BACHELOR OF SCIENCE IN ELECTRONIC AND TELECOMMUNICATION ENGINEERING

Resource Allocation & Energy Consumption Reduction for 5G (NR-New Radio) Wireless Communication

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CERTIFICATE OF APPROVAL

DECLARATION OF CANDIDATE

It is declared that the work presented here is authentic and has not been submitted concurrently for a degree. The conclusion we have reached is entirely dependent on our own research/work.

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Author

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Date:

ABSTRACT

Resource Allocation is one of the most challenging issues in LTE & 5G communication in the modern era. In wireless communication, the proper method of assigning resources to subscribers has received considerable attention. So, in this thesis, we are introducing an approach based on visualizing resource allocation. It will help the users allocate their resources correctly and effectively and divide the subscriber's situation into three parts (Good, Mid, Cell edge) by checking the RF condition. If the subscriber is in a cell edge situation, we won't count it to reduce computational complexity. Those users to whom we have allocated the resource will save a lot of time and energy if they are stable. We've used Adobe XD (UI/UX) software interface to design the layout of the resource allocation scenario. The layout shows our prototype on a live server. And we have also delivered some logic by using the IF-THEN statement through membership function in fuzzy logic. Using those logics, eNode B will get the user's information, so it would be easy for eNode B to decide how the machine will work.

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List of Abbreviations

5G	Fifth Generations
B5G	Beyond Fifth Generation
D2D	Device to Device
3GPP	Third Generation Partnership Project
5G-NR	Fifth Generations – New Radio
LTE	Long Term Evaluation
LTE-A	Long Term Evaluation Advanced
NSA	Non-Stand Alone
SA	Stand Alone
EPCE	Evolved Packet Core
RA	Resource Allocation
TDMA	Time Division Multiple Access
FDMA	Frequency Division Multiple Access
CDMA	Code Division Multiple Access
OFDMA	Orthogonal Frequency Division Multiple Access
CQI	Channel Quality Indicator
UI	User Interface
UX	User Experience
MCS	Modulation Coding Scheme
SINR	Signal to Interface & Noise Ratio
RSRP	Reference Signal Receive Power
BLER	Block Error Rate
QoS	Quality of Service
LIP	Linear Integer Programming
M2M	Machine-to-Machine
MEC	Mobile Edge Computing
MIMO	Massive Input Massive Outpur
RT	Real Time
NRT	Non Real time
UTRAN	UMTS Terrestrial Radio Access Network
BS	Base Station

MSC	Mobile Switching center
SBS	Service Based Scheduling
OLLA	Outer Look Line Adaptation
UID	User Interface Design
ARCS	Analytical Rate Control Scheme
NN	Neural Network
RB	Resource Block
TTI	Transmission Time Interval
UE	User Equipment
MCT	Maximum Capacity for Transmission
RE	Resource Elements
QPSK	Quadrature Phase Shift Keying
FEC	Forward Errors Correction
FL	Fuzzy Logic
FLC	Fuzzy Logic Control
RF	Radio Frequency
SDMA	Space Division Multiple Access
SE	Spectral Efficiency
PSO	Particle Swarm Optimization
RPSO	Refined Particle Swarm Optimization
Q-Learning	Quality Learning
HTML	Hyper Text Markup Language
CSS	Cascading Style Sheet
DMO	Direct Mode Operation.

Chapter-1

Introduction

1.1 Wireless Communication

Since Guglielmo Marconi first revealed radio's capacity to maintain continuous communication with ships navigating the English Channel in 1895, effective communication with individuals on the go has advanced dramatically. People worldwide have embraced new wireless communications technologies and services since they were first introduced in 1897, and the trend has continued to this day[1].

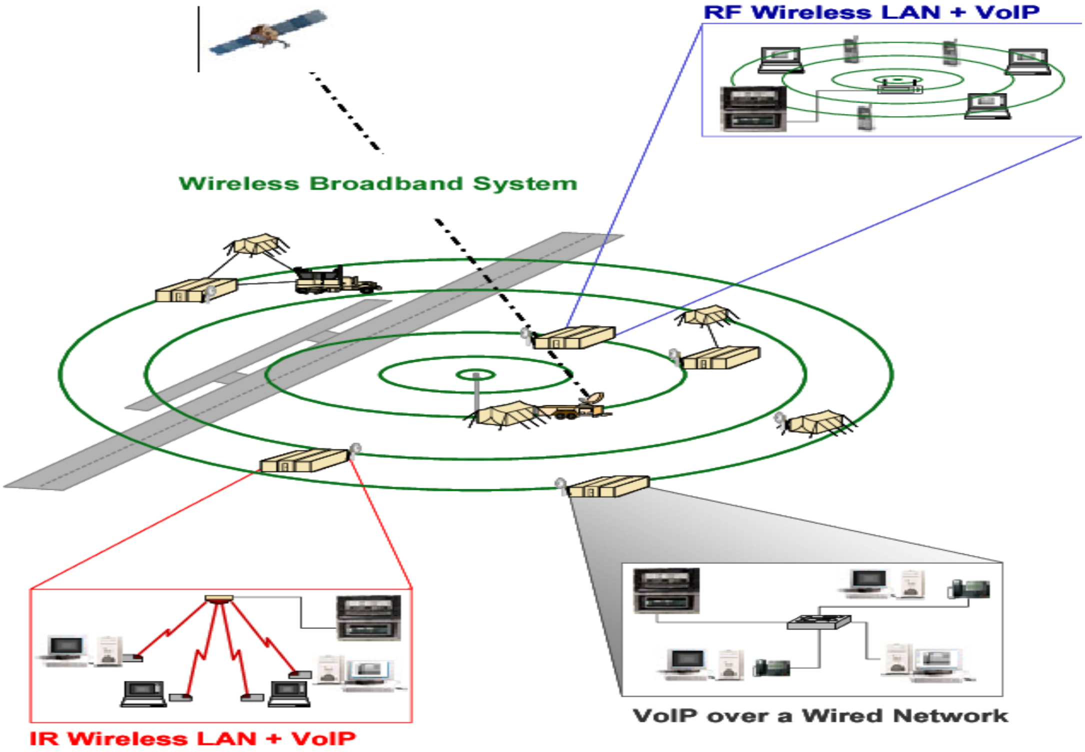


Figure 1.1 Wireless communication Scenario [2]

The mobile radio communications industry has grown exponentially over the last decade, fuelled by digital and RF circuit fabrication advancements [1]. Newly developed circuit assimilation and other micro-machining technologies have resulted in relatively small, more cost-effective, and more reliable portable radio equipment. Digital switching techniques have made it possible to construct radio communication networks on a wide scale that are both inexpensive and simple to use. Over the coming decade, these trends are expected to accelerate much more rapidly than they now are.

Wireless communication is one of the most rapidly expanding and dynamic technology fields in the communication sector. It is also the most demanding. Wireless communication is the way to transfers information from one location to another without wires, cables, or any other physical media to link the two locations.

Information is typically transferred from the transmitter to receiver in a communication process located at a fixed distance from the transmitter. When using wireless communication, the sender and receiver can be found anywhere between a few meters (such as a television remote control) to several thousand kilometers (such as a satellite dish) (Satellite Communication).

1.2 Background of 5G

The communication network of the future generation is over rapid data speeds and higher capacity. Humans and billions of intelligent machines must communicate in a smooth and real-time manner to survive. 5G wireless technology is promising a world of wealth, reliability, and connectivity.

Mobile devices are exploding in popularity due to the fast growth of wireless technology. On a global scale, it has been claimed that there are over 290 million mobile phone users in the Americas, with an estimated total of over 6.5 billion mobile phone users worldwide. The widespread use of smart gadgets has resulted in an exponential increase in demand for digital wireless communication services. Consequently, the issue of a scarcity of frequency resources is brought to the public's attention. Although new technologies like tiny cells and high-order modulation can enhance frequency efficiency to a certain amount, they can still not meet the required levels. Known as the fifth-generation communication system (5G), it is a relatively new technology that has gained popularity in recent years because it improves data speed, ultra-reliable low latency, energy efficiency, and colossal machine type connection.[3] Additionally, 5G wireless communication is designed for specific mobile devices such as smartphones and laptops and includes Device to Device (D2D) communication capabilities.[3]

1.3 5G technology

Because of introducing new technologies, consumers and business people went to more opportunities in the latest technologies, which have to be faster and fulfill several services.

The revolution of the fifth-generation network will co-operate in the primary sector, such as – education, healthcare, smart device, transportation, and smart homes. [4][5]

The first set of 5G standards, known as Release 15, was delivered in December 2017, marking a significant step forward on the road to the deployment of the next generation. There are still many advancements that must be made to meet all of the requirements for the future generation. Following Release 16, the 3rd Generation Partnership Project (3GPP) anticipates that commercial deployment of a 5G mobile network will commence in 2019 - 2020. [6]

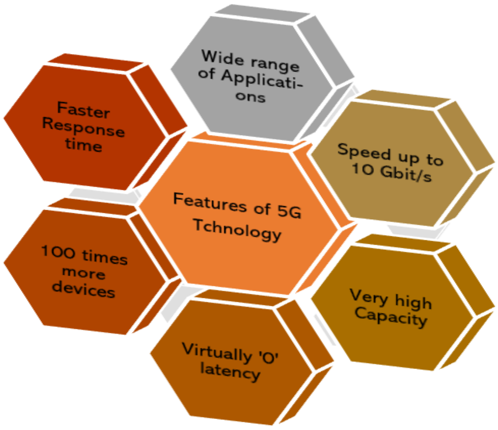


Figure 1.2 Features of 5G Technology

1.4 5G New Radio (NR)

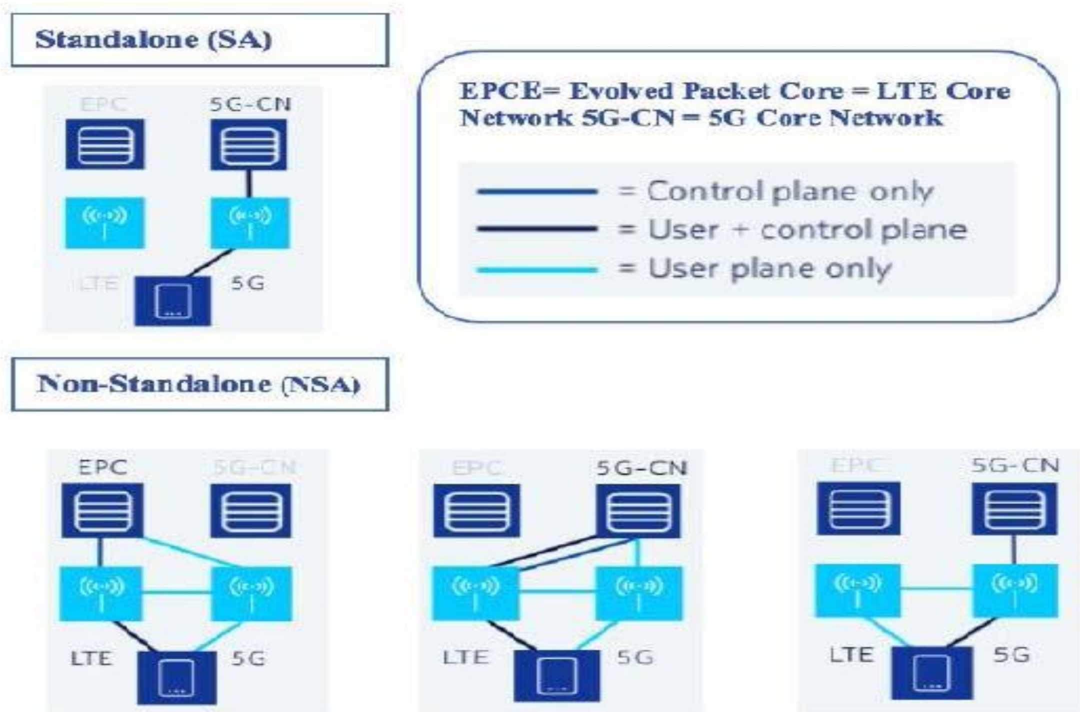


Figure 1.3 SA and NSA of 5G NR Operations [7]

The first steps toward achieving 5G will be made possible through LTE, LTE-Advanced, and LTE-Pro technologies. Following that, a substantial step-up will be implemented by introducing a new air interface (5G NR).[5] The Non-Standalone 5G NR (NSA) release, validated in December 2017, uses the existing LTE radio and core network infrastructure. The standalone 5G NR (SA) mode was initially scheduled to be completed by September 2018, but it was completed earlier than expected, in June 2018. The new 5G core network architecture implies complete user and control plane functionality.

