLSM
------------------------------------------
Cell statistics:

Fairness index: 0.705206
Peak/Avg/Edge UE throughput:
6.62/2.93/0.70 Mb/s
Average cell throughput: 58.59Mb/s
Ignored cells (disabled): 0
mean RB occupancy: 100.00%
------------------------------------------
```

Figure 7.6: Simulation statistics of RR.

It also gives a decent average UE throughput than Proportional Fair. The average UE throughput and average spectral efficiency for Proportional Fair are shown in Figure 7.7 and Average UE throughput and Average UE spectral efficiency for Round Robin is shown in Figure 7.8.

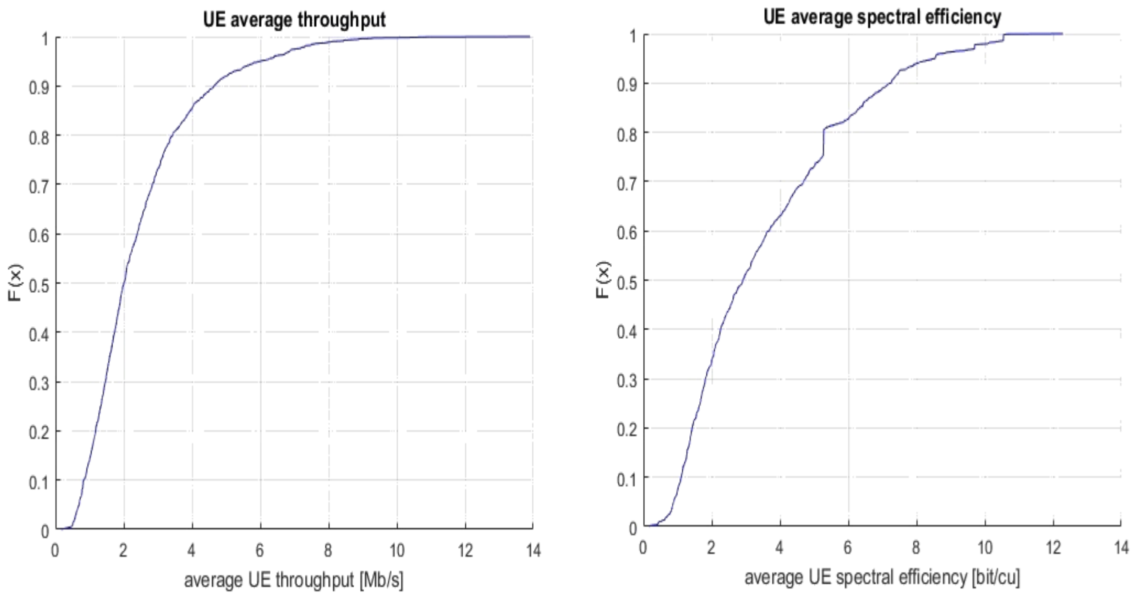


Figure 7.7: Average UE throughput and Average UE spectral efficiency of PF

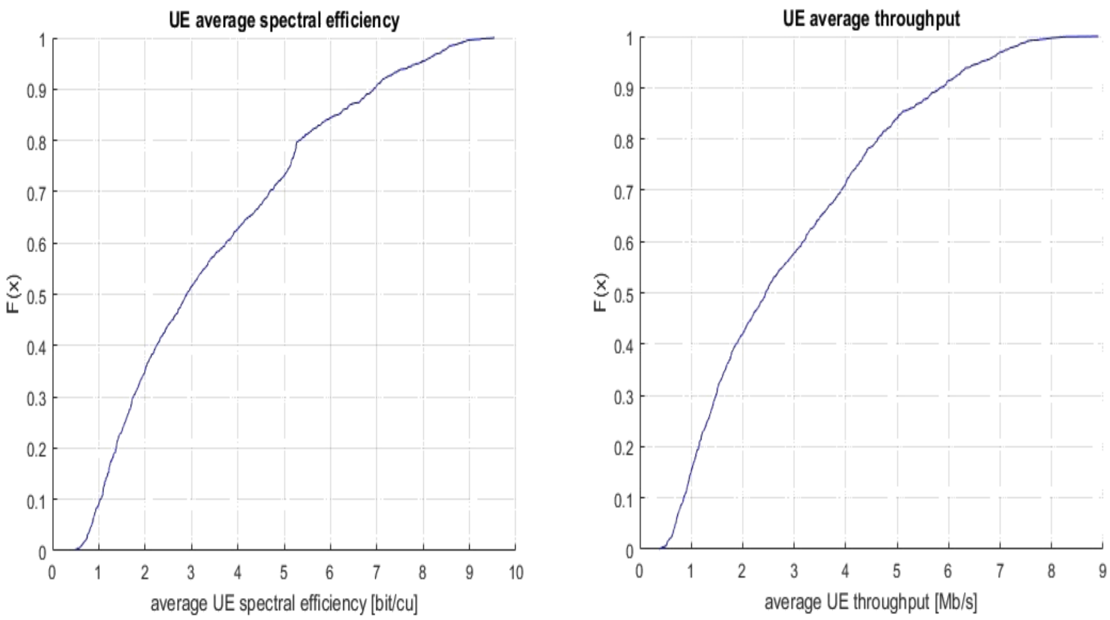


Figure 7.8: Average UE throughput and Average UE spectral efficiency of RR

7.3 For high user mobility

Here Round Robin completely outperforms Proportional Fair in the case of cell edge throughput. The cell edge throughput of Proportional Fair is zero. The simulation statistics for Proportional Fair and Round Robin are shown in Figure 7.9 and Figure 7.10 respectively.

