SEAMLESS CONNECTIVITY ACROSS HETEROGENEOUS WIRELESS NETWORKS

Project Submitted to the
SRM University AP, Andhra Pradesh
for the partial fulfillment of the requirements to award the degree of

Bachelor of Technology
in
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School of Engineering & Sciences

submitted by

Kolli sai sriram reddy(AP20110010008)

Thadimarri Sameer(AP20110010028)

Bandapu Karthik reddy(AP20110010068)
Aravapalli Prahas(AP20110010436)

Under the Guidance of

Dr. Ajay Bhardwaj

Department of Computer Science & Engineering
SRM University-AP
Neerukonda, Mangalgiri, Guntur
Andhra Pradesh - 522 240
May 2024

DECLARATION

I undersigned hereby declare that the project report **Seamless Connectivity Across Heterogeneous Wireless Networks** submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology in the Computer Science & Engineering, SRM University-AP, is a bonafide work done by me under supervision of Dr. Ajay Bhardwaj . This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree of any other University.

Place	:	SRM University, AP	Date	:	May 11, 2024
Name of student	:	Kolli sai sriram reddy	Signature	:	
Name of student	:	Thadimarri Sameer	Signature	:	
Name of student	:	Bandapu Karthik reddy	Signature	:	
Name of student	:	Aravapalli Prahas	Signature	:	

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

SRM University-AP

Neerukonda, Mangalgiri, Guntur

Andhra Pradesh - 522 240

CERTIFICATE

This is to certify that the report entitled **Seamless Connectivity Across Heterogeneous Wireless Networks** submitted by **Kolli sai sriram reddy, Thadimarri Sameer, Bandapu Karthik reddy, Aravapalli Prahas** to the SRM University-AP in partial fulfillment of the requirements for the award of the Degree of Master of Technology in in is a bonafide record of the project work carried out under my/our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Project Guide	Head of Department
Name : Dr. Ajay Bhardwaj	Name : Prof. Niraj Upadhyaya
Signature:	Signature: ....

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Kolli sai sriram reddy, Thadimarri Sameer, Bandapu Karthik reddy, Aravapalli Prahas

(Reg. No. AP20110010008, AP20110010028, AP20110010068, AP20110010436)

B. Tech.

Department of Computer Science & Engineering

SRM University-AP

ABSTRACT

With the constantly changing environment within the telecommunication sector, Heterogeneous Wireless Networks serve as a key base to help meet the demands of the growing need for global connections and innovative mobile capabilities. The involved review effectively examines critical components like network selection technologies, vertical handover opportunities, added protection to decrease risks, and power effectiveness improvements among much else. Although other methods involve protecting sensitive data and other available alternatives to guarantee high levels of cohesion for users, this particular examination is critical for the current situation worldwide. Indeed, the users require constant access to their capabilities even as they change their areas and devices.

These networks are better positioned to cope with the high-density and extremely mobile user bases by ensuring very smooth and effective transitions as well as prioritizing user preferences and service requirements to maintain the best accessible networks in any way times without interruption. As the telecommunication networks have grown in complexity and necessity of advanced decision-making technologies such as fuzzy logic, Analytical Hierarchy Process (AHP) and many more will significantly help the network selection strategies and the handing over techniques. These adaptive approaches are crucial for ensuring that users always have best possible network available without interruption, optimizing both user experience and network resource utilization.

In summary, these advances network strategies enhance connectivity and service reliability, meeting modern user's expectations for seamless access and robust performance across diverse telecommunication environments.

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Chapter 1

INTRODUCTION TO THE PROJECT

Heterogeneous Wireless Networks represent an era at the forefront of the next wave of communication technology, designed to address the increasing demand for faster and more reliable connections. These networks cleverly combine different types of wireless technologies, like Wi-Fi, 3G, 4G, and 5G, to create a more robust and efficient network.

1.1 ADVANTAGE OF HETEROGENEOUS WIRELESS NETWORKS OVER TRADITIONAL NETWORKS

Heterogeneous wireless networks are considered an advancement because they make the best use of available wireless spectrum and network resources, which leads to a substantial growth in network capacity and coverage. In other words, this implies that service quality will be improved for users who will also experience faster internet speeds as compared to single technology networks.

Communication technology has gone through numerous advances over time and heterogeneous wireless networks are one major step in this evolution. They combine several wireless access technologies so as to extend coverage area and improve data throughput. The traditional model is limited by its inability to allow devices move between different types of wireless networks such as wifi or cellular. Moreover, these networks facilitate a scalable infrastructure that can adapt to future advances and ever-growing data demands. As a result, they are pivotal in enabling an interconnected world, from urban to remote areas, underpinning the vast ecosystem of the Internet of Things (IoT).

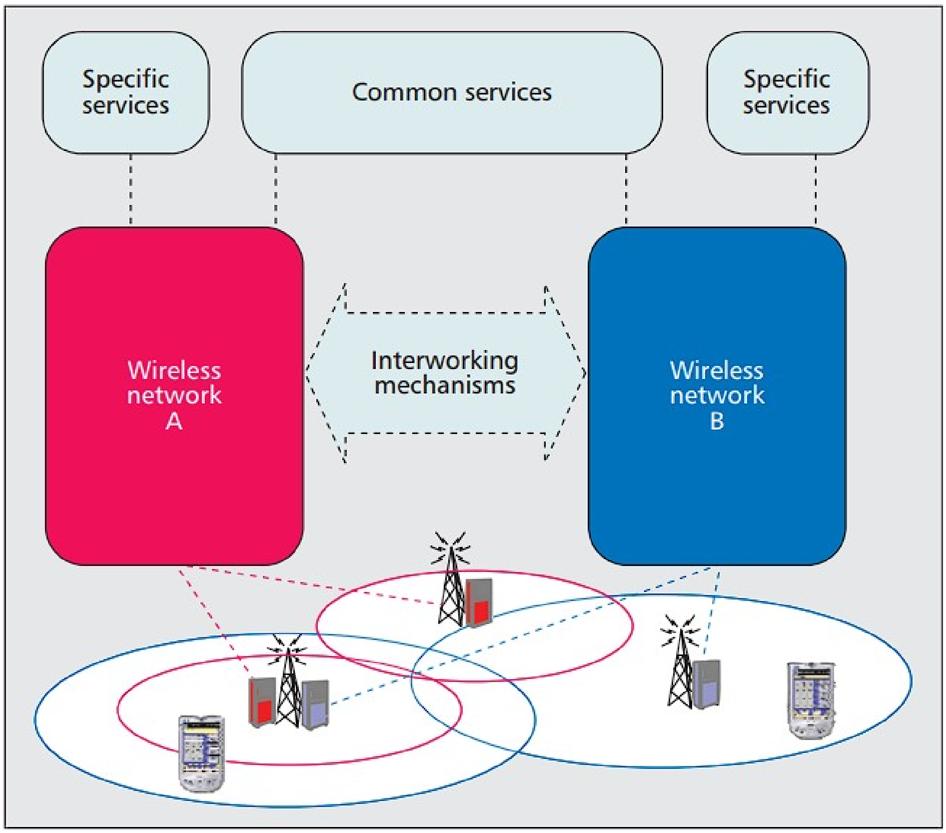


Figure 1.1: Heterogeneous Wireless Networks [1]

In the schematic, "Wireless network A" and "Wireless network B" showcase a heterogeneous wireless network's structure, connected by interworking mechanism that allow shared services. This network configuration emphasizes the seamless integration and interoperability of different wireless technologies, ensuring extensive coverage.

Chapter 2

MOTIVATION

2.1 MOTIVATION FOR STUDYING HETEROGENEOUS WIRELESS NETWORKS

At SRM University AP, the need for robust and reliable wireless connections has grown with the surge in mobile and IoT devices on campus. This mirrors a global trend where traditional networks are struggling to keep up.

Heterogeneous Wireless Networks(HWNs) offer a solution by integrating different wireless technologies, leading to improved and uninterrupted internet access. This not only benefits our campus community but also reflects the larger shift towards more advanced network systems worldwide, ensuring everyone stays connected and up-to-date with technology.

2.1.1 Identifying Real-Time problem and Providing Solutions

Within the field of Engineering, identifying real-world problems is the first step towards innovation. Our project aims to discern pressing issues in wireless communication, especially in data transmission and coverage limitations. By focusing on heterogeneous wireless networks, we intend to provide tangible solutions that can be implemented to enhance connectivity in an increasingly digital world.

2.1.2 Choosing Diversified Research Topics.

The Choice of a research topic is pivotal to the success of any engineering project. Our motivation in selecting Heterogeneous Wireless Networks stems from a desire to delve into a field that is not only rich with academic challenges but also have practical applications. This diversity ensures that our work remains relevant and impactful.

2.1.3 Understanding and Analyzing Project Documentation.

Our Research is based on an effective analysis of project documentation. By research heterogeneous wireless networks, we commit to gaining a complete grasp of the design, implementation, and operating complexities that such system require. The level of analysis is critical for providing significant insights into the field.

2.1.4 Effective Planning

Effective Planning is Crucial for the success of any project. Our project on heterogeneous wireless networks follows a comprehensive strategy, neat outlining of each phase from preliminary research to the implementation.

2.1.5 Platform for self-expression

Engineering projects are about more than just technical skill; they're also a means of expressing our creativity and other skills. By tackling the dynamic and evolving field of heterogeneous wireless networks, we are provided with a extraordinary platform to showcase our innovative spirit and contribute uniquely to the technological landscape.

Chapter 3

LITERATURE SURVEY

Heterogeneous Wireless Networks (HWNs) represent a significant evolution in the landscape of connectivity, enabling, more robust, flexible, and efficient network integration across various environments. This adaptability allows HWNs to seamlessly combine and switch between different wireless access technologies such as Wi-Fi, LTE, and the emerging 5G and 6G, thus providing an optimal user experience regardless of location. By integrating these diverse technologies, HWNs are able to meet the increased data demands of modern users, support a larger number of connected devices, and ensure reliable service even in densely populated areas or regions with traditionally poor connectivity. Heterogeneous Wireless Networks Provides -

- Advanced Network Integration
- Smart Resource Allocation
- Energy Efficiency
- Handover Mechanisms
- Seamless User Experience
- Enhanced Security Protocols

HWNs are playing a vital role in enabling a wide range of cutting-edge applications, ranging from high-definition video streaming and online gaming to critical communications in smart cities and IoT deployments that are driving the movement towards a world that is genuinely interconnected.

3.1 NETWORK SELECTION AND HANDOVER MECHANISMS

This Research Paper examines how heterogeneous wireless networks (HWNs) manage network selection and handover mechanisms. HWNs are created to give high bandwidth and data throughput while supporting quality of service(QoS). They allow multi-interface terminals to connect with different wireless technologies simultaneously e.g. Wi-Fi(802.11), WiMAX(802.16), cellular networks(LTE etc. . .).

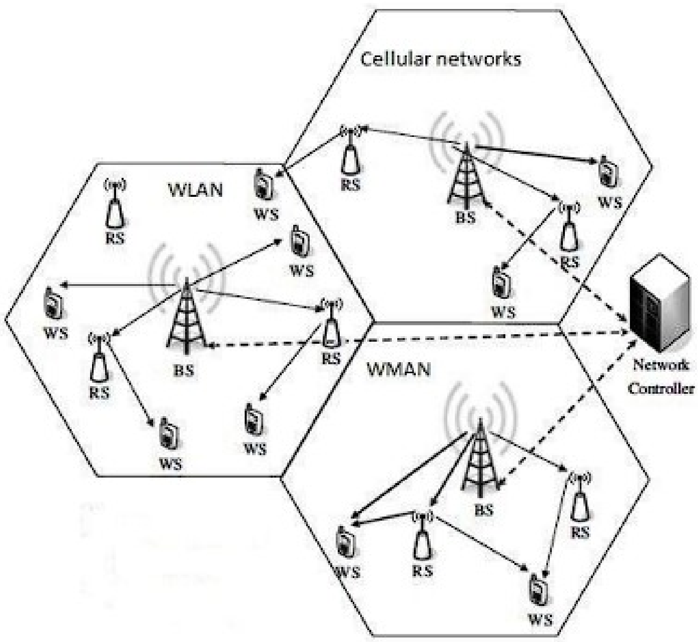


Figure 3.1: HWNs System [2]

A critical aspect of HWNs is the Handover process, which enables a device to maintain connectivity as it moves between different network coverage's. This paper[2] categorizes handovers in **Horizontal(Within the same network type) and Vertical(across different network types)**. The complexity of managing these handovers is significant in HWNs due to the need to maintain uninterrupted service and optimize network performance.

This Research Paper[3] provides quite detailed insights into what multi-connectivity in 5G is leading towards an increase in service performance even while different network technologies are being used at the same time. It studies the existing standards, technologies, and strategic implications of multi-connectivity. The purpose of this questionnaire was to increase bandwidth and connectivity needs that multi-connectivity will be added. Besides, there is an increase in user mobility and service quality management across diverse network environments to provide better handling and network management capacity.