1.5 Resource Allocation

The stream of data that can be retrieved at the receiver in a wireless communication system is controlled by the available resources and the resource allocation methods used at the transmitter. Different techniques for resource allocation result in a wide range of system performance.[8] An efficient resource allocation method efficiently distributes precious resources among receivers, maximizing limited resources and achieving the most significant system performance.

Allocating resources in the spectrum entails allocating time, space, and frequency domains. It is categorized as TDMA, FDMA, CDMA, and SDMA according to the method. All recommendations in wireless communication systems are considered for allocating resources. Additionally, a data file belonging to a single user/system can be assigned or dispersed to many users.

The Resource Allocation(RA) Type property describes how the scheduler distributes resource blocks for each session. Resource Allocation Type defines a method for allocating resources in the frequency domain. Simply in terms of flexibility, the optimal technique for allocating resource blocks would be to employ a string containing a bit map (bit-stream), with each bit representing a resource block.

The concept to prepare an app's interface to make the teaching-learning environment conformity is not yet done and addressed in any literature above for telecommunication switching.

1.6 CQI

The feedback of the channel quality indicator (CQI) in a long-term evolution (LTE) system is critical for expressing the instantaneous channel status information in the system.[9] The precision of the channel estimate procedure is crucial to the accuracy of the CQI calculations, which are used to assign the proper modulation and coding scheme.

CQI is commonly utilized to select the most appropriate MCS for the present channel circumstances and calculate priority metrics for packet scheduling algorithms. Measurement of SINR, injection of measurement error into SINR, the transformation of SINR values to discrete CQI steps, and finally, CQI reporting according to a given scheme are the four essential phases of the CQI measurement system.[10]

1.7 UI/UX Interface

It is an online and mobile applications user experience (UX) design tool based on vectors. It creates every interface of the application to show the visual of the whole process. It connects those interfaces by creating wireframes that leap in logic and expose any flaws to see the project from usability. Visualizations, layouts, and UI designs mixed with the user experience in real-time, allowing the user to replicate the flow.

Figure 1.4 Procedure for designing UI/UX interface

1.9 Fuzzy Logic Interface

Lotfi A. Zadeh was the first to propose Fuzzy Logic (FL), a logic representing uncertain and imperfect knowledge. The FL concept has been chiefly used in nonlinear systems to describe their performances. To handle complicated issues effectively, FL is employed, rather than true or false, to express their outcomes in the form of a range. Combining objects into a fuzzy set is conceivable, and each component of the fuzzy set is defined by a fuzzy membership function with an upper and lower bound of 0 to 1.

[11]. Due to the fuzzy character of fuzzy-based rules contributes to the handling and representation of nonlinear systems[12,13]. The four primary modules of FL's rule-based architecture are fuzzification, inference engine, rule base, and defuzzification. FL's rule-based architecture is composed of a rule-based architecture and four core modules. [14].

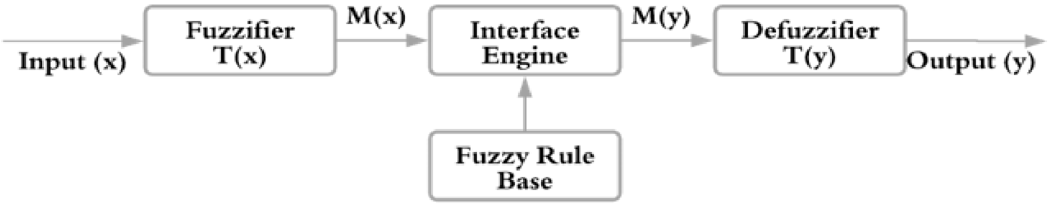


Figure 1.5 Fuzzy Logic Control System

From figure 1.5, the fuzzifier convert an input $\boldsymbol{x_i}$ of fuzzy set $\boldsymbol{F_x^k}$ with a degree of membership function $M_{x_i}^{k_i} i = 1 \dots \dots \dots m$. The fuzzy rule base stores control information of domain that specifies Fuzzy IF-THEN rule for a set of linguistic statements, which define an FL based association between *m*-dimensional input $\boldsymbol{x_i}$ and *n*-dimensional output $\boldsymbol{y_i}$. When the fuzzification process is complete, the inference engine creates a decision parameter for deriving the values of the input language variable from the fuzzification process to acquire the output language variable F(xi), namely fuzzy IF-THEN rules[14]. When the defuzzifier has access to the output linguistic variable of F(yi), the defuzzification function creates non-fuzzy values from the output yi. The fuzzy logic controller incorporates domain-specific knowledge gleaned from previously established systems [14].

1.10 Motivation and Goal

1.10.1 Motivation

Today, cellular phone systems are now on their fifth generation (5G), although the fifth generation (5G) and the Beyond fifth-generation (B5G) communication network are still being developed. To achieve at least a 1,000-fold increase in capacity while decreasing energy consumption by many orders of magnitude and boosting spectral efficiency (SE) by ten times for 5G and beyond 5G (B5G) networks, designing efficient communications infrastructure represents a significant challenge. It is possible to take various methods in these areas, including efficient resource allocation schemes, improved data compression algorithms, and channel coding systems. This thesis will concentrate on studying resource allocation optimization because of the complexity and difficulty of addressing all approaches[15]

1.10.2 Goal

Regardless of the users' mobility and location, future Wireless Communication Systems will deliver high data rates to facilitate personal and multimedia conversations. Voice, file transfer, online browsing, wireless multimedia, voice over internet protocol, and interactive gaming are examples of the varied types of traffic supported by heterogeneous services. During the last several years, information and multimedia services have risen in importance in wireless communications networks. Consequently, the demand for bandwidth and the number of users becomes complex issues to deal with. It is critical to deploy limited resources as effectively as possible to handle the high data rate requirements of the future wireless communication system. The dynamic nature of the wireless channel, limited resources like power and frequency spectrum, and a wide range of Quality of Service (QoS) needs are the most significant obstacles to overcome.

1.11 Objective

The primary purpose of this thesis is to allocate proper resources for users based on the CQI index.

1. To propose an effective resource allocation technique for 5G technology with reduced complexity.
2. To utilize different SINR values to obtain the CQI values for each user to allocate proper resources, significantly improving the system performance.

1.12 Thesis Outline

This thesis book is divided into the following sections:

Chapter -1: Introduction

- ❖ This chapter gives a theory-based overview of wireless communication, the background of 5G, 5G technology, 5G New Radio, Resource Allocation (RA), CQI, UI/UX interface, Fuzzy Logic Interface. Also, explain our motivation and goal for doing this research.

Chapter-2: Literature Review

- ❖ This chapter shows the overview of all papers that help us in doing this research.

Chapter-3: System Model

- In this chapter, we show our proposed model and its working principle. We develop a system model and flowchart of our research which we explain elaborately in this chapter.

Chapter-4: Simulation and Result

- This chapter shows the simulation process of our proposed system model and the result of our research. Also, discuss the limitation of our study.

Chapter-5: Conclusion and Future Work

- This chapter gives an overview of our research through conclusion. And also provides information about the scoops of further work on this research.

Chapter-2

Literature Review

2.1 Paper review

1. **Giambrone, Giovanni Ali Yahiya, Tara Conference: Wireless Days 2013 At Valencia, Spain**

Research paper on 'LTE Planning for Soft Frequency Reuse.'

For LTE Technology, this study developed an SFR technique (Soft Frequency Reuse) to estimate the radius of the cell-center region and the border-to-center power ratio, which maximized the cell capacity and cell planning. [16].

Table X: Characteristics of the Different Transmission Modes and SNR Thresholds for Different Channel Conditions with SISO

CQI	MCS	Modulation	Code Rate	Modulation Size	SINR [dB] AWGN	SINR [dB] Rayleigh
1	0	QPSK	78/1024	4	-5.45	1.95
2	2	QPSK	120/1024	4	-3.63	4
3	4	QPSK	193/1024	4	-1.81	6
4	6	QPSK	308/1024	4	0	8
5	8	QPSK	449/1024	4	1.81	10
6	10	QPSK	602 /1024	4	3.63	11.95
7	12	16QAM	378/1024	16	5.45	14.05
8	14	16QAM	490/1024	16	7.27	16.00
9	16	16QAM	616/1024	16	9.09	17.90
10	18	64QAM	466/1024	64	10.90	19.90
11	20	64QAM	567/1024	64	12.72	21.50
12	22	64QAM	666/1024	64	14.54	23.45
13	24	64QAM	772/1024	64	16.36	25
14	26	64QAM	873/1024	64	18.18	27.3
15	28	64QAM	948/1024	64	20	29

2. **Muntadher Qasim Abdulhasan Abdulhasan·MustafaIsmael Salman · (2015)**

Research paper on 'A Feedback Compression Scheme Based on Channel Quality Indicator (CQI) in Long Term Evolution (LTE) System Adaptive Threshold.'

To increase system performance in terms of throughput and error rate in the LTE system, an adaptive threshold feedback compression technique based on the CQI scheme was designed and applied in the LTE system[17].

3. **Xian Liu (2016-IEEE Conference)**

Research paper on 'Solving the Nonlinear LTE Resource Allocation Problem with a linear Approach.'

Model implementation, numerical analysis, and performance are all hampered as a result of these limitations. They have proposed a theoretical model called LIP (Linear Integer Programming) to handle the nonlinear LTE resource allocation problem. In this study, they build an analogous linear model which is comparable to the original model[18].

4. **Tan-Hsu Tan, Bor - A Chen, Yung-Fa Huang. (2017)**

Research paper on 'Performance of Resource Allocation in Device-to-Device Communication Systems Based on Evolutionally Optimization Algorithms'

They have refined the PSO (Resource allocation in the D2D system). They suggested a refined PSO algorithm and a noble Genetic algorithm to increase user equipment's throughput and improve the system capacity theorem. They proposed an advanced PSO method and a noble Genetic algorithm to optimize the system capacity theorem.[16]

5. **Anum Ali, Ghalib A.Shah & Junaid Arshad (2019)**

Research paper on "Energy-Efficient Resource Allocation for M2M devices in 5G."

The research was conducted into the issue of resource allocation for small conserving M2M devices operating on the 5G network, and an algorithm was devised that allotted resource blocks according to the Quality of Service indicator.[19]

6. **Ammar Bathich, Mohd Asri Mansor, Saiful Izwan Suliman, Sinan Ghassan Abid Ali (2020)**

Research paper on "Q-learning vertical handover scheme in two-tier LTE-A networks."

An effective handover decision mechanism based on users' profiles is developed and implemented in LTE-A macrocell-femtocell networks using the Q-learning technique, based on the Q-learning approach [20].

7. **Steffi Jayakumar & Nandakumar (Journal-2020)**

Research paper on 'A review on resource allocation techniques in D2D communication in 5G & beyond 5G technologies'

As discussed in this paper, D2D faces many practical issues and constraints, the most notable of which is resource allocation, which substantially impacts overall efficiency. Several resource allocation algorithms and techniques have been thoroughly examined and evaluated in this work, depending on the degree of Base Station participation. This work aims to identify a research gap and provide a solid theoretical foundation for resource allocation problems in D2D communication systems[21].