```
------------------------------------------
 Simulations statstics:

 57 cells, 1140 UEs
 Simulation length: 10 TTIs
 Scheduler: prop fair Sun
 Mode: 1x4, CLSM
------------------------------------------
 Cell statistics:

 Fairness index: 0.508443
 Peak/Avg/Edge UE throughput:
 2.70/0.96/0.00 Mb/s
 Average cell throughput: 19.12Mb/s
 Ignored cells (disabled): 0
 mean RB occupancy: 100.00%
------------------------------------------
```

Figure 7.9: Simulation Statistics of PF.

```
------------------------------------------
 Simulations statistics:

 57 cells, 1140 UEs
 Simulation length: 10 TTIs
 Scheduler: round robin
 Mode: 1x4, CLSM
------------------------------------------
 Cell statistics:

 Fairness index: 0.686849
 Peak/Avg/Edge UE throughput:
 4.93/2.21/0.50 Mb/s
 Average cell throughput: 44.15Mb/s
 Ignored cells (disabled): 0
 mean RB occupancy: 100.00%
------------------------------------------
```

Figure 7.10: simulation statistics of RR.

In the case of high user mobility, Round Robin tries to give a very low average UE throughput but not zero as Proportional Fair. The average cell throughput and spectral efficiency is also way better than Proportional Fair. The average UE throughput and average spectral efficiency for Proportional Fair are shown in Figure 7.11 and Average UE throughput and Average UE spectral efficiency for Round Robin is shown in Figure 7.12.

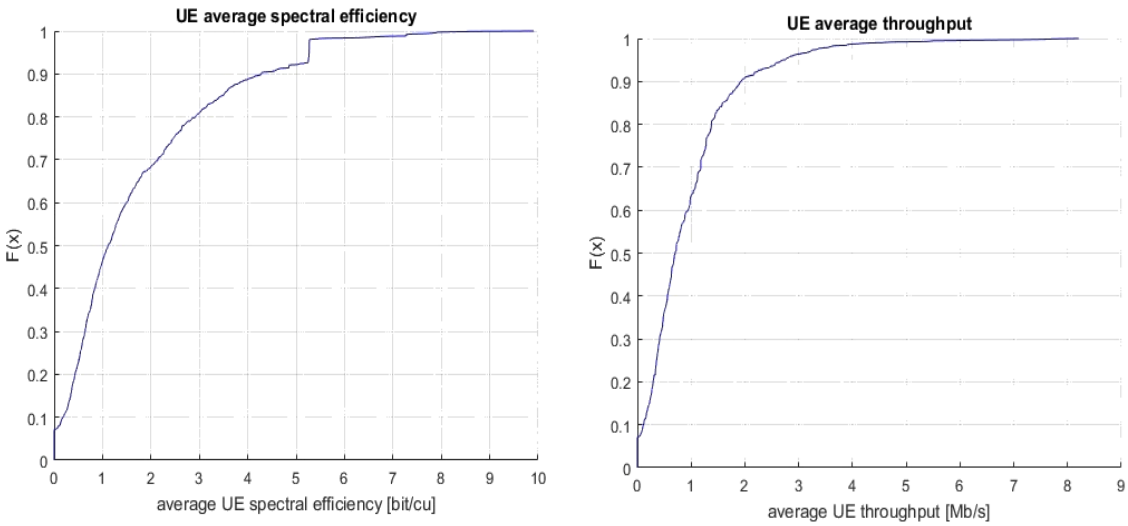


Figure 7.11: Average UE throughput and average spectral efficiency for Proportional Fair

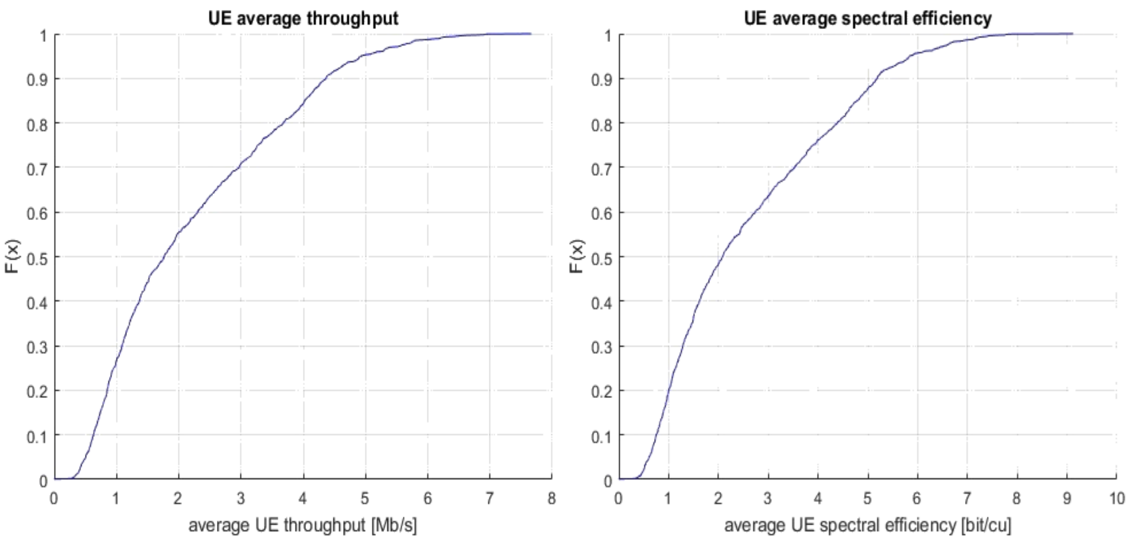


Figure 7.12: Average UE throughput and average spectral efficiency for Round Robin

From table 7.2 the comparison between Round Robin and Proportional Fair scheduling technique according to different state of velocity.