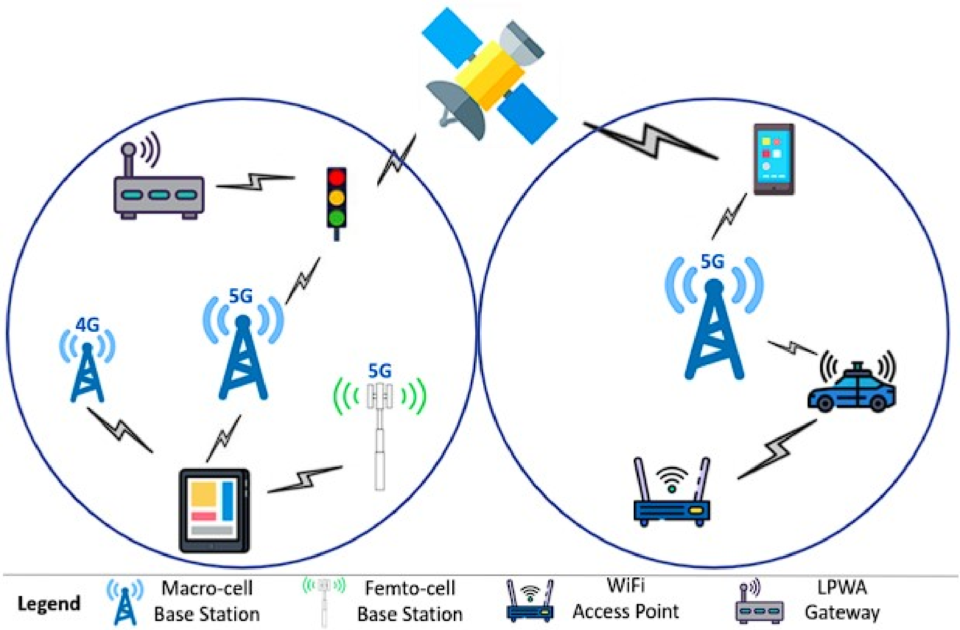


Figure 3.2: Multi-Connectivity Scenarios for 5G Networks [3]

The paper[3] reviews current standards like Dual Connectivity and Multi Connectivity, highlighting their roles in enhancing network performance through better resource management and connection strategies. There are various applications of multi-connectivity in improving QoS, energy efficiency, mobility management. It compares different research efforts, summarizing the benefits and identifying common lesson and challenges.

This paper[3] also discusses "Taxonomy" which means a classification system is developed to organize different aspects of multi-connectivity, including strategies, objectives, and technologies used, providing a structured way to evaluate its implementation in 5G networks.

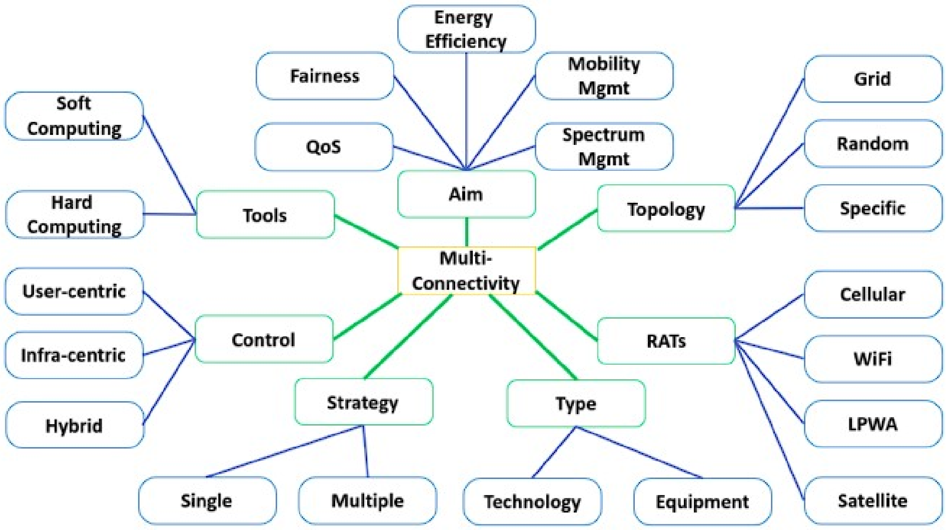


Figure 3.3: Taxonomy for multi-connectivity in 5G networks [3]

In heterogeneous wireless networks (HWNs), network selection and connectivity form the very crucial aspect that ensures users have a transparent experience over the available radio access technologies. In general, this allows HWNs to properly manage the connections for the realization of optimized network performance and device transition across the Wi-Fi, LTE, and shortly coming 5G networks. The function is essential to have a means that the network service cannot be interrupted. This is more so when the area has a high traffic load on the network or diversifies the coverage. HWNs further enhance the overall total ability and trustworthiness of mobile networks, whereby they facilitate efficient network selection and connection of users to the best available network, according to their location and service requirements at that time.

Service delivery in a heterogeneous all-IP wireless network environment requires the selection of an optimal access network. Selection of a non-optimal network can result in undesirable effects such as higher costs or poor service experience. Network selection in such an environment is influenced by several factors, and currently a complete solution is not available to solve this problem. This article describes a comprehensive decision making process to rank candidate networks for service delivery to the terminal. The proposed mechanism is based on a unique decision process that uses compensatory and non-compensatory multi-attribute decision making algorithms jointly to assist the terminal in selecting the top candidate network.

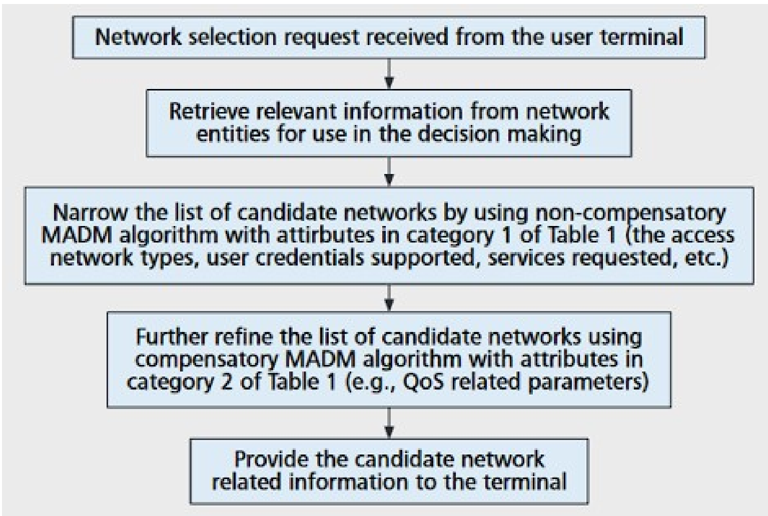


Figure 3.4: Decision Making in Network Selection

This article presents a comprehensive network-assisted network selection mechanism that combines non-compensatory and compensatory MADM algorithms. It analyzes TOPSIS, a compensatory MADM algorithm, and validates its application in various use cases. The mechanism is applied to networks with multilevel SLAs and discusses possible approaches to network selection when a service is already in use. The results provide a basis for further research in service delivery in heterogeneous networks.

3.2 RESOURCE ALLOCATION AND ENERGY EFFICIENCY IN HWNS

In this Study[5] the authors delves into optimizing energy efficiency in wireless networks. The focus is on allocating resources in a way that balance power consumption with performance, particular in networks where devices can connect to multiple network types simultaneously, known as multi-homing.

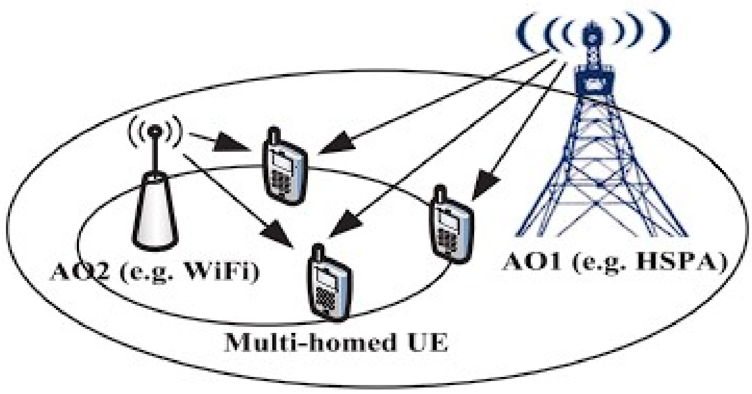


Figure 3.5: System model of HetNet with multi-homed UEs [5]

The Dual-Phase optimization proposes a method that would address the nonlinear complexities of maximization in energy efficiency of HWNs. Authors first consider the EEM problem as an energy efficiency maximization problem formulated in the form of a mixed integer nonlinear optimization problem. This method first looks at realization of minimum service quality levels before looking at the optimization of energy efficiency. It cleverly splits the resource allocation in a minimum rate-guaranteed phase and an energy-efficient phase make the computational workload simple. This balance of efficiency and performance pinpoints the potential of the proposed method in improving network management in future wireless systems in view of the growing demand for smarter and more energy-conservative networking solutions.

This Paper[6] discusses different schemes used for resource allocations in 5G HWNs. The main focus is given to the fact that effective resource management has capability to get higher performance and, therefore, customer satisfaction. The authors systematically retrieved and reviewed past studies, most of which are available in databases and journals, in the field of telecommunication.

Paper	Year	Network	Main addressed issues	Final target and benefits
[22]	2000	HetNet	TPC performance	Build an independent network type, to achieve TCP cope with a heterogeneous Internet via an end-to-end basis
[23]	2007	all-IP HetNet	Secure handoff optimization	Reduce the effect of handoff delay and support demanding multimedia service
[24], [25]	2009, 2010	HetNet	Vertical handover decision	Provide seamless roaming and mobility
[26]	2010	HVN	Vehicular telematics	Design the essential functional components of HVN and the protocols (radio link control, routing, congestion control, security, privacy, application development)
[27]	2011	HetNet	A comprehensive survey	Improve SE and create a network structure, overview the 3GPP LTE air interface, network nodes, cell range expansion, the enabling mechanisms in heterogeneous scenario
[28]	2013	HetNet	Mobile cloud computing	Provide vast computation resource and abundant network services
[29]	2014	HetNet	EE and SE	Cooperative HetNet to balance and optimize SE and EE.
[30]	2014	HMN	Converging solution	Improve the performance of M2M communications by using WiFi or Bluetooth
[31]	2014	HetNet	QoS and QoE mechanisms	Achieve the best possible configuration of connectivity, price and user application
[32]	2015	HVN	Architecture, challenges	Provide efficient real-time information exchange among vehicles and the wide coverage for vehicular users simultaneously
[33]	2015	HCN	EE based traffic offloading	An online reinforcement learning resolves the time-varying traffic and task offloading
[34]	2015	H-CRAN	System architecture	Fulfill the centralized cooperative process and suppress co-channel interference
[35]	2016	HetNet	BS switching	Reduce EC and meet traffic needs
[36]	2018	Het-IoT	Data exchange formats	Improve the size of transmitted messages
[37]	2018	Het-IoT	Network architecture	Achieve smart home/city, intelligent transportation, advanced manufacture, security system
This paper	2020	HetNet	RA algorithms	Achieve interference management, SR sharing, high capacity, adaptive and intelligent optimization

Figure 3.6: Surveys On HWNs [6]

The authors focus was more on the quantitative research that considered the performance under each resource allocation scheme, including throughput, latency, and energy consumption. The study found that the dynamic resource allocation methods yield an improvement of network efficiency, remarkably above the static methods. The results indicated that the integration of Artificial Intelligence and Machine Learning methods is very critical in adjusting real-time distribution of resources to the ever-growing demands and conditions of the networks. The authors did simulation-based studies, and practical implementations across different scenarios in 5G networks.

3.3 LOAD BALANCING AND SECURITY MANAGEMENT IN HWNS

This Paper[7] proposes a approach for load balancing in HWNs using Hierarchical Semi-centralized Architecture (HSCA). The architecture proposed by this paper provides guidelines from grid computing in computer networks to offer effective management and optimization of the distribution of resources.

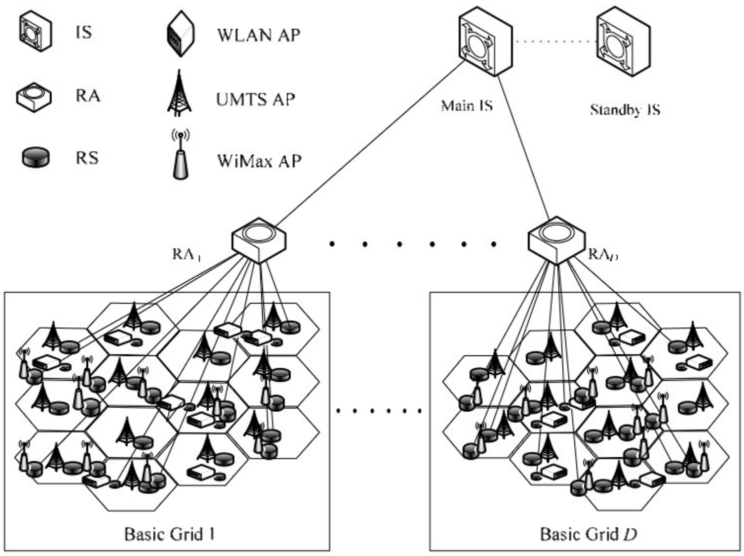


Figure 3.7: Hierarchical semi-centralized architecture [7]

The proposed research work methodology maps the HWNs to distributed grids and further uses a Resource Management Unit for structured resource handling. The simulation result shows that the hierarchical semi-centralized architecture significantly reduces the signaling overhead and enhances the overall system reliability.

In conclusion, the semi-centralized architecture, being hierarchical, gives a promising solution toward balancing the problem of load in HWNs. The former integrates perfectly with the benefits of the two architectures, presenting a rock-solid framework enhancing the performance and reliability of the network. This points to the finding that operational efficiency and management of resources would be optimized by applying grid computing concepts to HWNs. This literature review summarizes the most important points in the study, offering a clear view of what contribution the proposed architecture would bring to the advance in management of heterogeneous wireless networks.

In this Study[8] authors address the serious requirement for strengthening security in the allocation of resources across HWNs. It introduces a security-aware framework that incorporates cross-layer design principles to optimize resource distribution while ensuring robust security measures are maintained. This approach recognize the varying security requirements of different data types and network services, aiming to provide a balanced solution that does not compromise on network performance or security.

The authors propose an algorithm that integrates aspects of both physical and application layers to achieve optimal resource allocation. The methodology involves assessing the security vulnerabilities and requirements at each layer and using this information to guide the allocation process. his cross-layer strategy ensures that security considerations directly influence how resources are distributed, thereby enhancing the overall security posture of the network. Simulation results demonstrate that the proposed framework significantly improves the security of data transmission across the network without sacrificing efficiency. The security-aware allocation algorithm successfully prioritizes resources for services with higher security needs while maintaining adequate performance levels for less sensitive tasks. This balance is achieved through dynamic adjustments in resource allocation in response to real-time security assessments.