8. **Rickson S. Pereira 1 , Douglas D. Lieira 1 , Marco A. C. da Silva 2 (Journal-2020)**

Research paper on 'Resource Allocation mechanism for 5G Network using Mobile Edge Computing.'

A resource allocation and management mechanism for the 5G network was proposed, which uses mobile edge computing (MEC) and basic mathematical approaches to reduce model complexity while increasing efficiency. The procedure determines how much MEC resource to distribute to meet the users' needs [22].

9. **Xinjian Cao & Rui Wang (2016)**

Research paper on 'An optimal Traffic Control Algorithm for 4G LTE System.'

Developed a cooperative LTE wireless communication network model utilizing Lagrangian relaxation and sub-gradient approaches with other researchers. They claimed that the Optimal algorithm achieves more significant improvements than other primal heuristics, indicating the efficiency of the Lagrangean method[23].

10. Tan-Hsu Tan, Bor - A Chen, Yung-Fa Huang. (IEEE Confrence-2017)

Research paper on 'Performance of Resource Allocation in Device-to-Device Communication Systems Based on Evolutionally Optimization Algorithms'

To optimize resource allocation in the D2D system, a refined PSO (RPSO) algorithm has been developed. To improve the throughput of user equipment while also improving the system capacity theorem, they suggested a revised PSO algorithm and a noble Genetic algorithm (NGA)[24].

11. Sergey N. Moiseev, Stanislav A. Filin, Yun Sang Park, (2006)

Research paper on 'Practical Propagation Channel Robust BLER Estimation in the OFDM/TDMA and OFDMA Broadband Wireless Access Networks'

Developed a viable, robust algorithm for estimating the block error rate in orthogonal frequency division multiplexing networks using time division multiple access and orthogonal frequency division multiple access[25].

12. Muhammad Basit Shahab, Muhammad Arif Wahla ,Muhammad Tahir Mushtaq (IEEE-2015)

Research paper on 'Downlink Resource Scheduling Technique for Maximized Throughput with Improved Fairness and Reduced BLER in LTE.'

Their downlink resource scheduling technique is designed to maximize throughput while minimizing the block error ratio and promoting fairness among different users within the cellular region. For all users to receive an equitable portion of the resources they have paid for, fairness must be maintained. In addition, because the BLER is so high, a reduction in BLER is an essential consideration because more packets will be missed, and retransmission will be necessary, ultimately reducing throughput[26].

13. Xian Liu (IEEE-2016)

Research paper on 'Solving the Nonlinear LTE Resource Allocation Problem with a linear Approach.'

Model implementation, numerical analysis, and performance are all hampered as a result of these limitations. They have proposed a theoretical model called LIP (Linear Integer Programming) to handle the nonlinear LTE resource allocation problem. In this study, they build an analogous linear model comparable to the original model[27].

14. Suk-Bok Lee, Ioannis Pefkianakis, Songwu Lu (IEEE Conference-2009)

Research paper on 'Proportional Fair Frequency-Domain Packet scheduling for 3GPP LTE Uplink'

The underlying problem of LTE SC-FDMA uplink scheduling was discovered, as was the need for a time-domain PF algorithm to optimize its objectives (Proportional Fair) in a frequency-domain situation, and this was accomplished. They demonstrate that competitive performance in system throughput and fairness may be attained through a 3GPP LTE system model simulation, which was tested[28].

15. Yun Li, Xin Chen,Weiliang Zhao. (IEEE Conference-2012)

Research paper on 'Packet scheduling with QoS Support in LTE Downlink MIMO system.'

This paper describes how to pick the MIMO mode for SU-MIMO while taking the QoS requirements in the 3GPP LTE downlink into consideration and how to design an algorithm to improve the QoS needs in the 3GPP LTE downlink. QoS-DMO is the name of the algorithm. For RT and NRT services, the QoS-DMO method is developed, which seeks to satisfy the user QoS needs while also guaranteeing system throughput in the most efficient manner. It is successful in achieving time-frequency spatial scheduling for the system resources and other tasks[29].

16. Niko Kolehmainen, Jani Puttonen,Petteri Kela ,Tapani Ristaniemi (2008)

Research paper on 'Channel Quality Indication Reporting Schemes for UTRAN Long Term Evolution Downlink.'

Evaluates the performance of channel quality indicator reporting schemes and parameters on the overall system of the 3GPP UTRAN long-term evolution downlink. Also analyzed the various CQI reporting schemes based on performance and signaling overhead[30]

17. Fouziya Sulthana, R. Nakkeeran ()

Research paper on 'Performance Analysis of Service Based Scheduler in LTE OFDMA System.'

Develops an algorithm for resource scheduling approach named Service-Based Schedular (SBS). And mainly focuses on two parameters: maximum tag value and minimum ta deal, where leading tag value work on real-time services and minimum tag value work on non-real-time services[31].

18. Author1, Author2, Author3, Author4 ()

Research paper on 'Self-Optimization algorithm for outer look link adaptation in LTE'

Developed an Outer Look Link Adaptation (OLLA) based self-optimization algorithm for LTE downlink. And the goal is to increase the average radio link efficiency with user throughput. Also, decrease the overall BLER[32].

19. Fengyuan Ren and Yinsheng Xu, Hongkun Yang, Jiao Zhang, Chuang Lin, (2013)

Research paper on 'Frequency-Domain Packet Scheduling with Stability Analysis for 3GPP LTE Uplink'

Investigate the frequency domain packet scheduling problem in 3GPP LTE Uplink. And develop two algorithms to overcome those problems. 1^{st} algorithm based on simple greedy method and 2^{nd} algorithm based on Local-Ratio technique. And they also investigate the efficiency of the L-R algorithm.[33]

20. Hussam Ahmed, Krishna Jagannathan, Srikrishna Bhashyam ()

Research paper on 'Queue-Aware Optimal Resource Allocation for the LTE Downlink.'

We developed a policy for allocating sun-bands in the LTE downlink, called Queue-Aware policy. Mainly this policy is for the User Equipment (UE) resource block[34].

21. Rajendra k. Jain, Dah-ming W. Chiu, Willian R. Hawe ()

Research paper on 'A qualitative measure of fairness and discrimination for Resource Allocation in a shared computer system.'

Introduced a quantitative measure called an index of fairness. The index I applicable to any resource sharing or allocation problem. The critical contribution of this paper is to break down the problem of fairness in 2 parts selection approximate allocation metric and quantization of equality.[35]

22. Ali Darejeh & Dalbir Singh (Journal-2013)

Research paper on 'A review on user interface design principles to increase software usability for users with less computer literacy.'

This paper described how software usability for those with minimal computer literacy could be enhanced. By recognizing the similar issues faced by this group of users, it is possible to distinguish between different groups of people's levels of computer literacy. User interface design ideas such as (a) limiting the number of features available at any given time, (b) avoiding the usage of computer jargon, (c) permitting font, color, and size modification, and (d) including relevant graphical objects such as avatars or icons were extracted from these parallels [36].

23. M. Seraj and Chui Yin Wong (Conference-2012)

Research paper on 'A study of User Interface Design principles and requirements for developing a Mobile learning prototype.'

Using a mobile smartphone as a learning tool, this paper offers the results of an investigation into User Interface Design (UID) ideas and criteria. Techniques for designing and building a mobile learning prototype compatible with tiny screen interfaces and limited capabilities of mobile devices are proposed to ensure that learners can comprehend the ideas of a mobile learning prototype. These techniques are designed to provide that learners can understand the concepts of a mobile learning prototype. Also emphasized is the ARCS learning design strategy, which is well-suited for use in a mobile-based learning software like this one[37].

24. D Dharmayanti, A.M Bachtiar & A P Wibawa(2018)

Research paper on 'Analysis of User Interface and User Experience on Comrades Application.'

Examine the Comrades application's user interface and user experience to determine the user's purpose via design. The goal-directed design technique is used in the interface's creation stage, and the user experience is then analyzed using user flows to explain the difficulties that users encounter. Based on these concerns, an experience map will be created to show ideas for improving the user experience.[38]

25. Sanjeev Kumar & Krishan Kumar (2019)

Research paper on 'Neuro-Fuzzy based Call Admission Control for next Generation Mobile Multimedia Networks'

The goal is to construct an efficient computational model for traffic control and fair radio resource allocation for new calls and handoff calls. New calls and handoff calls are controlled using a neural fuzzy call admission control (CAC) scheme that is a hybrid technique that combines the semantic rule ability of fuzzy logic (FL) controller with the self-training capability of a neural network (NN). The results of the simulations reveal that a neural fuzzy-based CAC can achieve the lowest call dropping probability and the highest resource utilization in high-speed networks when compared to fuzzy logic-based CAC, classic CAC, or current CAC schemes, among other advantages[39].

26. Mostafa Zaman Chowdhury and Yeong Min Jang (2012),

Research paper on 'Call Admission Control and Traffic Modeling for Integrated Macrocell/Femtocell Networks'

For integrated macrocell/femtocell networks, proposed a call admission control method and a traffic model in this study. The numerical and simulation findings demonstrate the significance of the integrated macrocell/femtocell network and the proposed schemes' improved performance.[40]

27. Majid Ghaderi and Raouf Boutaba (Journal-2006)

Research paper on 'Call Admission Control in Mobile Cellular Networks: A Comprehensive Survey.'

Overview of cellular network admission control techniques and related research. They go over specific modeling and analytical fundamentals to better understand the performance and efficiency of cellular network admission control systems. They compare the performance and complexity of different admission control methods. These methods are all characterized by handoff priority. They look at several methods for accomplishing handoff priority, with a focus on reservation systems. In addition, the authors offer and analyze optimum and near-optimal reservation systems. Also included were multi-service networks and hierarchical systems and full knowledge schemes and call admission control utilizing price.[41

Chapter – 3

System Model

3.1 Proposed Model of Research Flow

In this research, we represent the resource allocation technique based on the CQI index. When any user sends a request for attending a call, we will figure out the channel condition of the call through SINR. Then we will check the CQI condition of the demanding call by SINR. And the states of the call will the estimate through mapping its discrete value, which we consider as the CQI INDEX.