Table -7.2: Comparison between RR and PF according to performance

Performance Parameter	Round Robin			Proportional Fair		
	0m/s	6m/s	20m/s	0m/s	6m/s	20m/s
Average UE throughput (Mb/s)	2.89	2.93	2.21	6.23	2.47	0.96
Peak Average Value (Mb/s)	8.12	6.62	4.93	20.06	6.01	2.70
Cell edge throughput (Mb/s)	0.46	0.70	0.50	0.0	0.69	0.0
Fairness Index	0.589	0.705	0.686	0.394	0.685	0.508

CHAPTER 8

CONCLUSION

In LTE, different resource schedulers are used in different state of user mobility. Proportional Fair and Round Robin are the most popular scheduling techniques of them. That's why this comparison has been performed using Round Robin and Proportional Fair schedulers in order to determine which scheduler is better with respect to user mobility. According to the results of simulation, in the case of high mobility, Round Robin scheduling technique performs way better than Proportional Fair scheduling technique on the basis of spectral efficiency and average user end throughput and also it gives a remarkably better fairness. On the contrary, Proportional Fair is unable to serve well at high user mobility, especially at the cell edges, it performs very poor. The results show that the average user end throughput depends on both user end density and user mobility. The Spectral efficiency is also dependent on both the matrics. According to the results, the values of both the parameters decrease with the increase of user end density and mobility. When a user is moving at a high velocity Round Robin scheduling technique will be the best option to go with. Therefore when a stationary user starts moving with an increasing velocity, the scheduler should switch the technique from Proportional Fair to Round Robin to obtain better throughput and spectral efficiency at any state of user mobility.

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