The study concludes that a security-aware approach to resource allocation can effectively enhance the security and efficiency of heterogeneous wireless networks. The integration of cross-layer design principles allows for a more nuanced understanding of network vulnerabilities, leading to better-informed allocation decisions. The paper advocates for the broader adoption of security-aware resource management strategies in future network designs to safeguard against evolving threats and ensure reliable service delivery.

Heterogeneous Wireless Networks (HWNs) are complicated systems with wireless technologies such as Wi-Fi, LTE, and Bluetooth that serve many purposes, posing a number of issues. The sensitivity of the data that most networks manage, along with its widespread use, makes security a top priority. Such a broad-based technology used on HWNs must offer unique security weaknesses and threats, rendering an omnipotent security solution equally unrealistic. This is the requirement to create and implement a strong security mechanism to address the unique characteristics and vulnerabilities of either network type within the HWN. These difficulties necessitate a thorough understanding of network protocols, a commitment to ongoing security assessments, and a progressive approach to lifelong progressive security solutions. The ultimate purpose is to be able to provide a secure communication environment that is efficient enough to protect from existing and future threats.

Chapter 4

DESIGN AND METHODOLOGY

4.1 NETWORK SELECTION USING FUZZY LOGIC AND ANALYTIC HIERARCHY PROCESS

The characteristics of Internet access in the different access networks, in regard to cost, network parameters, and security, among others, have a direct effect on the quality of service in multiple and diverse technologies of wireless access. This is the reason a computer has to determine the best access point in the given application. The network selection enables different techniques of evaluating and selecting classified network access points for proper provision that leads to concise handover without problems like the ping-pong effect.

The mobile terminals include laptops, notebooks, and phones that have evolved with multiple network interfaces and IP-based applications. The devices allow connection to different wireless networks providing always-best-connected experiences for real-time service to customers.

Handover Management Next Generation Wireless Networks has:

- Checking available networks
- Sorting and selecting the best access network
- Executing the handover

Vertical handover occurs between wireless networks with different technologies, while horizontal handover occurs between networks with the same technology. The network selection process classifies and selects the best access network among available ones, divided into three logic blocks: data collection, processing, and classification. Strategies and network parameters directly impact network selection, and can be categorized into the following categories:

- Category 1: Non-relative parameters like monetary cost, encryption.
- Category 2: Widely used parameters like jitter, delay, packet loss, throughput.

Parameter	**Description**	**Fuzzy Logic Application**	**Impact**
Signal Strength	Measures the quality of the network signal	Used to evaluate the reliability of the connection	High
Network Congestion	Indicates the level of traffic in a network	Helps determine the likelihood of service delays	Medium
User Mobility	User's speed and direction of movement	Assesses network switch frequency to maintain connectivity	Medium
Service Type	Type of service required (e.g., voice, data)	Prioritizes networks that best support the service needs	High
Battery Level	Current battery status of the user device	Considers energy efficiency in the network selection	Low
Cost	The expense associated with using the network	Integrates cost-efficiency into deciding the optimal network	Medium

Table 4.1: Application of Fuzzy Logic in Network Selection for HWNs

Fuzzy logic is utilized to enhance network selection strategies in heterogeneous wireless networks. It details various parameters such as Signal Strength, Network Congestion, and User Mobility, describing their impact on network performance and how fuzzy logic contributes to making informed decisions. This approach ensures optimal network connectivity based on user requirements and network conditions, thereby improving overall service quality and efficiency. The table effectively summarizes the role of fuzzy logic in balancing performance and cost, emphasizing its significance in modern telecommunications.

Method	Purpose
Fuzzy Logic	Used for accurate output from raw data input and to handle the uncertainty in data. Specifically, it helps manage the linguistic terms and thresholds in network traffic, particularly for audio and video, ensuring that network quality is assessed based on human perceptible standards.
AHP	Utilized for efficient weight generation for objective data, allowing for the prioritization of network selection criteria based on their importance. AHP aids in determining the relative importance of each criterion (like jitter, delay, and packet loss) to make informed decisions.

Table 4.2: Purposes of Fuzzy Logic and AHP in Network Selection

The proposal for network selection combines two widely used strategies: fuzzy logic and Multi attribute decision making methods (AHP). Fuzzy logic is chosen for accurate output from raw data input, AHP for efficient weight generation for objective data. This approach aims to rank and select the best available network access efficiently.

The system consists of three functional blocks: collector, processor, and decision maker. The collector collects data on delay, jitter, and packet loss from the ICMP. The monetary cost parameter is fixed and only needs to be informed by the mobile operator about the wi-fi network values and base station values, as only terminal access to the access point is considered. The collection process involves two rounds of 10 ICMP, based on the user's terminal to the access point. The collected values are stored in a file called the medium RTT (Round Trip Time), which is used to calculate the end-to-end delay. The processor then uses fuzzy logic techniques, AHP methods to classify access networks in the terminal's environment.

The fuzzy system has four inputs and one output, indicating network quality. The classification is made possible by the weights provided by the AHP method for each criterion.The weight values for network QoS criteria in audio transmission were based on their importance. Jitter has a higher importance than delay for voice traffic and packet loss, while monetary cost is more significant than these criteria. The decision maker module selects the best access network based on the NQI variable, which is an arithmetic average of fuzzy logic and AHP methods. The user will always choose the cheaper access network.

4.2 ENERGY-EFFICIENT RESOURCE ALLOCATION IN HWNS

In today's constantly increasing digital landscape, reliable and efficient wireless networks are more important than ever. "Energy-Efficient Resource Allocation in Heterogeneous Wireless Networks" optimises how resources like power and bandwidth are divided between different types of network access points, such as cell towers and WiFi routers, to improve overall network performance. Heterogeneous networks, which integrate many types of access points, confront distinct issues due to the diverse capabilities and expectations of each node. This simulation tries to address these difficulties by dynamically allocating resources to maximise energy efficiency, lowering operational costs and enhancing service quality in a variety of wireless scenarios. This method is not only vital for maintaining high-volume data flow, but also for progressing towards more sustainable and eco-friendly.

- **Access Points (APs) –** Access points, also known as routers or hubs, exclusively provide wireless services.
- **User Equipment's (UEs) –** User Equipment's are devices such as cellphones or laptop computers that connect to the internet via access points (APs).
- **Resources –** Each AP is delivered with a stipulated amount of power and bandwidth. The power indicates how strong the signal might be, while the bandwidth determines the amount of data that can be delivered simultaneously.
- **User Requirements –** Every UE has a requirement for a minimum amount of data speed.

Each AP is allotted a random amount of power and bandwidth. Channel gains indicate how well each User Equipment (UE) can 'hear' each AP, considering distance and obstructions. An Energy Efficiency Array measures the system's efficiency after each cycle. The simulation runs in a loop with 100 iterations. In each iteration, the system distributes available power and bandwidth from each AP to each UE at random. The allocation is changed depending on feedback from prior rounds, with the goal of optimising for the best-known distribution.

After distributing resources, the system estimates energy efficiency by comparing power use to data transmission.The system may adapt its power or bandwidth to match user needs while conserving energy, similar to real-world adjustments.

After all iterations are completed, the simulation presents a graph indicating how energy efficiency varied.The ultimate energy efficiency figures for each iteration indicate how the system optimised resource utilisation over time. This entire process helps in understanding how different strategies for distributing resources among APs and UEs impact overall system efficiency, and it's particularly useful in optimizing networks for better performance with minimal energy waste.

4.3 LOAD BALANCING IN HETEROGENEOUS WIRELESS NETWORKS

Load balancing is one of the most important features that should be implemented in Heterogeneous Wireless Networks, since it increases the utilization of resources and the overall performance of the network. It maintains a uniformly balanced load in the typically diverse networks and access technologies of an HWN to ensure no part of the network gets overloaded, thus maintaining high quality and availability of service. Load balancing helps improve network reliability, throughput, and latency, thus directly impacting user experience. In other words, it is all about spreading network traffic or computing load over a number of effectively located nodes or access points so as not to overburden any single point; otherwise, it would cause a traffic jam. This makes load balancing one important concept in any dynamic network or one that has high performance demands.

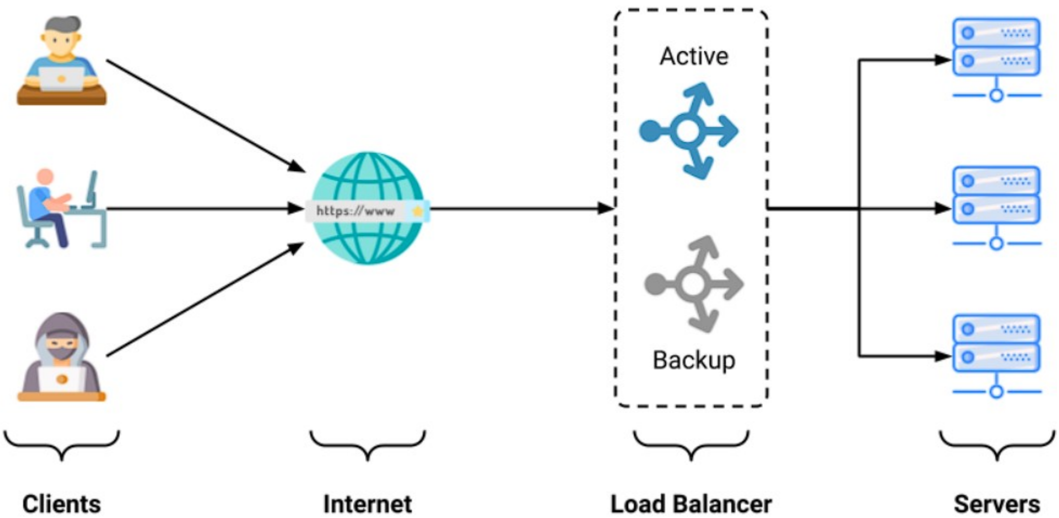


Figure 4.1: Load Balancing in HWNs

Load balancing of devices to access points in Heterogeneous Wireless Networks is done based on their proximity to and capacity available at each access point. In this simulation, each access point and device is placed randomly within an area to be defined in the simulation, hence also satisfying the requirement of varied geographical distribution that is common in real-world cases. The proposed method is to calculate the Euclidean distance of each device from each and every one of the access points. The solution is to connect the device to the nearest access point that is not over its handling capacity. The result would be an equal sharing of the network load, where no single access point would be overloaded while keeping the level of service up across the network. This process is realistically visualized in the simulation by dynamically plotting connections of the devices to their respective access points and is an extremely intuitive illustration of how the process of load balancing can be used to enable effective network management. This practical visualization coupled with a strategic allocation algorithm effectively demonstrates the fundamental principles of load balancing in HWNs, underscoring the importance of spatial consideration and capacity management in attaining an evenly distributed network load.

The underlying theoretical concept for the simulation uses two different load balancing strategies in HWNs to adequately distribute device connections among different access points, ensuring there are no bottlenecks in the network and that the highest possible service quality prevails across all access points. The design of each strategy, Least Connections and Least Response Time, is to optimize the use of network resources by preventing any one access point from becoming a bottleneck, thereby ensuring service quality across the network is maintained at a high level.

Least Connections: This technique will assign devices to the access point with the least number of connections. Through pointing connections to the least utilized access points, this would generally allow more uniform distribution of the load in the network. This way, overloading can be avoided, and no single access point is subjected to too much burden to guarantee operational stability and reliability in the network.

Least Time to Respond: This approach, however, prioritizes access points with the best response time. With this method, devices will be connected to the access point with the least response time. This feature is helpful primarily when fast data processing is a demand for an hour. When response times are maximized, the network can be optimized for users, especially at the level of the user experience in performance-critical applications with fast data exchanges.

4.4 SECURITY IN HETEROGENEOUS WIRELESS NETWORKS

Network security is a critical concern in modern IT environments, where threats range from data breaches and Denial of Service (DoS) attacks to more sophisticated threats like Advanced Persistent Threats (APTs) and ransomware. The diversity of these threats necessitates a multi-layered approach to security, integrating both proactive and reactive measures.

Simulating Network Attacks:

- Tools like "Scapy" are essential for security test. They allow organizations to emulate the malicious traffic and check the respective network ability for resisting known attack vectors.
- Scapy can create a variety of packets, change packet headers, and deliver sequences that replicate attack patterns, such as
- **HTTP Request Flooding:** Dos attacks by flooding the server or an application or a device wioth HTTP requests.
- **Malicious Login Attempts:** Performing brute-force attacks to test the robustness of the systems.

Real-Time Monitoring and Anomaly Detection:

- Tools like "Wireshark" and "Scapy" for sniffing and analyzing network traffic are important. They help in identfying unusual patterns that may be a security breach or an ongoing attack.

Prevention/Response Mechanisms:

- **Packet Analysis:** Examining the headers and payload of packets for signs of malicious activity.
- **Anomaly Detection:** Identifying the malicious traffic, such as Repetitive Packets from same IP address.
- **Response Protocols:** Automatically blocking suspicious IP addresses and issuing alerts to administrators.

Chapter 5

IMPLEMENTATION

5.1 HWNS NETWORK SELECTION USING FUZZY LOGIC

Simulation - 1

To Simulate the Network Selection between two Heterogeneous wireless Networks we have used “MATLAB”.

Pre-Set Fuzzy Logic rules in the Matlab simulation code:

```
ruleMatrix = [
    If signalStrengthA is strongA and bandwidthA is highA
    then network is NetworkA (AND) .
    If signalStrengthB is strongB and bandwidthB is highB
    then network is NetworkB (AND).
    If signalStrengthA is weakA and bandwidthA is lowA and
    signalStrengthB is weakB and bandwidthB is lowB then
    network is NetworkB (AND).
    If signalStrengthA is weakA and signalStrengthB is weakB
     then network is NetworkB (AND).
    If signalStrenghA is strongA and signalStrengthB is
    strongB then network is NetworkA (AND).
];
```

This above Fuzzy Rules have Two Parameters that are ”Signal Strength” and ”Bandwidth”. It begins by defining input variables representing signal strengths and bandwidths for two different networks, as well as an output variable indicating the selected network. Fuzzy membership functions are then defined to categorize input values into linguistic terms such as ”weak” and ”strong”.