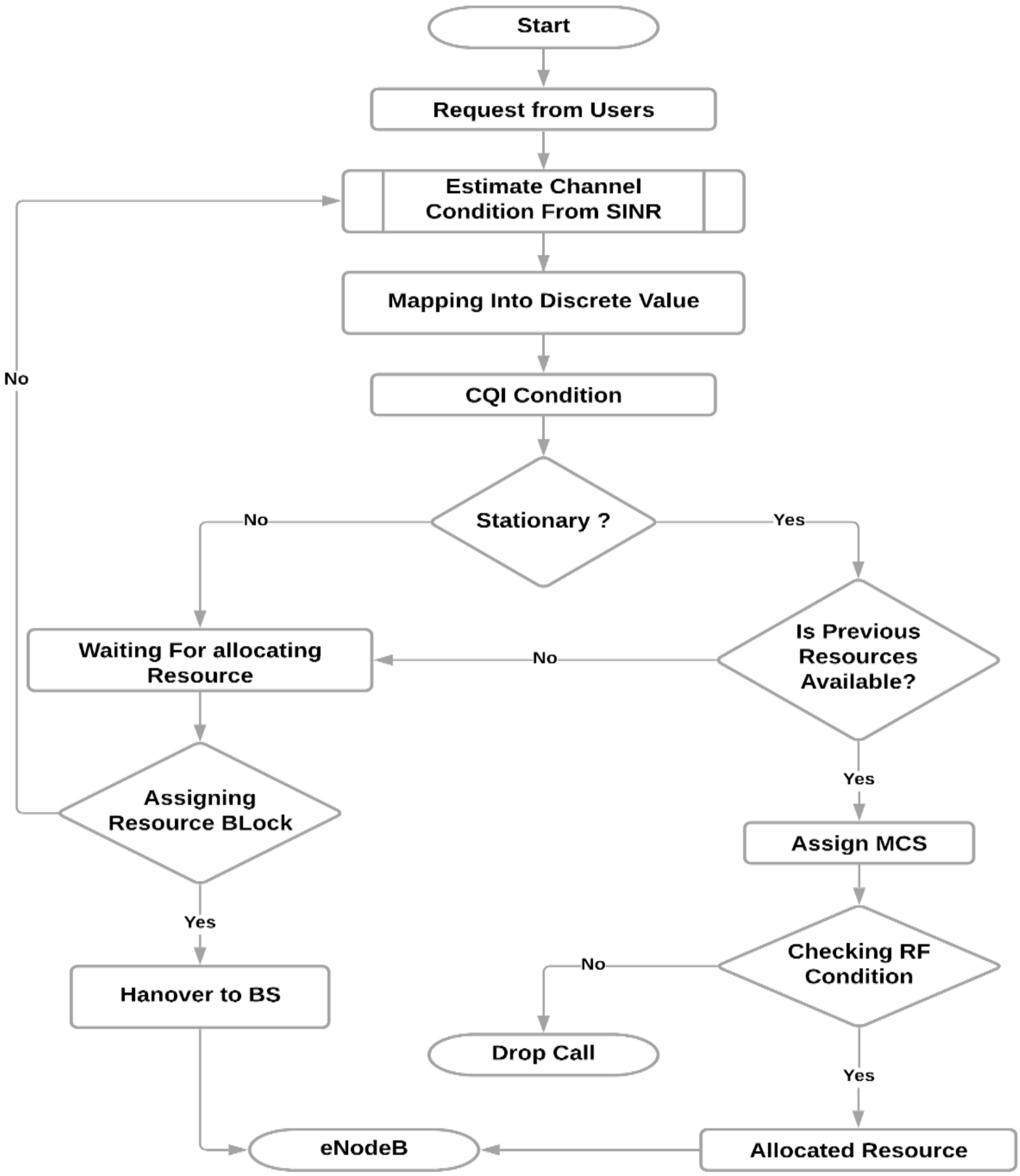


Figure 3.1 Flowchart of Proposed System Model

After that, we check the state of the call based on the CQI Index. Like- is the user either in stationary condition or in dynamic condition?? If the user is in a stationary condition, then check if previous resources are available or not. If the resources are available, then assign the User as MCS. After that, we will review the RF condition of the user. For figuring out the condition of the call, either Good or Middle or cell edge. If the call maintained Good or Middle condition, then allocated the resources and forwarded it to the next step through eNode B.

Otherwise, if the user is not in Stationary condition, then will wait until the allocation of the resources block. If the resource block remains empty, then we will assign it to the user. After that, the proposed system will be sent to the eNode B in the next step. If the resource block is not empty, we will send it back to the user to check the SINR value.

3.2 Measurement of CQI

It is commonly utilized in selecting the appropriate MCS for the present channel circumstances and computing priority metrics for packet scheduling algorithms, among other things. The CQI measurement model in the simulator is based on four fundamental phases: measuring SINR, injecting measurement error into SINR, transforming SINR values to discrete CQI steps, and lastly, CQI reporting according to a specified scheme, among others. The ideal linear SINR is computed for each (RB) m based on the received power and total interference at the end of each measurement period. (RB) *m* is represented in decibels by the linear SINR value recorded for each (RB) *m* [42].

$$SINR_{(dB)}(m) = 10 * log_{10}[SINR_{lin}(m)] + Error_{(dB)} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

$Error_{(dB)}$ Represent Gaussian distributed error with a zero mean and defined variance incorporated into the measured ideal SINR. Quantization steps are often used to transform SINR data into discrete CQI values $StepQ_{(dB)}$:

$$CQI_{(dB)} = StepQ_{(dB)} * ground\left(0.5 + \frac{SINR_{(dB)}}{StepQ_{(dB)}}\right) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2)$$

CQI is calculated in the simulator at parameterized time intervals equal to the length of a Transmission Time Interval's multiplier (TTI). CQI parameters are listed sequentially and following a CQI reporting technique. While the entire system reports CQI for a specified number of consecutive RBs, compressive methods rely on more sophisticated reporting techniques. The primary reporting scheme's granularity can be modified by modifying the amount of CQI reports per TTI. Individual CQI values for all RBs are measured and reported for complete feedback reporting. Wideband CQI provides the least granularity, as it is an average value derived across all RBs.[43]

3.3 Measurement of SINR

The UE determines the signal-to-interface plus noise ratio (SINR) using the Resource Block (RB) in which the signal is received. The SINR value indicates the MCS for an RB, the number of bits per modulation symbol to be supplied, or the throughput for that particular RB[44]. When the UE calculates the SINR on each RB, transforms it to CQI, and reports it to the eNodeB, the CQI is used to determine the optimal MCS for user data transmission in that RB. eNodeB assigns RBs to users based on their SINR value.

In CRS resource elements, *signal power (S)* is divided by the total *interference and noise (I+N),* expressed as SINR. SINR is a measure of signal strength.

$$SINR_{(dB)} = \frac{S}{N+I} \dots \dots \dots \dots \dots \dots \dots \dots (3)$$

3.4 Modulation and Coding Scheme (MCS)

Modulation and Coding Scheme (MCS) is a communication technique that determines the number of usable bits conveyed by a single symbol in any communication technology. In contrast to 5G or 4G, a symbol is defined as a Resource Element (RE), and the Maximum Capacity for Transmission (MCT) is defined as the maximum number of usable bits that may be sent per Resource Element (RE) [44]. A wireless link's MCS is determined by the quality of the radio signal being transmitted; better signal quality results in a higher MCS and the ability to send more valuable bits within a symbol, while poor signal quality results in a lower MCS and the inability to transmit as much useful data as possible within a symbol.

An MCS encapsulates the following two characteristics:

3.4.1 Modulation

Modulation specifies the maximum number of bits that may be conveyed by a single RE, regardless of whether they are usable or parity bits. 5G NR modulation formats include QPSK, 16 QAM, 64 QAM, and 256 QAM. With QPSK, two bits may be sent to each RE; with 16QAM, four bits can be carried per RE; with 64QAM, six bits can be broadcast per RE; and with 256QAM, eight bits can be forwarded every RE.

These modulation orders of 16, 64, and 256 are referred to as QAM modulation orders, and the number of bits for each modulation order may be determined using the following formula.

$Modulation\ order = 2^{n}$ … … … … … … … … … (4)

('n' is the number of bits)

$2^{4} = 16$

$2^{6} = 64$

$2^{8} = 256$

$2^{10} = 1024$

3.4.2 Code Rate

Physical layer's top: Additionally, it is a measurement of the physical layer's redundancy. The code rate is defined as the ratio of usable bits to total bits transmitted (Usable + Redundant Bits). This means that the number of information bits at the Physical layer's top is divided by PDSCH's number of bits at the Physical layer's bottom. These superfluous bits are provided to prevent the Forward Error Correction algorithm from being used (FEC). Increased redundancy is linked to a low rate of coding.

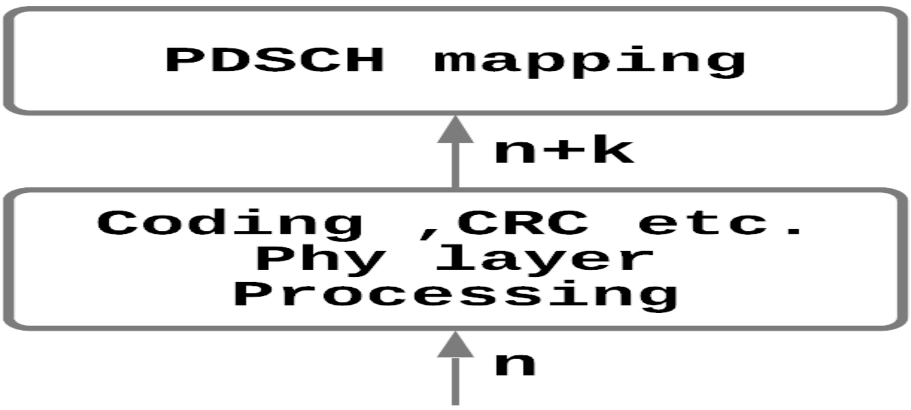


Figure 3.2: Workflow of Code Rate

$$Code\ Rate\ (R) = {}^{n}/_{n+k} \dots\dots\dots\dots\dots\dots\dots\dots\dots (5)$$

3.5 UI/UX Illustration By Adobe XD

The Adobe XD apps show better effectiveness and create a better user-friendly environment when using UI/UX design rather than programming. As we know, UI stands for user interface, and UX stands for user experience. So, we used UI/UX design to experience the best possible environment in a human-machine interface.

- ➢ It makes the system more reliable.
- ➢ Increase the tendency of any user to use the apps more.

Here, we have 2types of working processes -

1. Design
2. Prototype

In design, we have to design frame-by-frame. Each frame shows the numbers and activities of the user animatedly. The frames are processed as singular blocks. And, this process we can control in the prototype level, which aims at interconnect every frame. The animation of the Apps depends on how we have designed them in these two levels.

We have used UI/UX design to gain the users' best possible experience and satisfaction rather than programming. If we need the program/code of this interface, we could easily export the code from Anima. It will show the code of HTML, CSS, and Bootstrap.

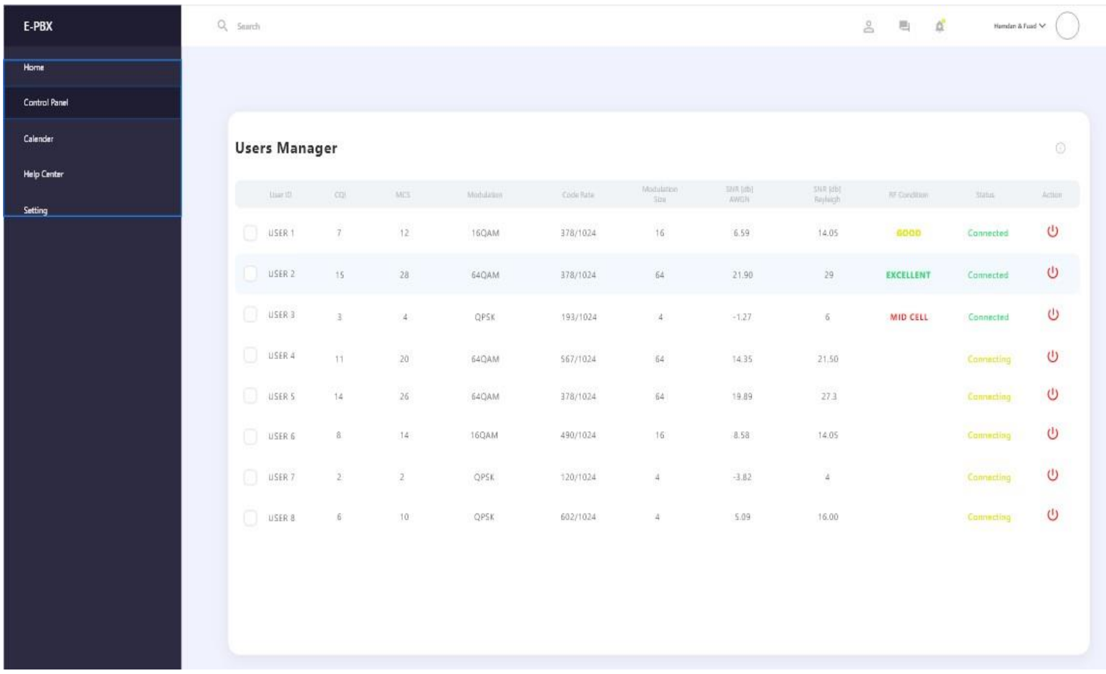


Figure 3.3 Layout of UI/UX based Proposed System Model

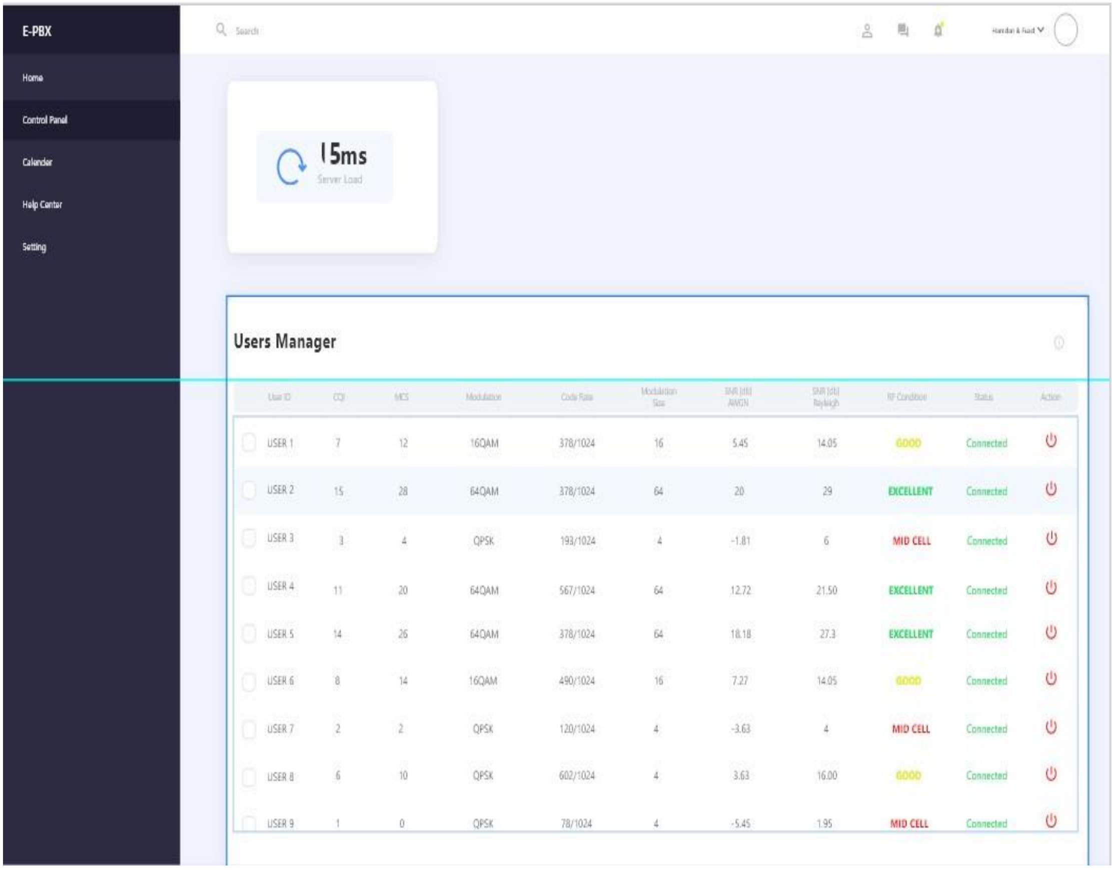


Figure 3.4: Assigning users requirements to make layout

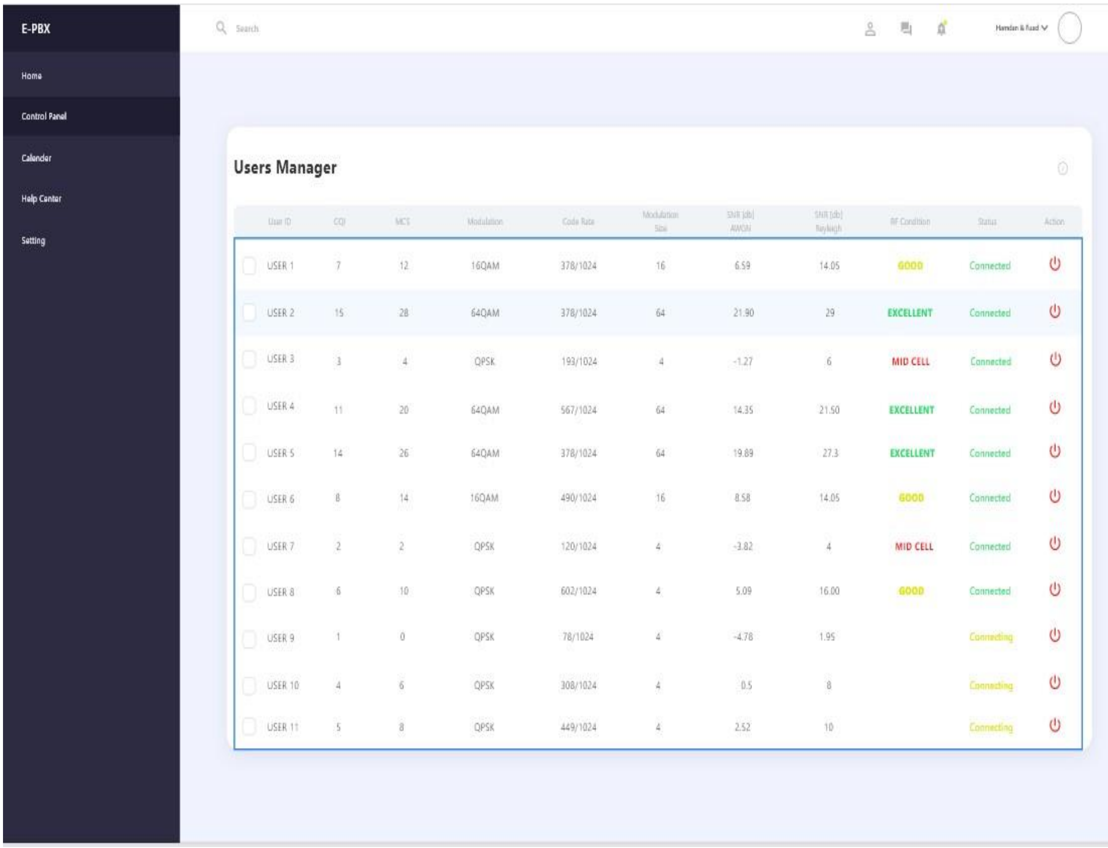


Figure 3.5: Estimating schedule for all users

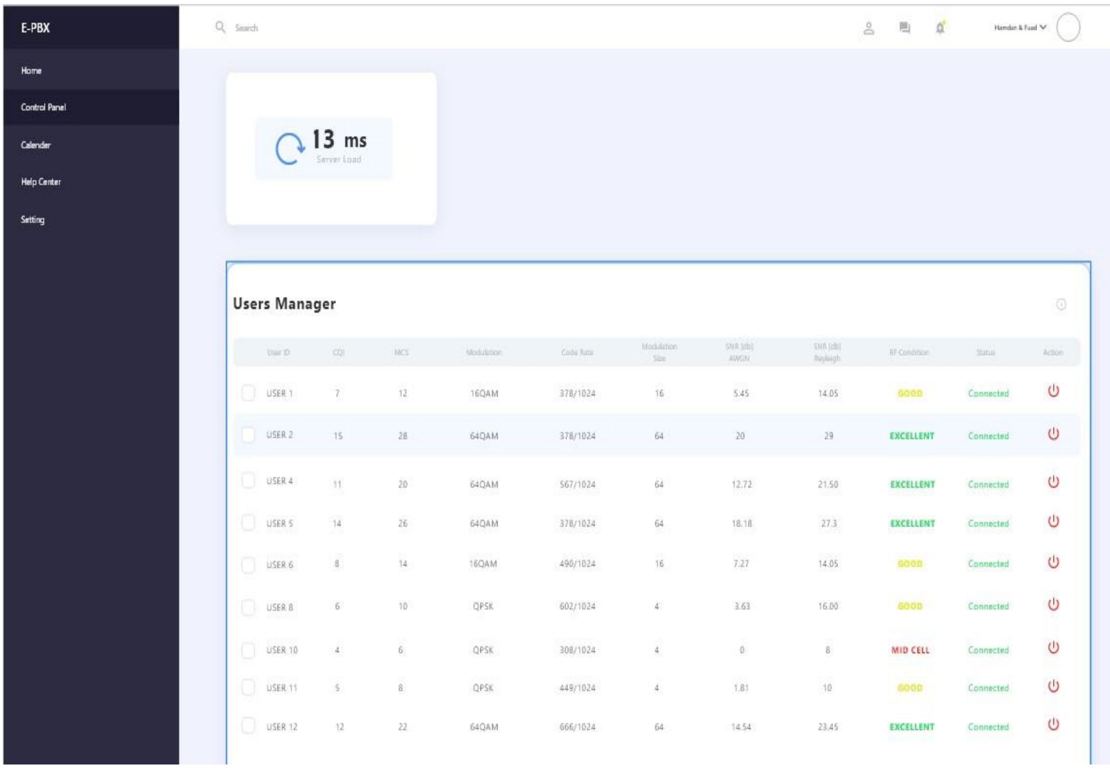


Figure 3.6: Rejecting Cell edge users

3.6 Proposed Fuzzy Logic Control Model

In figure 12 illustrates the Fuzzy Logic Control Interface with the Mamdani modification model.

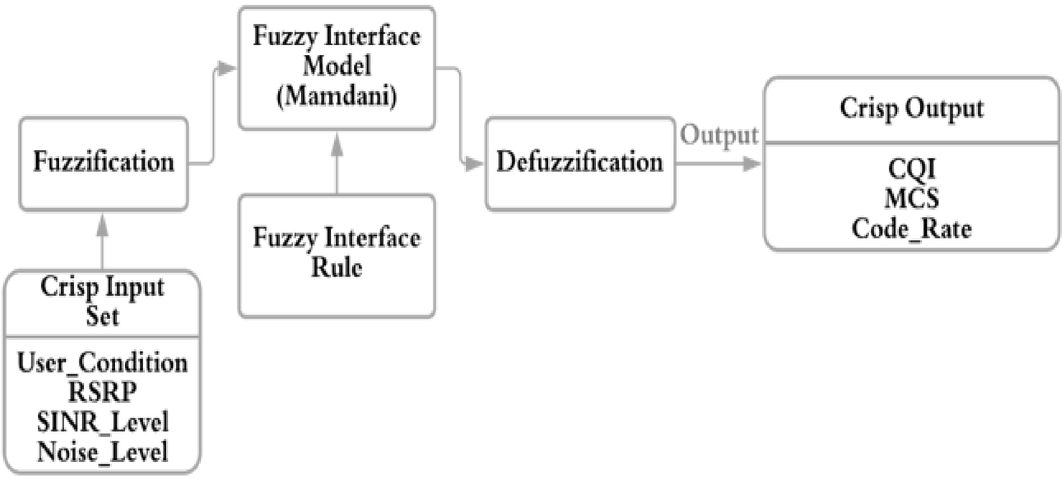


Figure 3.7: Block diagram of Fuzzy Logic Controller (Mamdani)

The FLC interface has four inputs as User Condition, RSRP Level, SINR Level, Noise Level. And have three outputs as CQI, MCS, Code Rate. This FL worked based on IF-THEN rules. Where IF condition used as inputs and THEN condition used as outputs. This FLC followed five-step to complete a task.

Step-1:

Crisp Input Set: This step takes variables as input. In our model, User Condition, RSRP Level, SINR Level, and Noise Level as inputs.

Step-2:

Fuzzification: The fuzzification is the way to convert the inputs of the fuzzy set with a degree of membership function.

Step-3:

Fuzzy Interface Model (Mamdani): When the fuzzification process is complete, the Mamdani interface model generates a decision parameter based on given fuzzy interface rules.

Step-4:

Defuzzification: In this step, the defuzzification function generates non-fuzzy values for outputs function based on decision parameter which already been completed in the previous step.

Step-5:

Crisp Output: Finally, this step gives the output parameters that help make the decision for designing logic. In our research, output parameters are CQI. MCS, Code rate.