Membership Functions of Fuzzy Inference System (FIS)

For Signal Strength:

- **Weak (weakA, weakB) –** 0 to 70, with full weak from 0 to 30
- **Strong (strongA, strongB) –** 30 to 100, with full strong from 70 to 100

For Bandwidth:

- **Low (lowA, lowB) –** 0 to 80, with full low from 0 to 20
- **High (HighA, HighB) –** 20 to 100, with full high from 80 to 100

Time	Signal Strength A	Bandwidth A	Signal Strength B	Bandwidth B	Selected Network
1	82	91	12	92	A
2	63	9	28	55	B
3	96	97	15	98	B
4	96	49	80	14	A
5	42	92	80	96	B
6	62	3	85	94	A
93	15	86	65	38	B
94	19	43	48	12	B
95	59	22	38	58	A
96	25	29	62	26	B
97	83	99	73	34	A
98	58	10	91	88	A
99	82	26	60	2	A
100	42	31	16	18	B

Table 5.1: Result Of Fuzzy Logic Simulation

Total 100 iteration, in each iteration there are two networks and one network is selected based on Fuzzy logic pre-set rules as shown above.

Simulation - 2

To Simulate the Network Selection and Graphical Representation using various Parameters we have used “MATLAB”.

Input Variables:

- **Delay –** Represents delay in network transmission.
- **Jitter –** Indicates the variation in packet delay.
- **PackLoss –** Reflects the percentage of lost packets.
- **Monetary –** Represents the cost factor associated with the network.

Output Variable:

- **QI (Quality Index) -** Indicates the quality level of a given network (1-5).

Fuzzy Inference System (FIS):

- Utilizes membership functions to fuzzify inputs (delay, jitter, packLoss, monetary) and outputs (QI).
- Rules are defined to map specific input conditions to QI values.

```
rules = [
"If delay is low and jitter is low and packLoss is low and
monetary is low then QI is excellent"
"If delay is low and jitter is low and packLoss is low and
monetary is medium then QI is great"
"If delay is low and jitter is low and packLoss is low and
monetary is high then QI is great"
```

```
"If delay is low and jitter is low and packLoss is medium
and monetary is low then QI is great"
"If delay is low and jitter is low and packLoss is medium
and monetary is medium then QI is good"
"If delay is medium and jitter is low and packLoss is low
and monetary is medium then QI is good"
"If delay is medium and jitter is low and packLoss is low
and monetary is high then QI is good"
"If delay is medium and jitter is low and packLoss is medium
 and monetary is low then QI is good"
];
```

There are other Combinations of Fuzzy Logic Rules as Shown above.

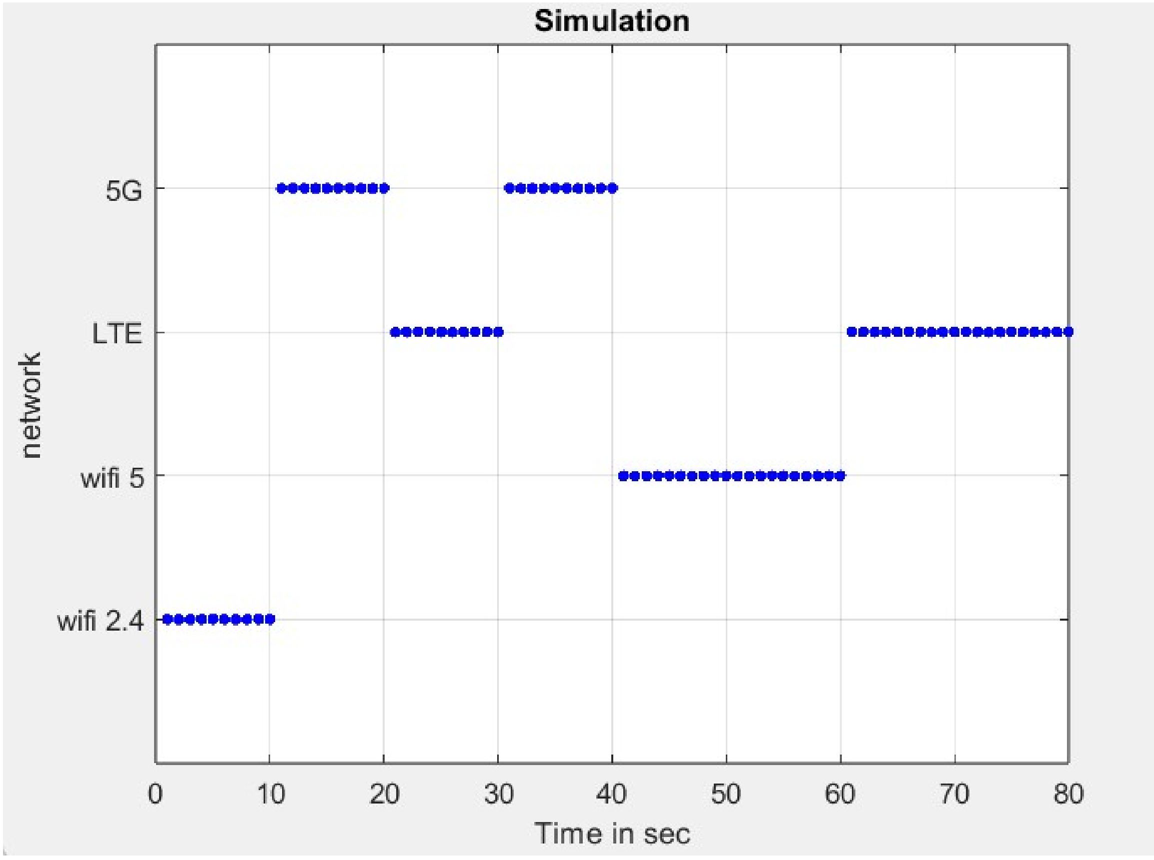


Figure 5.1: Graphical Representation of the Simulation (1)

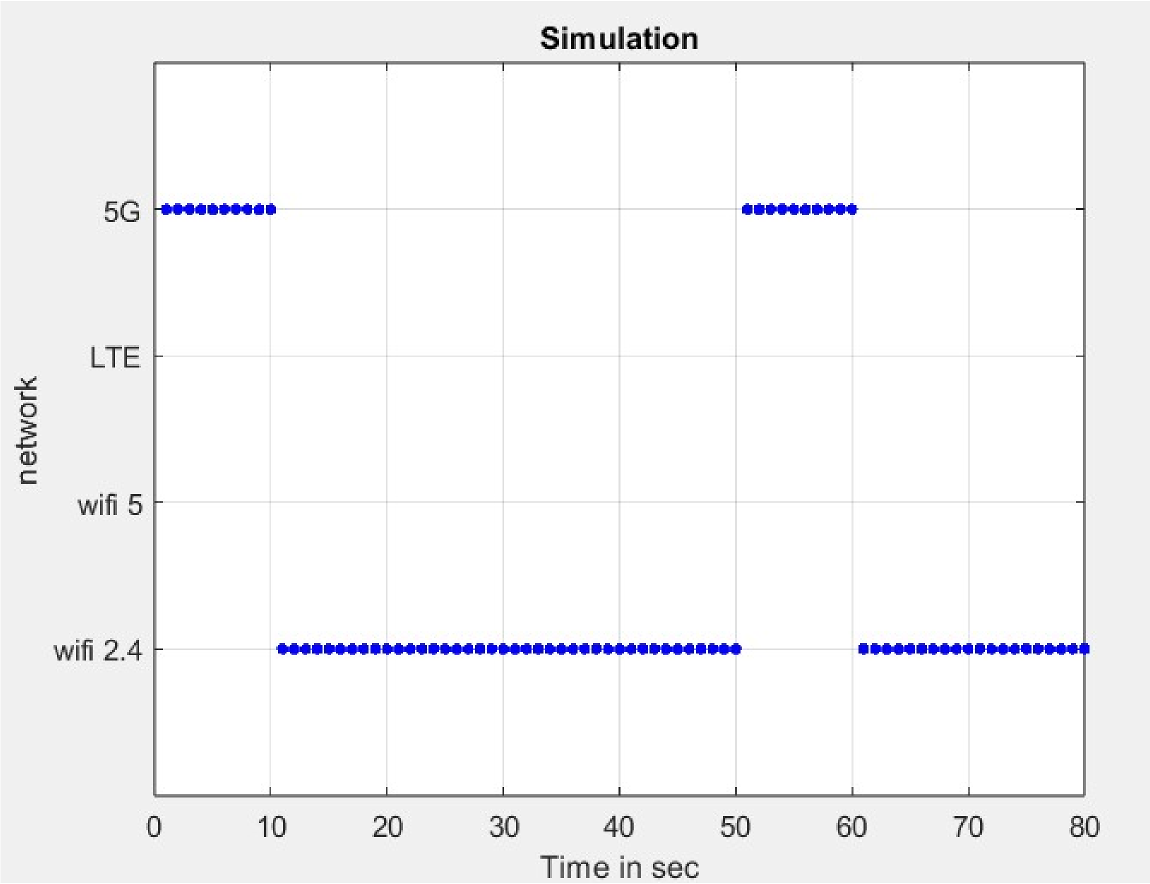


Figure 5.2: Graphical Representation of the Simulation (2)

- Random network conditions (delay, jitter, packLoss, monetary) are generated.
- Fuzzy logic is applied to evaluate the network quality (QI) for each of the four network options.
- The network with the highest QI value is selected.
- Plots the selected network over time.

5.2 ENERGY-EFFICIENT RESOURCE ALLOCATION IN HWNS

To Simulate Energy-Efficient Resource Allocation in HWNs we have used "MATLAB".

Simulation Parameters:

```
% Simulation parameters
numAPs = 5;  % Number of Access Points
numUEs = 10; % Number of User Equipments
maxIterations = 100;

% Initialize random system parameters
powerAPs = 10 * rand(numAPs, 1); % Maximum power
available at each AP
bandwidths = randi([5, 20], numAPs, 1); % Bandwidths
available at each AP
userRequirements = randi([1, 5], numUEs, 1); % Data rate
 requirements for each UE

% Random channel gains matrix for APs to UEs
channelGains = rand(numAPs, numUEs);

% Array to store energy efficiency per iteration
energyEfficiency = zeros(maxIterations, 1);
optimumFound = false;
```

Energy Efficiency Metric Calculation (Example Scenario):

Consider Following Parameters -

- **2 Access Points (APs)** with maximum power capacities of 10 Watts each.
- **3 User Equipment's (UEs).**

Power Allocation and Channel Gains -

- AP1 to UE1: 2 Watts, AP1 to UE1: 0.8
- AP1 to UE2: 3 Watts, AP1 to UE2: 0.5
- AP1 to UE3: 1 Watt, AP1 to UE3: 0.7
- AP2 to UE1: 4 Watts, AP2 to UE1: 0.9
- AP2 to UE2: 2 Watts, AP2 to UE2: 0.4
- AP2 to UE3: 0 Watts, AP2 to UE3: 0

Effective Power Usage - Power x Channel Gains

- AP1 to UE1: 2 x 0.8 = 1.6 W
- AP1 to UE2: 3 x 0.5 = 1.5 W
- AP1 to UE3: 1 x 0.7 = 0.7 W
- AP2 to UE1: 4 x 0.9 = 3.6 W
- AP2 to UE2: 2 x 0.4 = 0.8 W
- AP2 to UE3: 0 x 0 = 0 W

Total Effective Power Used - 1.6 + 1.5 + 0.7 + 3.6 + 0.8 + 0 = 8.2 Watts

Total Power Consumption - 10 + 10 = 20 Watts

Energy Efficiency Calculation -

Energy Efficiency (EE) = $\frac{\text{Total Useful Energy Output}}{\text{Total Energy Input}}$

Energy Efficiency (EE) = $\frac{8.2\text{ W}}{20\text{ W}}$ = 0.41

This result means that 41 percent of the total power consumed is effectively used in data transmissions, considering the channel conditions and power allocations.