Chapter-4

Result and Simulation

4.1 Proposed FLC Simulation Model

The figure illustrates the fuzzy logic controller using the Mamdani modification model associated with the inputs and outputs membership functions. Four parameters are set as input functions with three outputs variables. The FLC takes four inputs as User condition, RSRP level, SINR level, Noise level. It also takes three outputs as CQI, MCS, and code rate. Firstly, identify users' conditions using equation (6) to determine the slow, medium, and fast situations.

$$a(value) = \max\left(min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots (6)$$

In input-1 (User_Condition), input-2 (RSRP_Level), input-3(SINR_Level) input-4(Noise_Level) have fourteen membership functions.

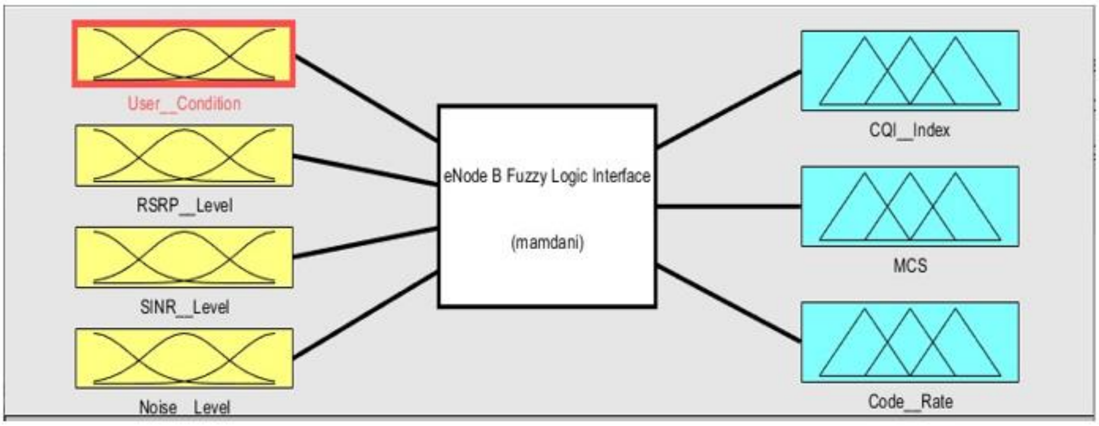


Figure 4.1: FLC Interface Model using Mamdani Modification

In figure 4.2 shown the membership function of User Condition, which are: Slow= S; Middle= M; Fast= F.

$$I_{User\_Condition} = \{S, M, F\}$$

Table 1: The membership function range of User Condition

Membership function	Lowest	Middle	Highest
Slow	0	0	0.33
Middle	0.33	0.45	0.63
Fast	0.63	1	1

In figure 4.3 showing the membership functions of the RSRP Level, which are: Very Low= VL, Low= L, Medium= M, High= H, Very High= VH.

$$I_{RSRP\_Level} = \{VL, L, M, H, VH\}$$

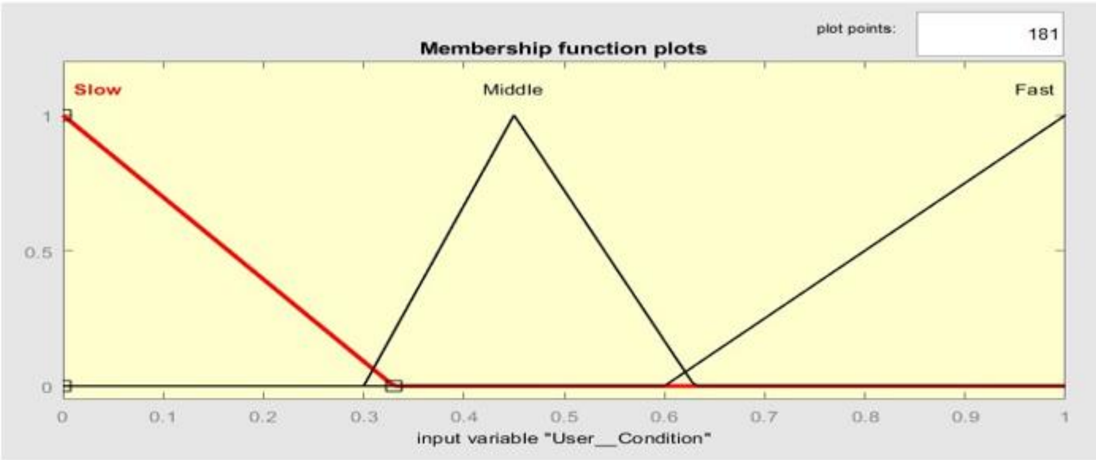


Figure 4.2: Input variable for User Condition.

Table 2: The membership function range of RSRP Level

Membership function	Lowest	Middle	Highest
Very Low	-0.2	-0.2	2.79
Low	2.79	5.22	7.65
Medium	7.65	11.33	15
High	15	16	17.3
Very High	17.3	24	24

In figure 4.4 showing the membership functions of the SINR Level, which are: Low= L, Medium= M, High= H.

$$I_{SINR\_Level} = \{L, M, H\}$$

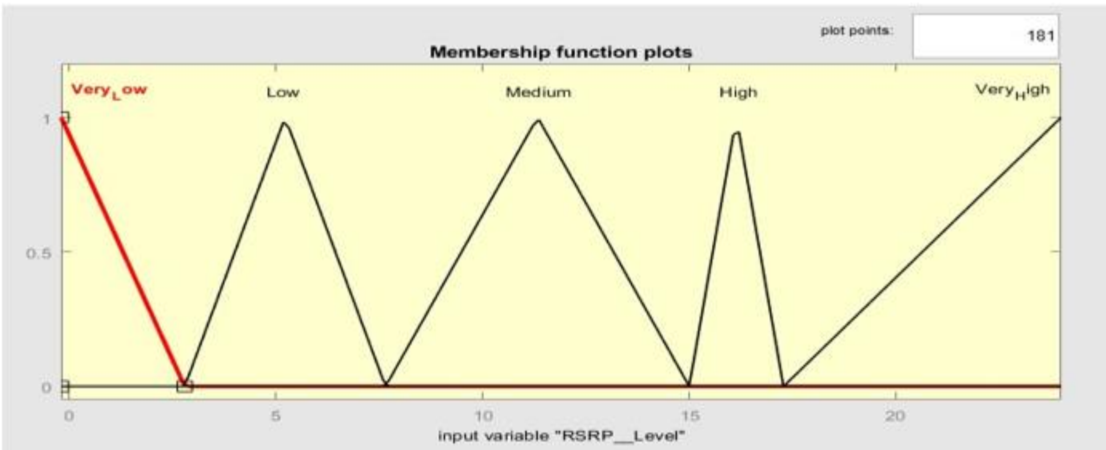


Figure 4.3: Input variable for RSRP Level

Table 3 The membership function range of SINR Level

Membership function	Lowest	Middle	Highest
Low	-4.28	-4.28	4.28
Medium	4.28	8.54	12.81
High	12.81	21	21

In figure 4.5 showing the membership functions of Noise Level: Low= L, Medium= M, High= H.

$$I_{Noise\_Level} = \{L, M, H\}$$

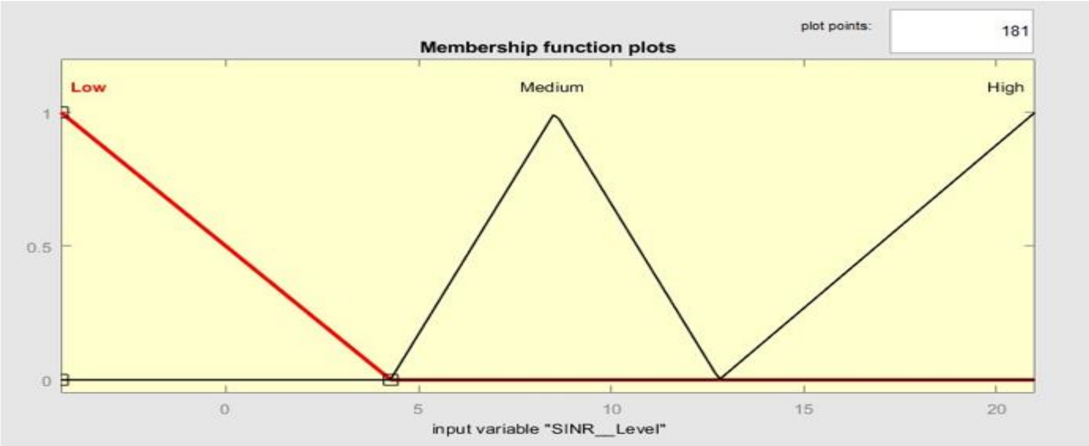


Figure 4.4: Input Variable for SINR Level

Table 4: The membership function range of Noise Level

Membership function	Lowest	Middle	Highest
Low	-11	-11	-6.577
Medium	-6.577	-4.365	-2.154
High	-2.154	2.27	2.27

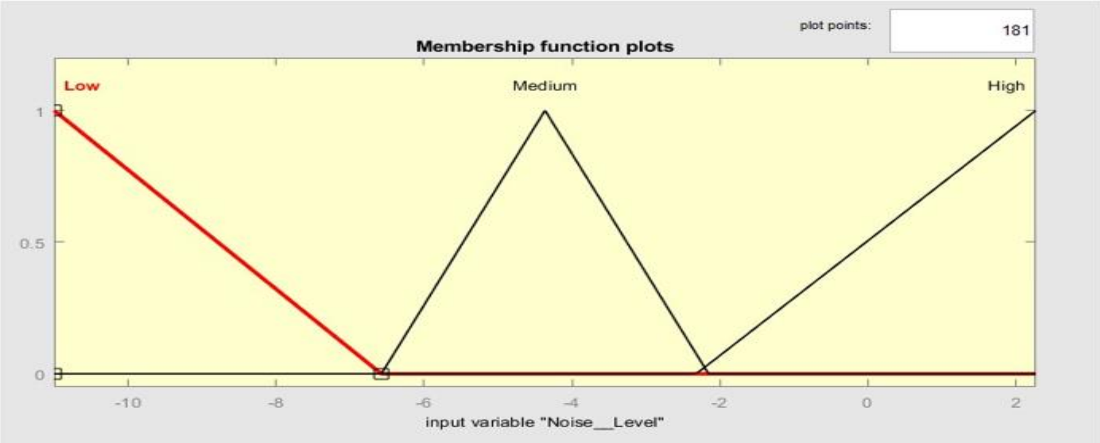


Figure 4.5: Input Variable for Noise Level

In output-1 (CQI Index), output-2 (MCS) and output-3 (Code Rate) have ten membership functions.

In figure 4.6 showing the membership function of the CQI Index, which are: Cell Edge= CE, Mid Cell= MC, Good= G, Excellent= E.

$$O_{CQI} = \{CE, MC, G, E\}$$

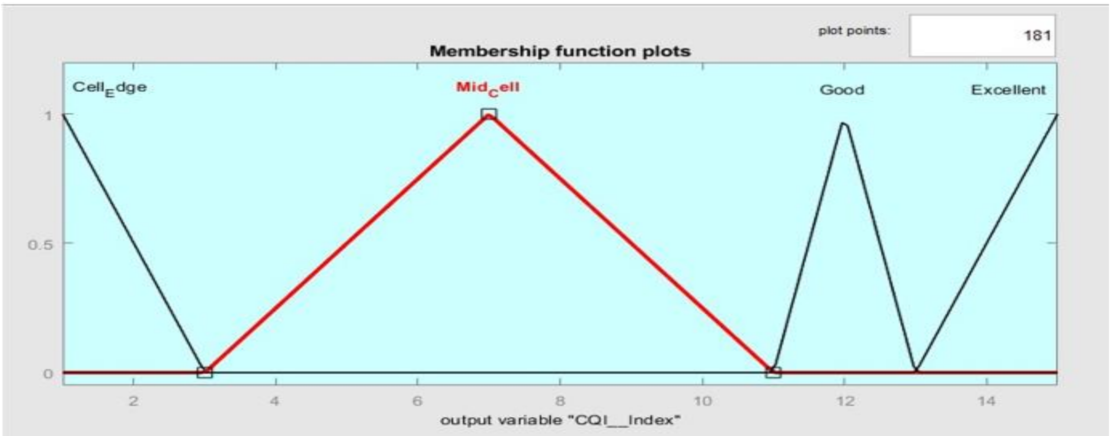


Figure 4.6: Output variable of CQI Index

Table 5: The membership function range of CQI Index

Membership function	Lowest	Middle	Highest
Cell Edge	1	1	3
Mid Cell	3	7	11
Good	11	12	13
Excellent	13	14	15

In figure 4.7 shown the membership function of MCS, which are: Level 1= L1, Level 2 = L2, Level 3= L3.

$$O_{MCS} = \{ L1, L2, L3\}$$

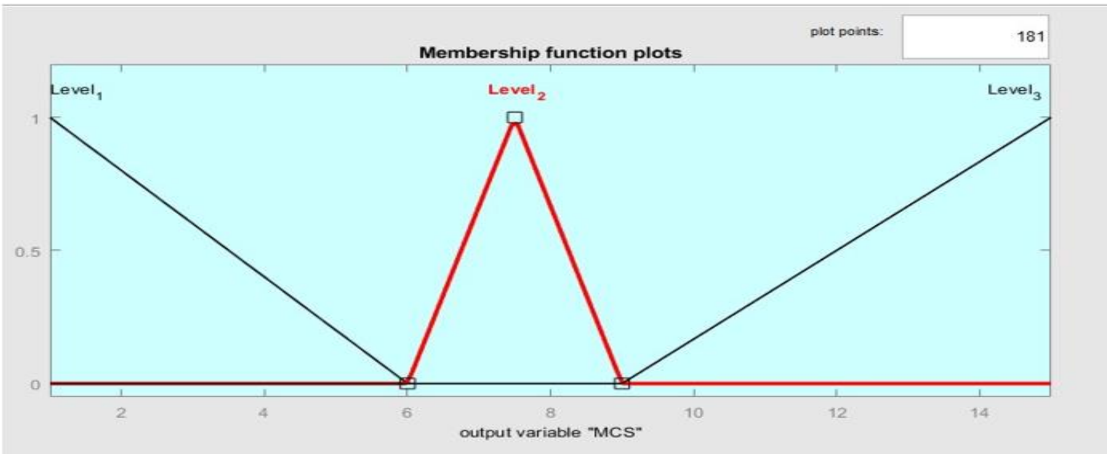


Figure 4.7: Output variable of MCS

Table 6: The membership function range of MCS

Membership function	Lowest	Middle	Highest
Level 1	1	1	6
Level 2	6	7.5	9
Level 3	9	15	15

In figure 4.8 showing the membership function of Code Rate, which are: Low= L, Medium= M, High= H.

$$O_{Code\_Rate} = \{ L, M, H \}$$

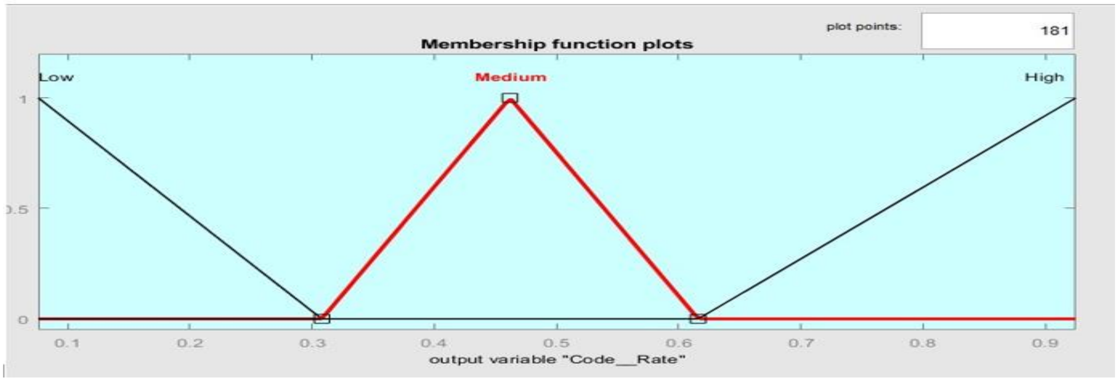


Figure 4.8: Output variable of Code Rate

Table 7: The membership function range of Code Rate

Membership function	Lowest	Middle	Highest
Low	0.076	0.076	0.308
Medium	0.308	0.462	0.616
High	0.616	0.925	0.925

We utilized four inputs in this simulation, which have different membership functions. Based on those input variables, we create 5*3*3*3 =135 fuzzy interface rules to generates outputs using IF and THEN statements. And, following FL interface rules were implemented for simulating the result.

1. If User Condition is Slow and RSRP Level is Very Low and SINR Level is Low and Noise Level is Low, then CQI Index is Cell Edge and MCS is Level_1 and Code Rate is Low.
2. If User Condition is Slow and RSRP Level is Medium and SINR Level is Medium and Noise Level is Low, then CQI Index is Mid Cell and MCS is Level_2 and Code Rate is Medium.

3. If User Condition is Slow and RSRP Level is Medium and SINR Level is Low and Noise Level is Low, then CQI Index is Mid Cell MCS is Level_1 Code Rate is Medium.
4. If User Condition is Slow and RSRP level is Very High and SINR Level is High and Noise Level is Low, then CQI Index is Good, MCS is Level_3, Code Rate is High.
5. If User Condition is Slow and RSRP Level is Medium and SINR Level is Low and Noise Level is Low, then CQI Index is Mid Cell, MCS is Level_1, Code Rate is Medium.
6. If User Condition is Slow and RSRP Level is High and SINR Level is High and Noise Level is Low, then CQI Index is Mid Cell, MCS is Level_3, Code Rate is Medium.
7. If User Condition is Middle and RSRP Level is Very Low and SINR Level is Low and Noise Level is Low, then CQI Index is Cell Edge, MCS is Level_1, Code Rate is Low.
8. If User Condition is Middle and RSRP Level is Medium and SINR Level is Medium, and Noise Level is Medium, then CQI Index is Mid Cell, MCS is Level_2, Code Rate is Medium.
9. If User Condition is Middle and RSRP Level is High and SINR Level is Medium and Noise Level is High, then CQI Index is Mid Cell, MCS is Level_2, Code Rate is Medium
10. If User Condition is Middle and RSRP Level is Very High and SINR Level is High and Noise Level is High, then CQI Index is Good, MCS is Level_3, Code Rate is Medium.
11. If User Condition is Fast and RSRP Level is Very Low and SINR Level is Low and Noise Level is Low, then CQI Index is Cell Edge, MCS is Level_1, Code Rate is Low.
12. If User Condition is Fast and RSRP Level is Low and SINR Level is Low and Noise Level is Low, then CQI index is Cell Edge, MCS is Level_1, Code Rate is Low.
13. If User Condition is Fast and RSRP Level is Medium and SINR Level is Low and Noise Level is High, then CQI Index is Mid Cell, MCS is Level_1, Code Rate is Medium.

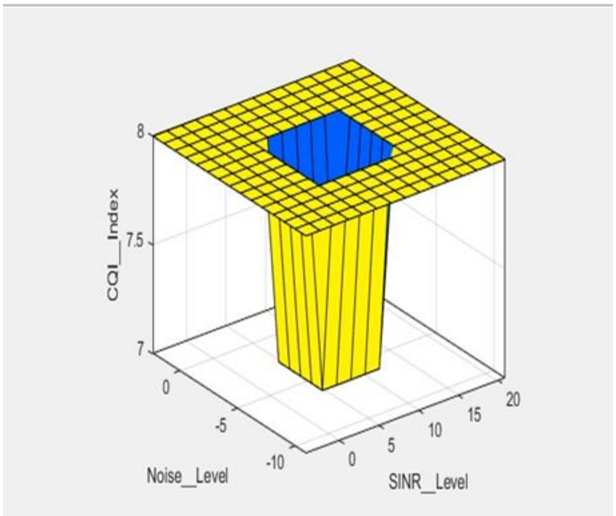
14. If User Condition is Fast and RSRP Level is High and SINR Level is Medium and Noise Level is Medium, then CQI Index is Mid Cell, MCS is Level_2, Code Rate is Medium.
15. If User Condition is Fast and RSRP Level is Very High and SINR Level is High and Noise Level is High, then CQI Index is Good, MCS is Level_3, Code Rate is Medium.

To estimate the errors and compare Simulation Performance, we used Mamdani's modification model.

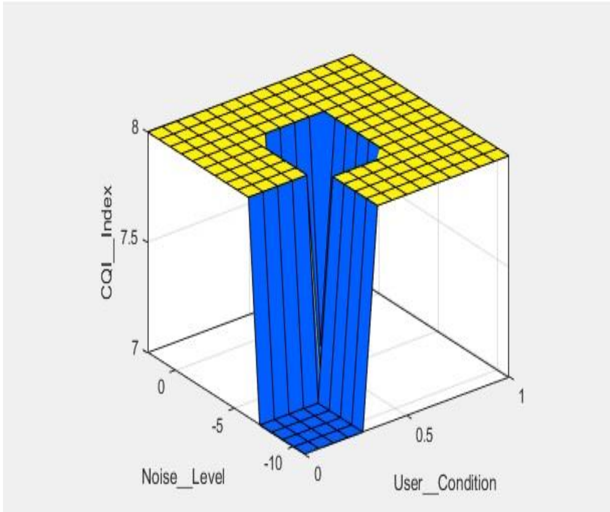
In figure 4.9 shows the rule viewer graph. A set of fuzzy values is chosen from this rule viewer graph, and more measurements are carried out on them.

Figure 4.9: FL Interface Rule Viewer Plot.

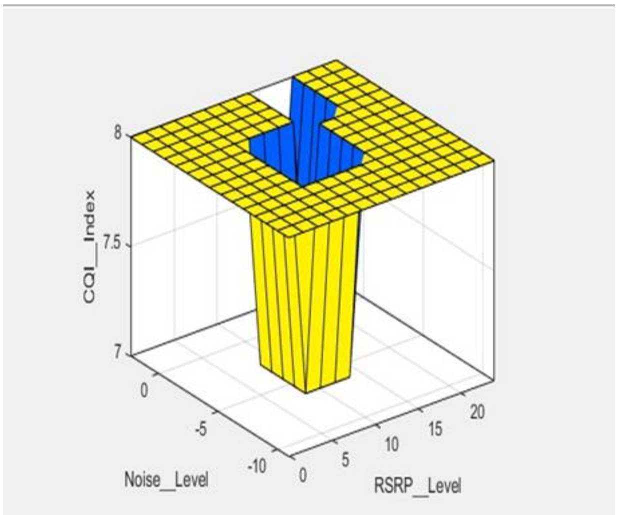
Figure 4.10 illustrates a 3D surface view of the simulation result, where four inputs are used to produce surface view variations versus three outputs, as shown in the simulation.