Simulation Code Result :

At the start of the Simulation we can see in the below images that the energy efficiency is changing after each iteration because the simulation is trying to find Optimal Energy Efficiency.

```
Simulation completed.
Energy Efficiency Metrics:
    2.7002
    2.8755
    2.8049
    2.5943
    2.3586
    2.5500
    2.5198
    2.2902
    3.0442
    2.7473
    2.2781
    2.1881
    2.7152
    2.3069
    2.9750
```

Figure 5.3: Energy Efficiency (Before Stabilization)

```
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
2.4487
```

Figure 5.4: Energy Efficiency (After Stabilization)

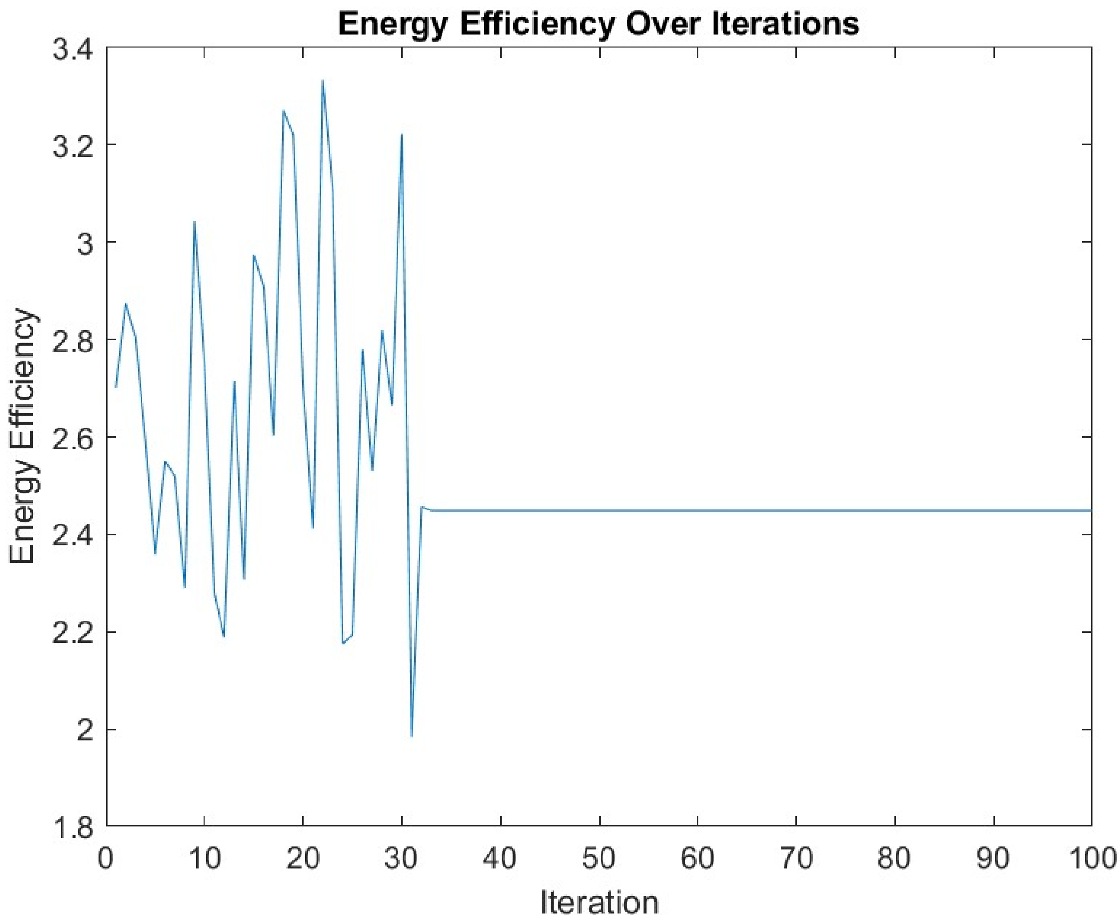


Figure 5.5: Graphical Representation of the Simulation

The graph shows the energy efficiency of a system after 100 iterations, revealing an unexpected dynamic in its performance. Initially, the energy efficiency exhibits severe variations, including a sudden drop into low values followed by a peak, indicating an unstable start, potentially due to initial random or inadequate resource allocations. Following these first oscillations, the graph quickly stabilises and flattens out, suggesting that the system has reached a consistent level of energy efficiency. This behaviour could indicate that the resource allocation algorithm quickly discovered an efficient configuration or reached a local optimum.

5.3 LOAD BALANCING IN HETEROGENEOUS WIRELESS NETWORKS

Simulation Parameters -

```
% Number of access points and devices
numAPs = 5;     % Number of Access Points
numDevices = 50;  % Number of Devices

% Generate random positions for APs and Devices in a 2D area
APs = 100 * rand(numAPs, 2);       % AP coordinates
Devices = 100 * rand(numDevices, 2); % Device coordinates

% Capacity of each Access Point
APCapacity = repmat(15, numAPs, 1);  % Each AP can handle 15
 devices

% Assign Devices to Access Points based on proximity and
capacity
APLoad = zeros(numAPs, 1);   % Current load on each AP
DeviceAP = zeros(numDevices, 1);  % AP each device is
connected to
```

- Define the number of access points and devices.
- For both access points and devices.
- Assign each device to the closest access point unless it exceeds the capacity, then reassign to the next closest.
- Plot the network showing devices connected to their respective access points.

Output:

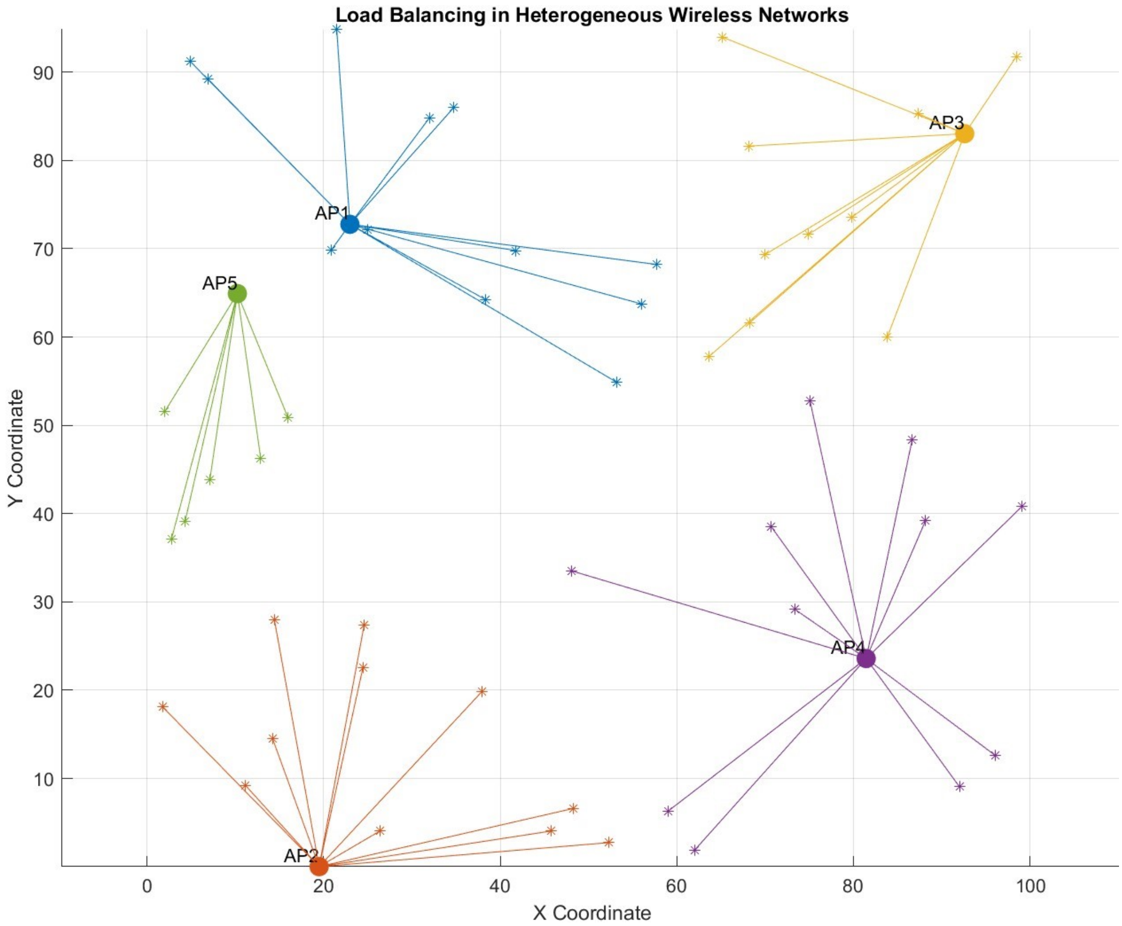


Figure 5.6: Load Balancing Plotting

Comparing two distinct load balancing methods in a simulated network environment:

- Least Connections (LC)
- Least Response Time (LRT)

Initialization of Network Elements: The network is composed of a fixed number of nodes and devices, in which each one has a random position over a specific area, representing a typical spread over the real world.

Least Connections Output:

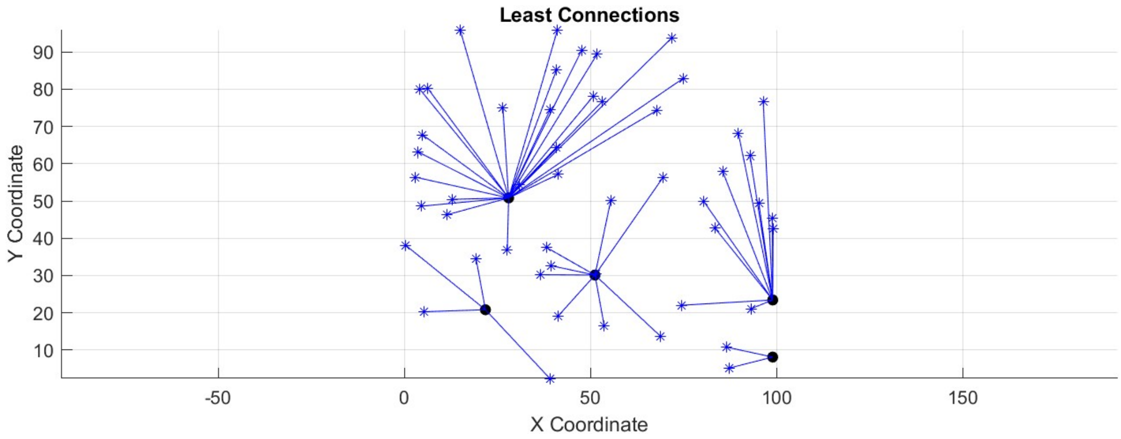


Figure 5.7: Least Connections

Least Response Time Output:

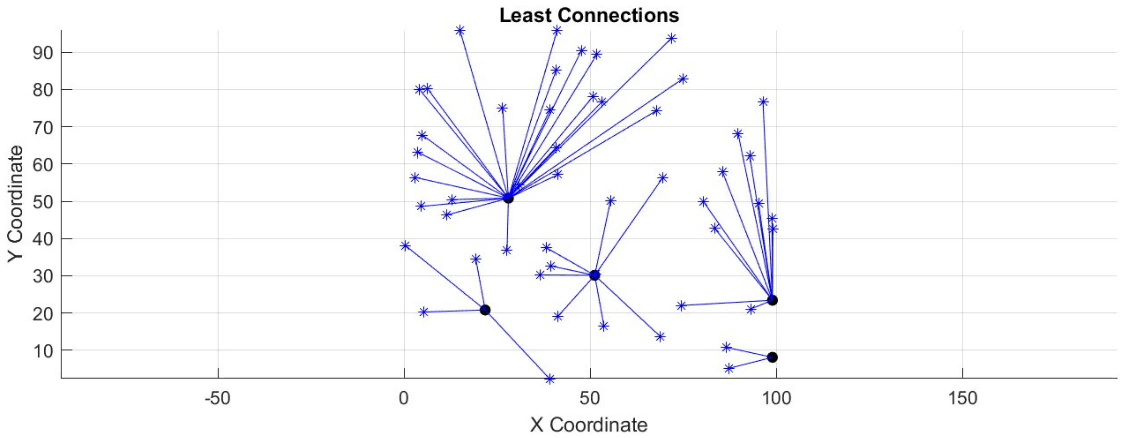


Figure 5.8: Least Response Time

5.4 SECURITY IN HETEROGENEOUS WIRELESS NETWORKS

To Simulate the Security in Heterogeneous wireless Networks we have used "Kali Linux" and "Wireshark".

Simulation Using Python (Scapy Library):

Generating Malicious HTTP Request -

```
def send_malicious_http_requests(target_ip, port,
num_requests):
    """Simulate multiple HTTP requests that might look
    suspicious."""
    for _ in range(num_requests):
        random_data = generate_random_data(10)
        payload = f"GET / HTTP/1.1\r\nHost: {target_ip}\r\
        nCookie: session={random_data}\r\n\r\n"
        packet = IP(dst=target_ip)/TCP(dport=port, sport=
        random.randint(1024,65535))/Raw(load=payload)
        send(packet, verbose=0)
```

The above script sends a series of HTTP GET requests to a specified target IP address. This type of activity can mimic behavior typical of reconnaissance attacks or attempts to exploit vulnerabilities in web application that might rely on cookie data.

Simulating Login Attempts -

```
def send_login_attempts(target_ip, port, num_attempts):
    """Simulate multiple failed login attempts."""
    for _ in range(num_attempts):
        username = generate_random_data(8)
        password = generate_random_data(12)
```

```
payload = f"POST /login HTTP/1.1\r\nHost: {target_ip
}\r\nContent-Type: application/x-www-form-urlencoded
\r\nContent-Length: {len(username) + len(password) +
 9}\r\n\r\nusername={username}&password={password}"
packet = IP(dst=target_ip)/TCP(dport=port, sport=
random.randint(1024,65535))/Raw(load=payload)
send(packet, verbose=0)
```

The above script sends multiple HTTP POST request aimed at a login endpoint, attempting to simulate a brute-force attack where an threat actor tries various Username and Password combinations to gain unauthorized access.

Monitoring Network Using Wireshark:

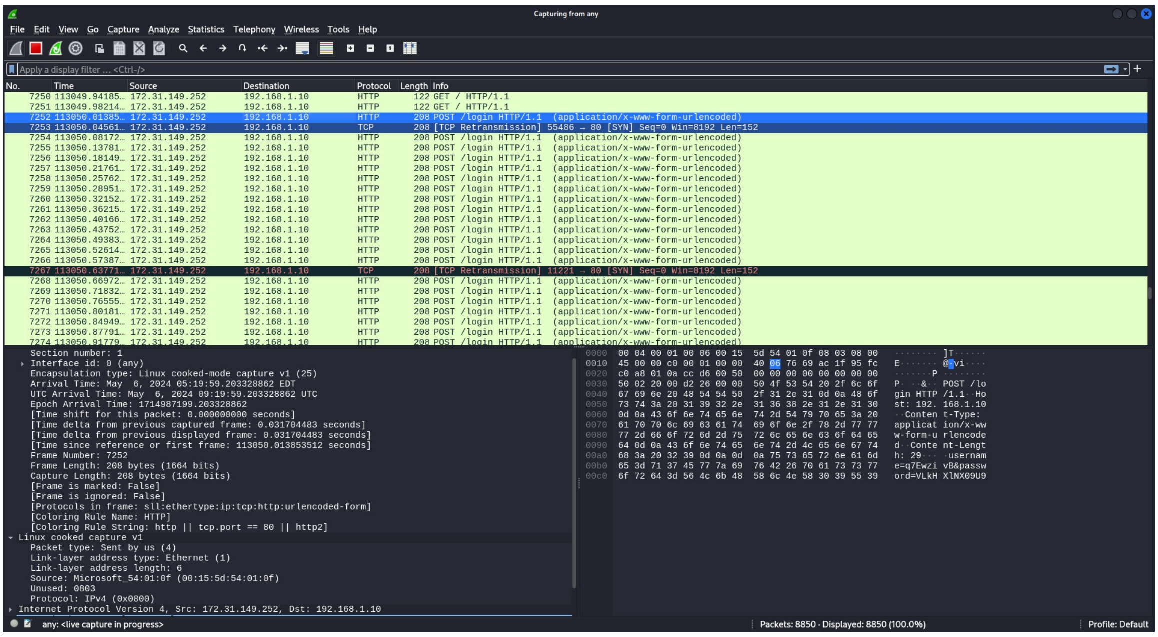
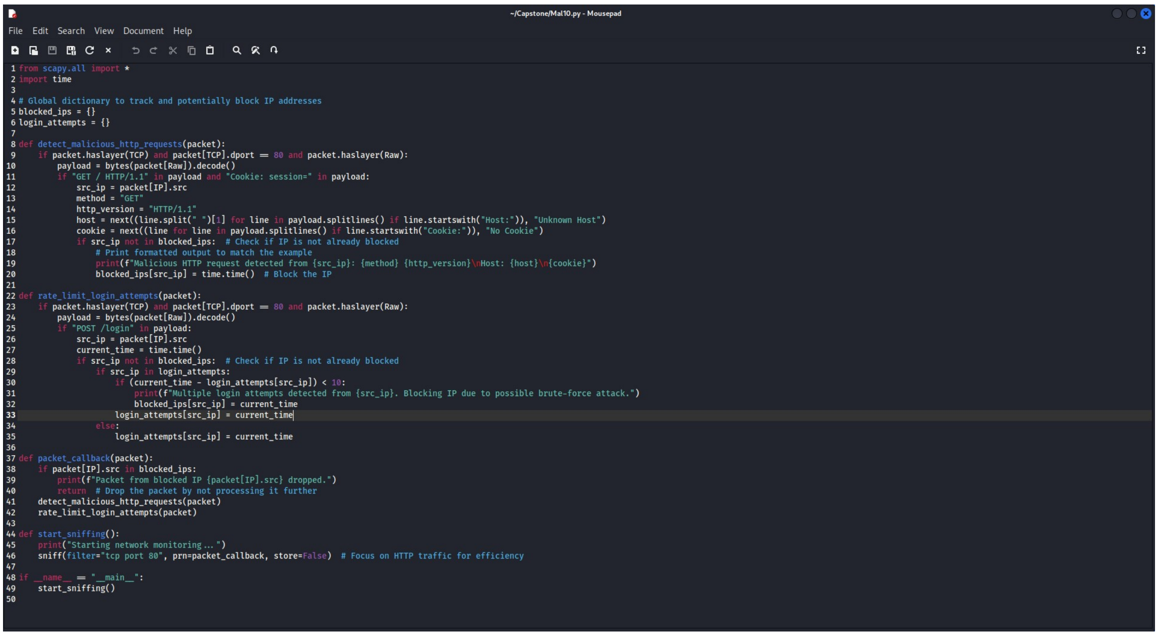


Figure 5.9: Malicious Traffic Captured by Wireshark

The Repetitive HTTP Requests and Login attempts that Wireshark captured can be malicious and cause a security breach in any network.

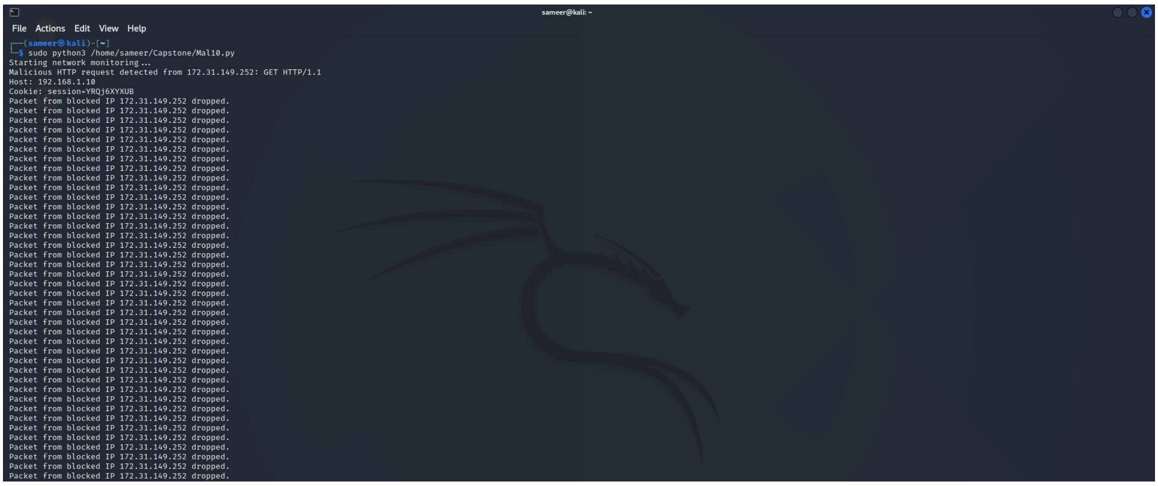
Using Scapy Script to Block Malicious Traffic -



```python
from scapy.all import *
import time

# Global dictionary to track and potentially block IP addresses
blocked_ips = {}
login_attempts = {}

def detect_malicious_http_requests(packet):
    if packet.haslayer(TCP) and packet[TCP].dport == 80 and packet.haslayer(Raw):
        payload = bytes(packet[Raw]).decode()
        if "GET / HTTP/1.1" in payload and "Cookie: session=" in payload:
            src_ip = packet[IP].src
            method = "GET"
            http_version = "HTTP/1.1"
            host = next((line.split(" ")[1] for line in payload.splitlines() if line.startswith("Host:")), "Unknown Host")
            cookie = next((line for line in payload.splitlines() if line.startswith("Cookie:")), "No Cookie")
            if src_ip not in blocked_ips:  # Check if IP is not already blocked
                # Print formatted output to match the example
                print(f"Malicious HTTP request detected from {src_ip}: {method} {http_version}\nHost: {host}\n{cookie}")
                blocked_ips[src_ip] = time.time()  # Block the IP

def rate_limit_login_attempts(packet):
    if packet.haslayer(TCP) and packet[TCP].dport == 80 and packet.haslayer(Raw):
        payload = bytes(packet[Raw]).decode()
        if "POST /login" in payload:
            src_ip = packet[IP].src
            current_time = time.time()
            if src_ip not in blocked_ips:  # Check if IP is not already blocked
                if src_ip in login_attempts:
                    if (current_time - login_attempts[src_ip]) < 10:
                        print(f"Multiple login attempts detected from {src_ip}. Blocking IP due to possible brute-force attack.")
                        blocked_ips[src_ip] = current_time
                    login_attempts[src_ip] = current_time
                else:
                    login_attempts[src_ip] = current_time

def packet_callback(packet):
    if packet[IP].src in blocked_ips:
        print(f"Packet from blocked IP {packet[IP].src} dropped.")
        return  # Drop the packet by not processing it further
    detect_malicious_http_requests(packet)
    rate_limit_login_attempts(packet)

def start_sniffing():
    print("Starting network monitoring...")
    sniff(filter="tcp port 80", prn=packet_callback, store=False)  # Focus on HTTP traffic for efficiency

if __name__ == "__main__":
    start_sniffing()
```

Figure 5.10: Scapy Script to Detect and Block Malicious Traffic

Output:



```
┌──(sameer㉿kali)-[~]
└─$ sudo python3 /home/sameer/Capstone/Mal10.py
Starting network monitoring...
Malicious HTTP request detected from 172.31.149.252: GET HTTP/1.1
Host: 192.168.1.10
Cookie: session=YRQj6XYXUB
Packet from blocked IP 172.31.149.252 dropped.
Packet from blocked IP 172.31.149.252 dropped.
Packet from blocked IP 172.31.149.252 dropped.
Packet from blocked IP 172.31.149.252 dropped.
Packet from blocked IP 172.31.149.252 dropped.
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Packet from blocked IP 172.31.149.252 dropped.
Packet from blocked IP 172.31.149.252 dropped.
Packet from blocked IP 172.31.149.252 dropped.
```

Figure 5.11: Blocking Malicious Traffic

Chapter 6

HARDWARE/ SOFTWARE TOOLS USED

6.1 MATLAB

MATLAB (Matrix Laboratory) is a powerful programming language for technical computing. It combines computing, visualisation, and programming in an easy-to-use environment where problems and answers are expressed in standard mathematical notation.

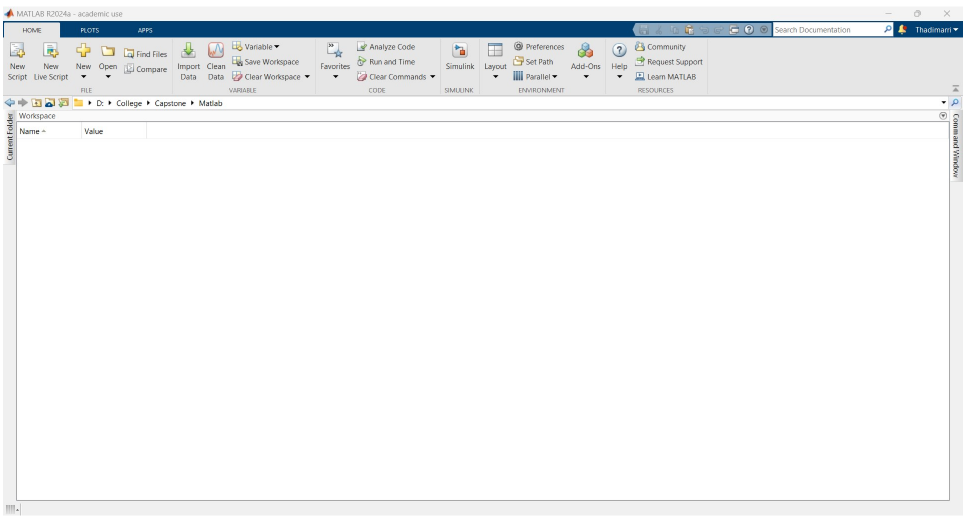


Figure 6.1: Matlab Interface

In the HWNs project, MATLAB was the major programming environment. It was chosen because of its advanced mathematical and engineering tools, which are perfect for modelling and simulating complicated systems.

6.2 FUZZY LOGIC TOOLBOX (FIS/FUZZY WITHIN MATLAB)

The Fuzzy Logic Toolbox includes tools for creating systems using fuzzy logic algorithms. This toolkit includes fuzzy inference systems (FIS), which allow you to describe complicated system behaviours using simple logical principles when the processes are too complex for typical quantitative studies.

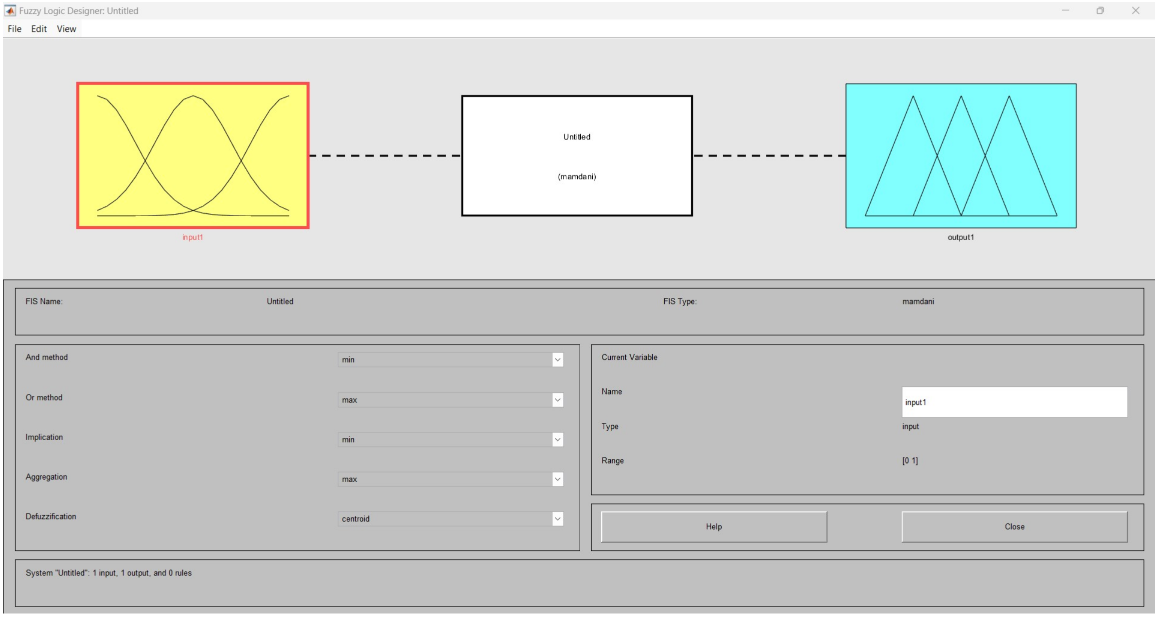


Figure 6.2: Fuzzy Logic Toolbox

The toolbox was used to create, analyse, and simulate systems using fuzzy logic. The project used this toolbox to handle decision-making processes where accurate inputs are difficult to collect or the linkages between input and output are ambiguous.