CQI__Index
Noise__Level
SINR__Level

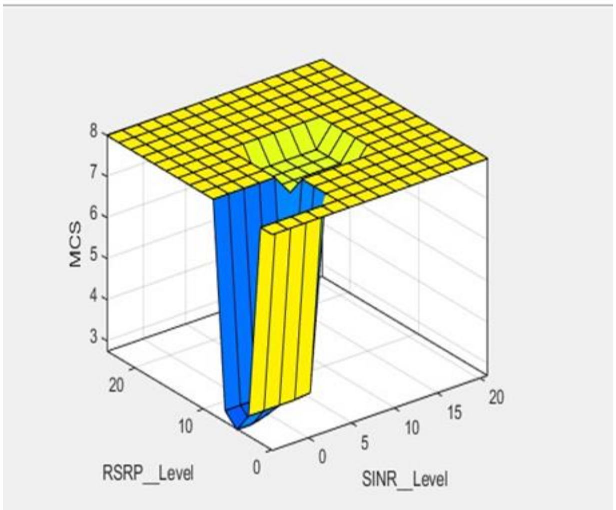
(a)


CQI__Index
Noise__Level
User__Condition

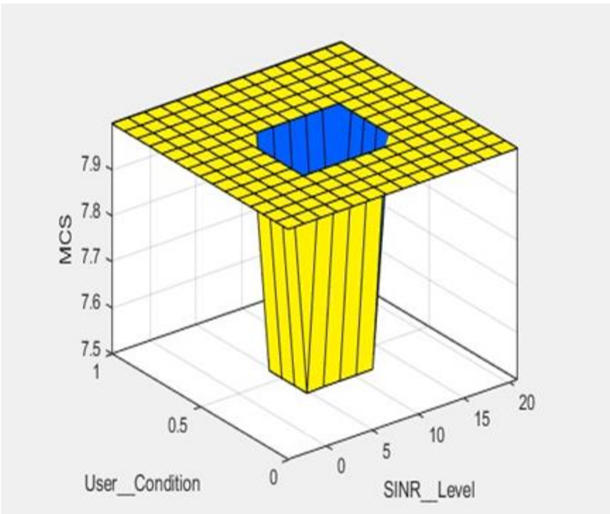
(b)


CQI__Index
Noise__Level
RSRP__Level

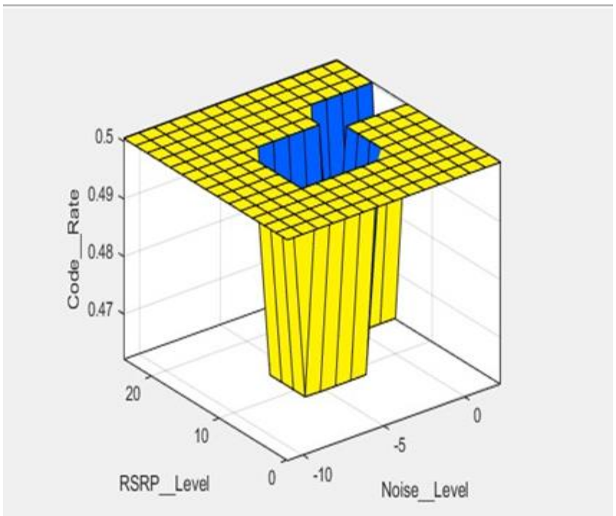
(c)


MCS
RSRP__Level
SINR__Level

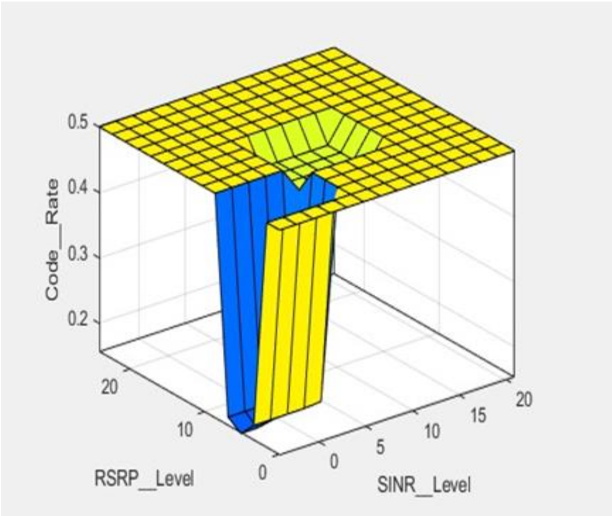
(d)

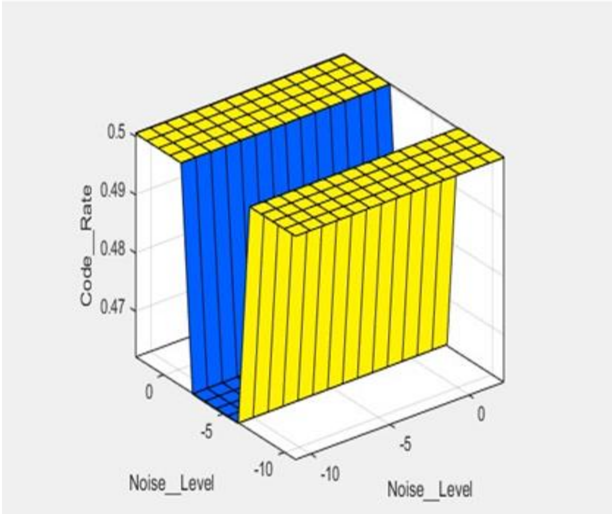

MCS
User__Condition
SINR__Level

(e)


Code__Rate
RSRP__Level
Noise__Level

(f)





(g) (h)

Figure 4.10: 3D Surface View of inputs and outputs. (a) Noise_Level, SINR_Level versus CQI_Index; (b) Noise_Level, User_Condition versus CQI_Index; (c) Noise_Level, RSRP_Level versus CQI_Index; (d) RSRP_Level, SINR_Level versus MCS; (e) User_Condition,SINR_Level versus MCS; (f) RSRP_Level,Noise_Level versus Code_Rate; (g) RSRP_Level, SINR_Level versus Code_Rate; (h) Noise_Level, Noise_Level versus Code_Rate.

4.2 Simulation Result

From the simulation part, we investigated that our proposed system worked correctly. When we provide rules in the Mamdani modification interface, it works dynamically to identify the user CQI, what MSC is used for the user, and the code rate of the user.

From the rule view graph, we have shown that when the user condition is middle and RSRP level, SINR Level and Noise level are in medium, then our design model dynamically calculates the user information as CQI condition is middle, MCS level-2 that means user used 16QAM modulation technique and code rate also the medium. From this output, data BS can allocate proper resources for the user.

The simulation result of four input membership functions is User condition = 0.5; RSRP level = 11.9; SINR level =8.36 ; Noise Level = -4.78 as shown is figure 4.8

Chapter 5

Conclusion and Future Work

5.1 Conclusion:

As we know, we have already introduced ourselves to a lot of resource allocation techniques. We are applying the CQI method, which is considered to be the best among them. The user who provides the best CQI gets the top priority and will allocate resources to that particular user. As there are many cells in 5G technology, the CQI method will play a decisive role in resource allocation. It will consume time and, along with that, will show less complexity. In this thesis, we have worked with two types of simulation. We introduce a well-designed system that will calculate the fixed value with UI/UX interface and work through interfacing. That means we are presenting the mechanism through the live server. And we have also implemented the Fuzzy Interface Logic (FLC) method at eNode B. Using the FLC IF-Then statement, eNode B will get the information of the user conditions, which is easy for eNode B to provide proper Resource allocation for the respective user with maintaining the QoS.

5.2: Limitation of UI/UX System Model

We used a predefined set of data in the UI /UX interface to develop this system model, so this system model is only applicable for static users. This system cannot be used for dynamic users. We are optimizing resources with a predefined dataset which is our main limitation.

5.3 Future Work

There are several scopes to work on the RA method based on the CQI index :

1. To present the accuracy of the logic, which is calculated through the IF-THEN statement in the fuzzy logic interface.
2. To find out any systematic error in this model and minimize it. Implementing machine learning and deep learning to this system will provide a new dimension and minimize systematic errors to deliver better output.

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Appendix A

VS Code for finding rsrp level:

```
function rsrpcond(rsrp){
    if(parseFloat(rsrp)>=-80){
        return "Excelent";
    }
    else if(parseFloat(rsrp)<-80&&parseFloat(rsrp)>=-90){
        return "Good";
    }
    else if(parseFloat(rsrp)<-90&&parseFloat(rsrp)>=-100){
        return "Mid Cell";
    }
    else{
        return "Cell Edge";
    }
function rsrqcond(rsrq){
    if(parseFloat(rsrq)>=-10){
        return "Excelent";
    }
    else if(parseFloat(rsrq)<-10&&parseFloat(rsrq)>=-15){
        return "Good";
    }
    else if(parseFloat(rsrq)<-15&&parseFloat(rsrq)>=-20){
        return "Mid Cell";
    }
    else{
        return "Cell Edge";
    }
```

VS Code for Code_Rate:

```
function sinrcond(sinr){
   if(parseFloat(sinr)>=20){
      return "Excelent";
   }
   else if(parseFloat(sinr)<20&&parseFloat(sinr)>=13){
      return "Good";
   }
   else if(parseFloat(sinr)<13&&parseFloat(sinr)>=0){
      return "Mid Cell";
   }
   else{
      return "Cell Edge";
   }
}
```

VS Code for CQI:

```
function codecalc_cqi(sinr){
   var input=parseFloat(sinr);
   if(input<=-3.5){
      return 1;
   }
   else if(input>-3.5&&input<=-2.6){
      return 2;
   }
   else if(input>-2.6&&input<=-1.5){
      return 2;
   }
   else if(input>-1.5&&input<=-0.3){
      return 3;
   }
   else if(input>-0.3&&input<=0.5){
```

```
   return 4;
}
else if(input>0.5&&input<=1.7){
   return 5;
}
else if(input>1.7&&input<=2.5){
   return 6;
}
else if(input>2.5&&input<=3.5){
   return 7;
}
else if(input>3.5&&input<=4.5){
   return 8;
}
else if(input>4.5&&input<=5.5){
   return 9;
}
else if(input>5.5&&input<=6.5){
   return 10;
}
else if(input>6.5&&input<=7.5){
   return 11;
}
else if(input>7.5&&input<=8.5){
   return 12;
}
else if(input>8.5&&input<=9.5){
   return 13;
}
else if(input>9.5&&input<=10.7){
```

```
    return 14;
}
else if(input>10.7&&input<=11.5){
    return 15;
}
else if(input>11.5&&input<=12.6){
    return 16;
}
else if(input>12.6&&input<=13.4){
    return 17;
}
else if(input>13.4&&input<=14.7){
    return 18;
}
else if(input>14.7&&input<=15.7){
    return 19;
}
else if(input>15.7&&input<=16.6){
    return 20;
}
else if(input>16.6&&input<=17.5){
    return 21;
}
else if(input>17.5&&input<=18.6){
    return 22;
}
else if(input>18.6&&input<=19.6){
    return 23;
}
else if(input>19.6&&input<=20.6){
```

```
        return 24;
    }
    else if(input>20.6&&input<=21.4){
        return 25;
    }
    else if(input>21.4&&input<=22.6){
        return 26;
    }
    else if(input>22.6&&input<=23.5){
        return 27;
    }
    else if(input>23.5&&input<=24.0){
        return 28;
    }
    else if(input>24.0&&input<=24.8){
        return 29;
    }
    else{
        return 30;
    }
}
```

VS Code for SINR

```
    if(sinr<-5.45){
        return 1;
    }
    else if(sinr<=-5.45 && sinr>-3.63){
        return 2;
    }
    else if(sinr<=-3.63 && sinr>-1.81){
```

```
    return 3;
}
else if(sinr<=-1.81 && sinr<=0){
    return 4;
}
else if(sinr>=0 && sinr<1.81){
    return 5;
}
else if(sinr>=1.81 && sinr<3.63){
    return 6;
}
else if(sinr>=3.63 &&sinr<5.45){
    return 7;
}
else if(sinr>=5.45 &&sinr<7.27){
    return 8;
}
else if(sinr>=7.27 &&sinr<9.09){
    return 9;
}
else if(sinr>=9.09 &&sinr<10.90){
    return 10;
}
else if(sinr>=10.90 &&sinr<12.72){
    return 11;
}
else if(sinr>=12.72 &&sinr<14.54){
    return 12;
}
else if(sinr>=14.54 &&sinr<16.36){
```

```
    return 13;
}
else if(sinr>=16.36 &&sinr<18.18){
    return 14;
}
else if(sinr>=18.18){
    return 15;
}
```