6.3 KALI LINUX AND WIRESHARK

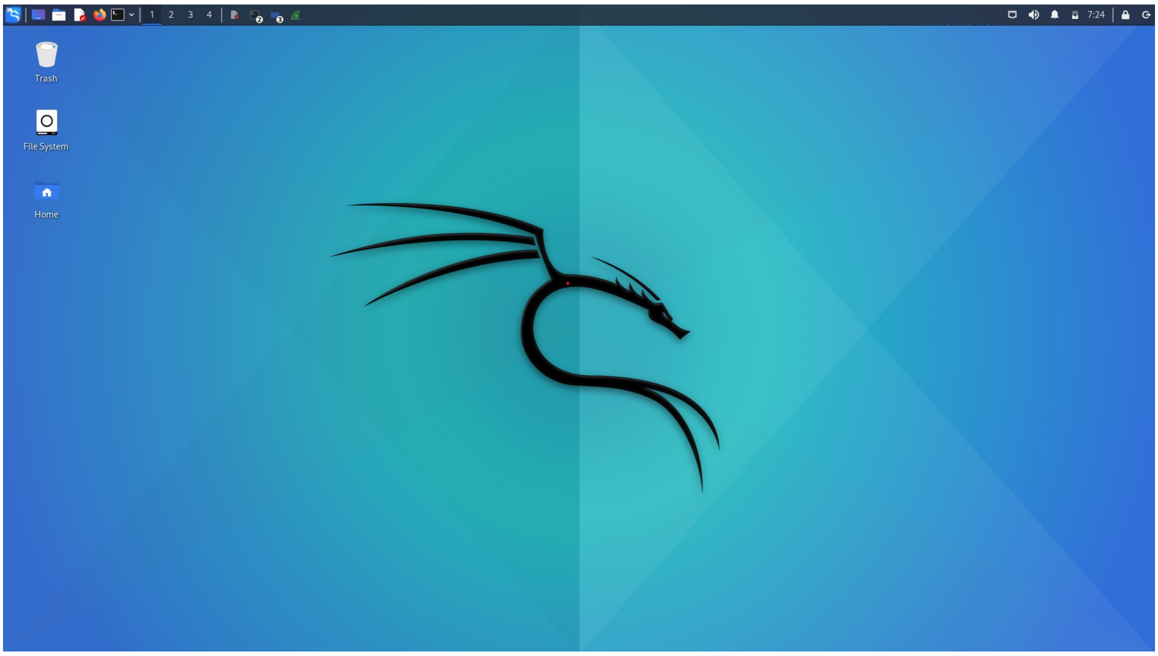


Figure 6.3: Kali Linux

Kali Linux is a widely used Linux distribution that is specifically developed for penetration testing, digital forensics, and security auditing. With over 300 open-source tools, it has emerged as one of the major penetration testing platforms

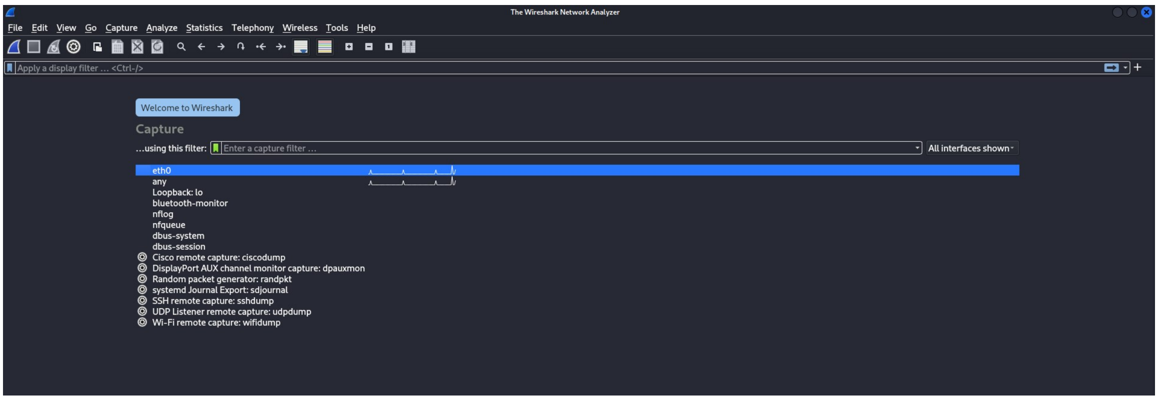


Figure 6.4: Network Monitoring and Analysis Tool

Chapter 7

RESULTS & DISCUSSION

7.1 NETWORK SELECTION IN HETEROGENEOUS WIRELESS NETWORKS

Network Selection Using Fuzzy Logic -

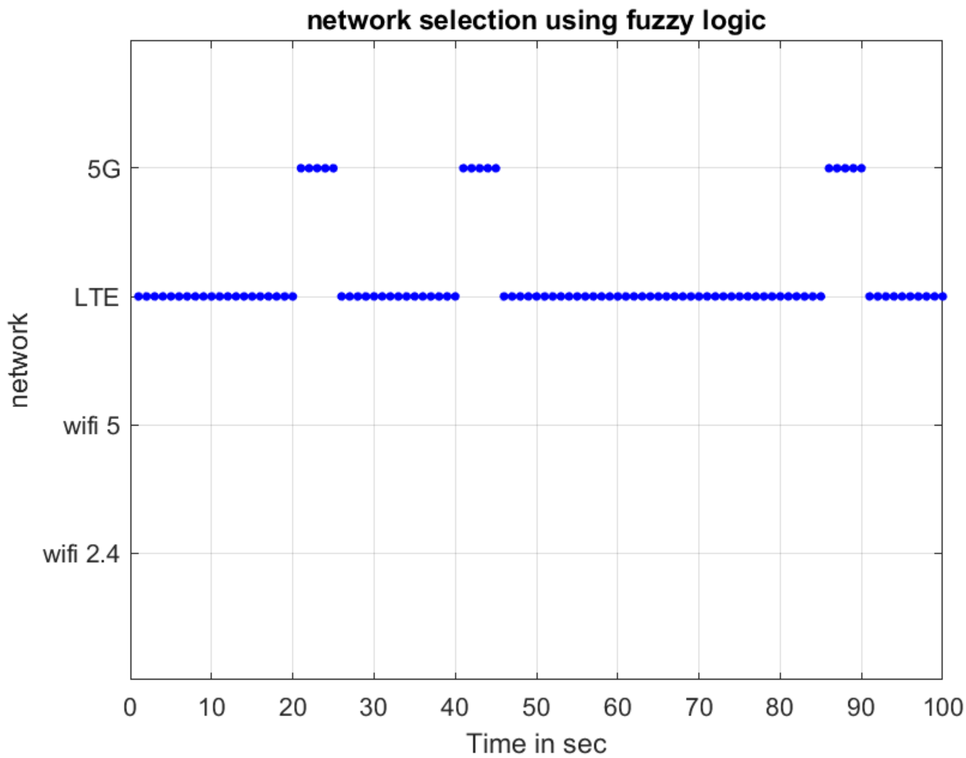


Figure 7.1: Fuzzy Logic Implementation

This is a graphical representation of network selection in fuzzy logic, which is an effective and reliable method of managing network connectivity for 100 seconds. This chart compares all types of networks, including 5G, LTE, WiFi 5, and WiFi 2.4. Each of them is represented by a blue dot within the specified time period. Such stability would result in fewer disruptions and potentially a higher quality of experience due to a dependable and efficient connection.

Network Selection Using AHP (Analytic Hierarchy Process) -

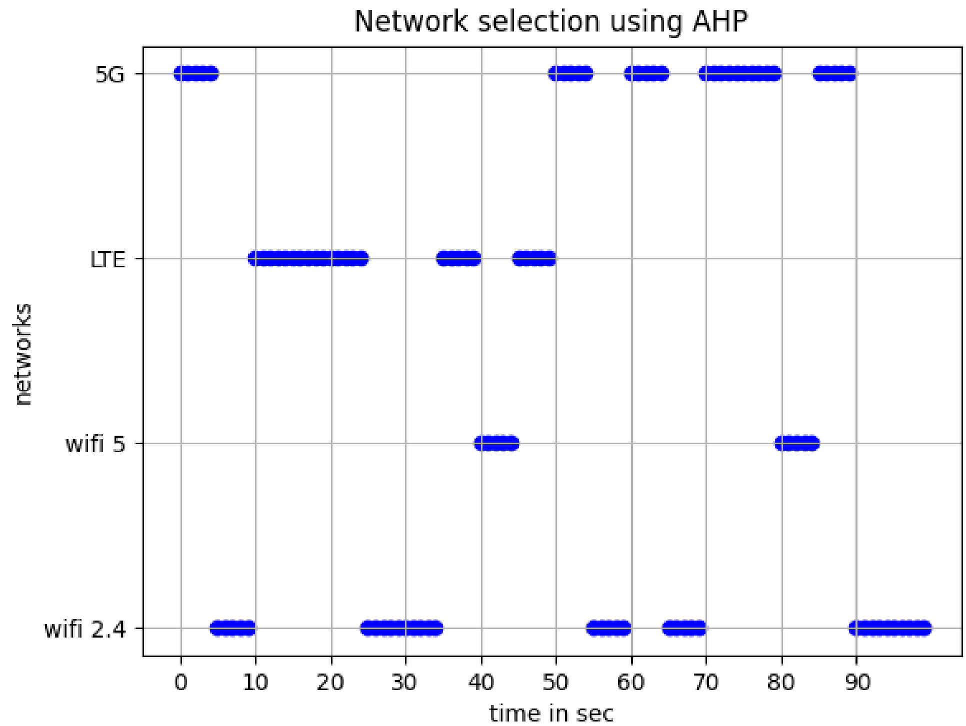


Figure 7.2: AHP Implementation

The image above demonstrates network selection using the Analytic Hierarchy Process (AHP). AHP's selection of networks, which include 5G, LTE, and multiple WiFi bands, is significantly more consistent than fuzzy logic's. This increased frequency of network modifications may result in increased network management costs and disruption of user experiences, perhaps jeopardising less reliable connectivity. In this comparison, fuzzy logic appears as the best technique for ensuring more consistent and stable network selection, as well as improving reliability while reducing the complexity associated with frequent network handovers.

Fuzzy Logic vs AHP (Analytic Hierarchy Process) -

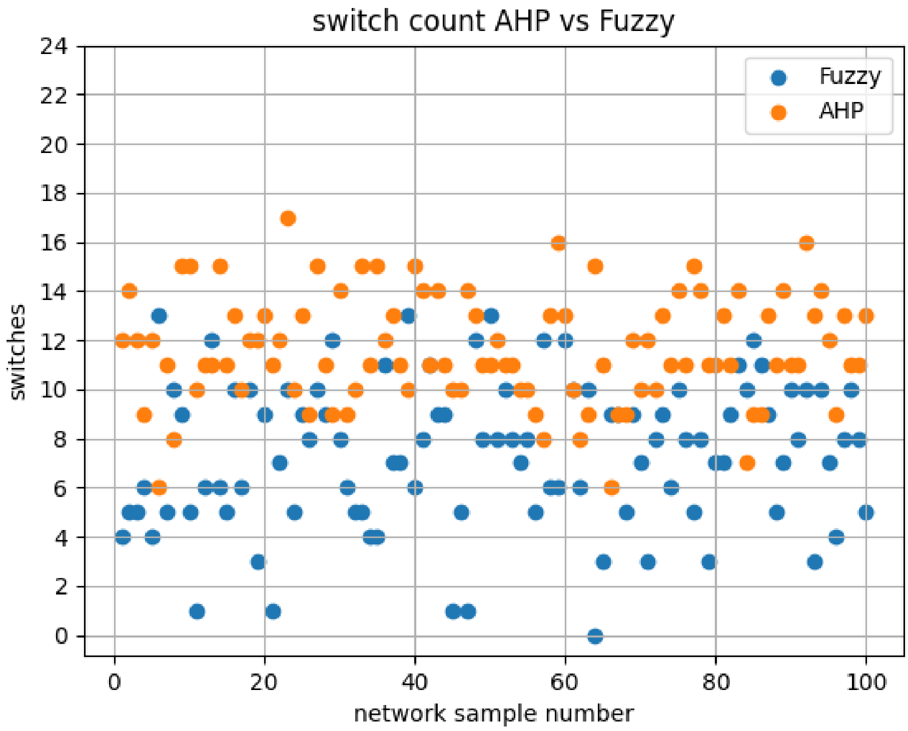


Figure 7.3: Fuzzy Logic vs AHP

In this simulation, the performance of two approaches in network condition management Fuzzy Logic and the Analytic Hierarchy Process (AHP) is considered in four different types of networks. The conditions for the networks of more than one hundred were generated for each, and then these two methods were applied iteratively. The results below show clearly that the Fuzzy Logic approach resulted in a substantial benefit, in this case bringing about a constant reduction of about 50 percent of switches in most iterations. Since the values generated are very close to practical life, this approach of Fuzzy Logic has more potential for better performance when tested on real network data. The use of the Fuzzy Logic approach in the future may be usable for further enhancement by integrating it with AHP. This dual approach can ideally reduce switches by up to 80 percent, hence assuring even more efficient network management. These findings will form the basis of the incorporation of such methods into the handoff software for mobile devices like cell phones. Dynamic testing in motion can offer an all-embracing solution regarding mobility management across different situations of the network if integrated under such conditions.

Standard Energy-Efficient Resource Allocation -

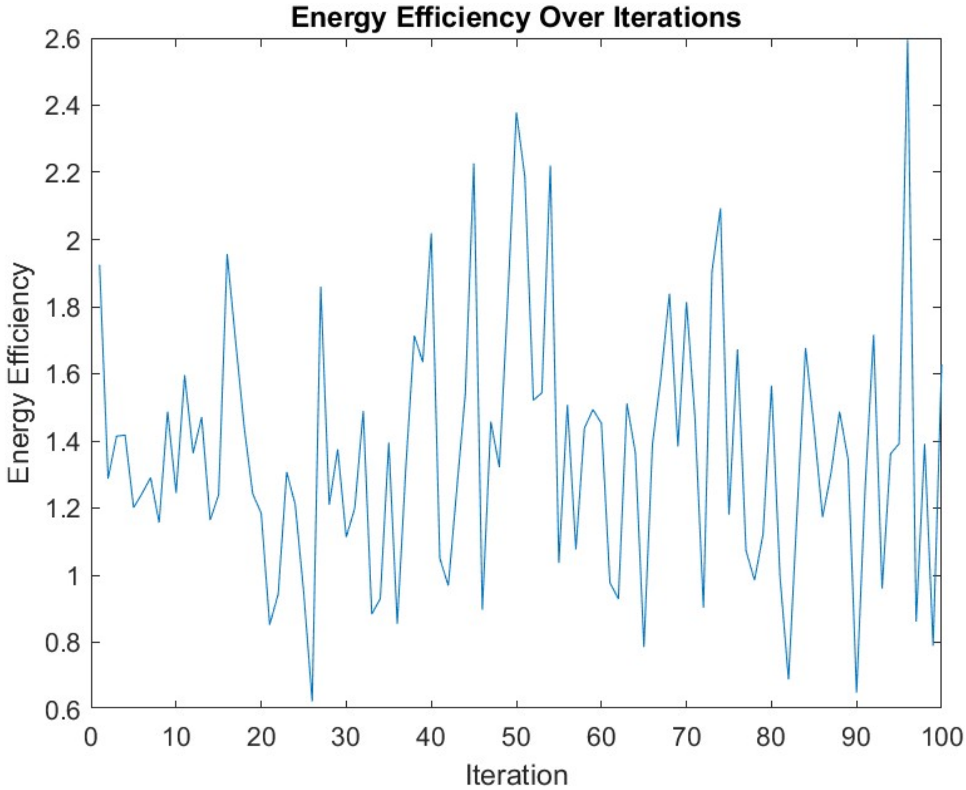


Figure 7.4: Standard Model

The simulation's random resource allocation mechanism has severe flaws, notably due to a lack of predictability and stability in network performance. Such unpredictability can be especially problematic in real-world applications where dependable and consistent service quality is required.

Energy-Efficient Resource Allocation with Feedback Mechanism (Our Implementation) -

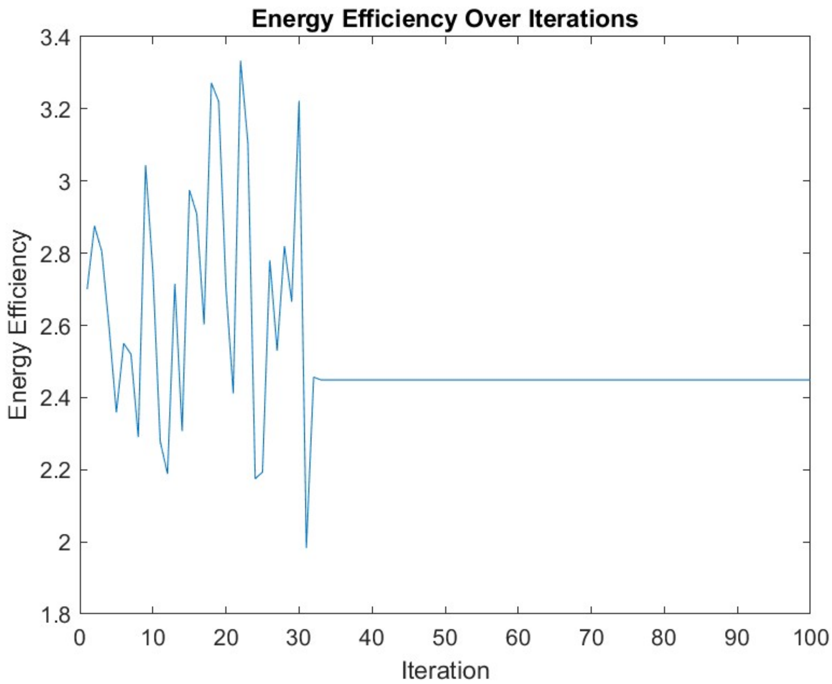
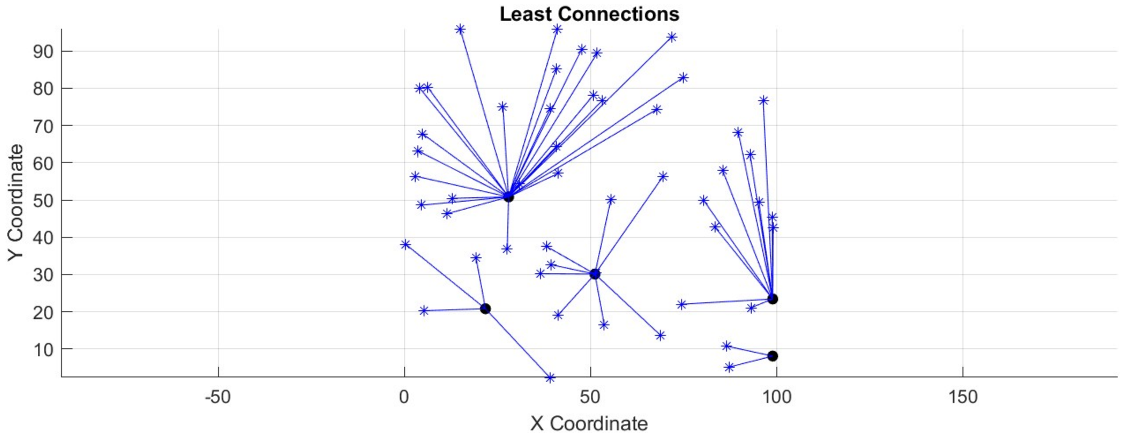
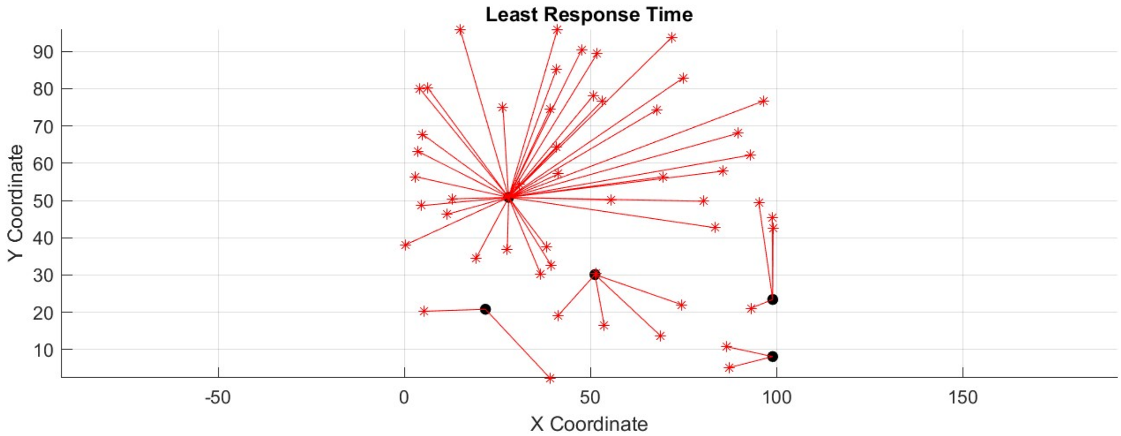


Figure 7.5: Feedback Mechanism Model

The updated simulation approach includes a feedback system that uses historical data to inform future decisions, thereby improving the allocation strategy. In contrast to earlier simulations, this strategy attempts to use the best observed allocations to maintain or enhance energy efficiency. The enhanced model has Best Allocation Memory, Conditional Allocation Strategy, Feedback Loop. The strategic improvement of the enhanced simulation technique in comparison to pure random allocation employs a learning process that capitalises on previous successful resource deployment for future resource distribution. Unless the feedback mechanism is intrinsically structurally implemented or the initial conditions or set parameters predispose the system to a disadvantage in learning and adaptation, such an approach should perform better in increasing and ensuring constant energy efficiency if carried out optimally.





Least Connections (LC) This method routes incoming traffic or requests to the server, or network node, with the fewest active connections or ongoing tasks. Focuses on balancing the number of connections among servers, assuming that this will naturally distribute the workload evenly.

Least Response Time (LRT) This method directs traffic to the server that currently has the shortest response time. It continuously monitors the response time of all servers and chooses the one that can respond the quickest at that moment. Focuses on performance and speed, aiming to reduce latency by choosing the fastest available server at any given time.

Chapter 8

CONCLUSION

Fuzzy logic turns out to be an appropriate technique in the midst of a complex decision-based process within a changing, heterogeneous wireless network. This capability enables it to handle uncertainty and partial truths, which makes it improve the user experience by assuring quality in the transmission of data without drops in connections. If fuzzy logic is employed, the outcome of network selection may be improved connectivity and stability, optimal use of bandwidth, and reduction of power consumption for a sustainability-oriented choice toward seamless mobile connectivity.

However, the flexibility and adaptability of fuzzy logic within such real-time and rapidly changing network environments continue to escape the assistance of the Analytic Hierarchy Process (AHP) in breaking down a complex decision into simpler, quantifiable elements. Fuzzy logic stands better in network selection because it can flexibly handle changing parameters and remains resilient despite incomplete data. Its continuous assessment and network selection process will ensure network stability and increase user satisfaction. This contrast underscores the importance of choosing the right decision-making framework based on the specific dynamics of the network environment.

The efficient assignment of resources in an energy-efficient manner to the multi-homed user equipment systems in the heterogeneous wireless network is an area of study. This paper explores the problem under consideration to maximize energy efficiency (EE) as a mixed-integer nonlinear optimization problem and proposes a novel two-phased optimization approach that enables balancing computational complexity against performance efficacy.

The simulation outcomes affirm that while the proposed suboptimal algorithm achieves significantly lower computational burdens compared to the optimal algorithm, it does not considerably sacrifice EE, ensuring that it remains competitively close to the ideal efficiency metrics achieved by more computationally intensive approaches. This balance underscores the potential of applying such methodologies in real-world scenarios where computational resources are limited but efficiency cannot be compromised, highlighting the practical implications for future wireless network designs that aim to support high-density data traffic with optimal resource utilization.

Security issues in Heterogeneous Wireless Networks are at their peak since these networks are always prone to a number of cyber threats due to their extensive use and sensitivity towards the data they carry. The simulation, according to the provided documentation, is going to use tools such as Kali Linux and Wireshark to identify and examine malicious activities, like floods of HTTP GET requests and brute-force login attempts.

In this setup, the generation of malicious traffic is demonstrated by the use of Python scripts with the Scapy library, which can then be detected and even prevented through blocking by the Snort and iptables firewall.

This proactive approach to simulating security measures helps understand not only the vulnerabilities but also the required defense for real-world deployment in unpredictable environments, reiterating the need for updated security protocols in view of the continuous change in security threats.

8.1 SCOPE OF FURTHER WORK

The scope for further work in the field of heterogeneous wireless networks (HWNs) offers numerous opportunities for research and development. Here are some potential areas for further exploration:

Advanced Decision-Making Algorithms: Investigate the possibility of integrating more advanced decision-making algorithms, such as machine learning and deep learning, for network selection and allocation of resources. Such could further optimize the efficiency of networks and the experiences of users based on real-time data analysis.

IoT and Edge Computing Integration: IoT devices and edge computing have revolutionized the hardware used in dealing with huge chunks of data at the edge of the network. Research may be focused on how to optimize such networks for greater loads and better data processing closer to the source.

5G and Beyond: It is thus imperative to consider how HWNs will need to evolve to support these new types of networks as research on 6G technology begins. The challenges include higher frequencies, massive device connectivity, and ultra-reliable low-latency communications.

REFERENCES

[1] **R. Ferrús, O. Sallent, and R. Agustí**, "Interworking in heterogeneous wireless networks: Comprehensive framework and future trends," in *IEEE Wireless Communications*, no. 1, pp. 1-2, April 2010.

[2] **F. Bendaoud, M. Abdennebi, and F. Didi**, "Network Selection schemes in Heterogeneous Wireless Networks," Laboratory of Telecommunication Tlemcen (LTT), Technology's Faculty, Tlemcen's University, and Laboratory of Processing and Transmission of Information (L2TI), Physics Department, University of North Paris, 2023.

[3] **T. Sylla, L. Mendiboure, S. Maaloul, H. Aniss, M. A. Chalouf, and S. Delbruel**, "Multi-Connectivity for 5G Networks and Beyond: A Survey," in *Sensors*, vol. 22, pp. 1-32, October 2022.

[4] **C. Monteiro, V. Rios, and P. R. L. Gondim**, "Use of Fuzzy Logic for Networks Selection in Heterogeneous Wireless Environment," in *Proceedings of the International Conference on Advanced Communication Technology (ICACT)*, February 2012.

[5] **R. Liu, M. Sheng, and W. Wu**, "Energy-Efficient Resource Allocation for Heterogeneous Wireless Network With Multi-Homed User Equipments," *IEEE Access*, 2018.

[6] **R. Liu, M. Sheng, and W. Wu**, "A Survey on Resource Allocation for 5G Heterogeneous Networks," *IEEE Access*, 2018.

[7] **Wenxiao Shi, Bin Li, Na Li, and Chuanjun Xia**, "A Network Architecture for Load Balancing of Heterogeneous Wireless Networks," *Journal of Networks*, April 2011.

[8] **Y. Zhang, J. Chen, and X. Wang**, "Security-Aware Cross-Layer Resource Allocation," *IEEE Transactions on Mobile Computing*, 2023.

[9] **F. Bari and V. Leung**, "Automated Network Selection in a Heterogeneous Wireless Network Environment," *IEEE Network*, vol. 21, no. 1, pp. 34–40, 2007.

[10] **A.L. Ramaboli, O.E. Falowo, and A.H. Chan**, "Bandwidth Aggregation in Heterogeneous Wireless Networks: A Survey of Current Approaches and Issues," *Journal of Network and Computer Applications*, 2012.

[11] **A. Monteiro, E. Souto, R. Pazzi, and M. Nogueira**, "Context-aware network selection in heterogeneous wireless networks," *Computer Communications*, vol. 135, pp. 1–15, 2019.

[12] **R. Arshad, M. Farooq-i-Azam, R. Muzzammel, A. Ghani, and C.H. See**, "Energy Efficiency and Throughput Optimization in 5G Heterogeneous Networks," *Electronics*, 2023.

[13] **M.I. Goh, A.I. Mbulwa, H.T. Yew, A. Kiring, S.K. Chung, A. Farzamnia, A. Chekima, and M.K. Haldar**, "Handover Decision-Making Algorithm for 5G Heterogeneous Networks," *Electronics*, 2023.

[14] **Shobanraj Navaratnarajah, Arsalan Saeed, Mehrdad Dianati, and Muhammad Ali Imran**, "Energy Efficiency in Heterogeneous Wireless Access Networks," *IEEE Access*, 2013.