TOPOLOGY-BASED APPROACH EVALUATION FOR WIRELESS SENSOR NETWORK

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TOPOLOGY – BASED APPROACH EVALUATION FOR WIRELESS SENSOR NETWORK

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DECLARATION

I declare that this report entitled "Topology-Based Approach Evaluation for Wireless Sensor Network" is the result of my own work except for quotes as cited in the references.

Signature : ………………………………….

Author : Revathi Manivanan

Date : 14 JUN 2021

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature : ....

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Date : 25/6/2021

DEDICATION

To my beloved parents Mr. Manivanan and Mrs. Vasanthy, family members and fellow friends.

ABSTRACT

The Wireless Sensor Network (WSN) is used to gather data and analyze environmental conditions like vibration, motion, sound, temperature, and many more. Topologies rules how a sensor node communicates with other sensor nodes in a network. There are several types of topology patterns like bus, hybrid, tree, ring, and more. Therefore, the aim of this project is about finding the best topology for WSN system. Ant Colony Optimization (ACO) algorithm is used in choosing the best topology for WSN. Hence, mesh topology is choose as the topology when compared to tree and star topology. Mesh topology is approaching in minimize energy consumption and minimize the communication latency where the throughput is more stable. The software used in designing the programmes is MATLAB software, where the code is constructed. The aim of these study is to choose the best topology in optimize the energy and to ensure the efficiency of energy and life longevity of WSN system. The WSN system can effectively pass data to a center location without losing information.

ABSTRAK

Wireless Sensor Network (WSN) digunakan untuk mengumpulkan data dan menganalisis keadaan persekitaran seperti getaran, gerakan, bunyi, suhu, dan banyak lagi. Topologi mengatur bagaimana simpul sensor berkomunikasi dengan nod sensor lain dalam rangkaian. Terdapat beberapa jenis corak topologi seperti bas, hibrid, pokok, cincin, dan banyak lagi. Oleh itu, tujuan projek ini adalah untuk mencari topologi terbaik untuk sistem WSN. Algoritma Ant Colony Optimization (ACO) digunakan dalam memilih topologi terbaik untuk WSN. Oleh itu, topologi mesh dipilih sebagai topologi jika dibandingkan dengan topologi pokok dan bintang kluster. Topologi mesh semakin hampir dalam meminimumkan penggunaan tenaga dan meminimumkan latensi komunikasi di mana throughput lebih stabil. Perisian yang digunakan dalam merancang program adalah perisian MATLAB, di mana kodnya dibina. Tujuan kajian ini adalah untuk memilih topologi terbaik dalam meningkatkan penggunaan tenaga dan untuk memastikan kecekapan tenaga dan umur panjang sistem WSN. Sistem WSN dapat menyebarkan data ke lokasi pusat dengan berkesan tanpa kehilangan maklumat.

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LIST OF SYMBOLS AND ABBREVIATIONS

WSN	:	Wireless Sensor Network
MATLAB	:	Matrix Laboratory
FFD	:	Full Function Devices
RFD	:	Reduced Function Devices
PIT	:	Packet Interval Time
LAN	:	Local Area Network
MEMS	:	Micro-Electro-Mechanical-System
ACO	:	Ant Colony Optimization
PEGASIS	:	Power Efficient Gathering in Sensor Information Systems
EECCPAR	:	Energy Efficient Clustered Chain based Power Aware Routing
Tg	:	Throughput
Db	:	Byte data
PLT	:	Packet Loss

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CHAPTER 1

INTRODUCTION

This thesis proposes the topology-based approach evaluation for a wireless sensor network. This chapter will discuss the project background, project objectives, problem statement of this project, and scope of work.

1.1 Background of Project

Wireless Sensor Network (WSN) has become an innovative technology with a wide variety of possible applications, including surveillance of the environment, object detection, scientific observation and forecasting, traffic management, etc. A WSN consists of many nodes that divided themselves into a group of wireless multi-hop network and these nodes will carry out a shared mission[1]. WSN is flexible and networked, with very little power needed. It is modish and programmable software which can also acquire data efficiently, consistently and effectively over the long term. Still, it is affordable to purchase and build and does not need any maintenance. In an unlimited range of possible implementations, WSN has the potential: e.g. for military applications; it can be used for the border and battlefield monitoring, tracking and surveillance; in the factory instrumentation and weapons industry; monitoring traffic and road conditions in large cities; monitoring patient conditions and hospitals in the healthcare industry; monitoring road conditions in civil engineering; and monitoring forest, oceans, bird migration, animals movement, precision agriculture, and bushfire detection in the environment. Management of complicated physical systems, like as airplane wings, and complex ecosystems are examples of other uses [2].

WSN consists of several autonomous sensor nodes spatially distributed and capable of monitoring physical characteristics. Sensor nodes connect the physical and digital worlds by recording and disclosing real-world events and transforming them into data that can be analyzed, saved, and acted upon. Data is acquired and sent by any sensor node. The data collected is sent to a supervisory system that assists the customer in finding the solutions to decision-making issues, such as maximizing the organization of services (trucks, personnel and specialized machinery), with the primary goal of minimizing costs. There are sensing modules in the wireless sensor node and on-board processing devices, chip radios, and storage units. With these developments, a sensor node is also responsible for gathering data and processing in-network data based on its integration and fusion with those collected from other nodes. Besides, sensor nodes with different data rates and latencies may vary in their communication capabilities[3]. The research started with the development of a sensor node a few years ago. This technology is still used in many fields since the evolution and enhancement of emerging technologies. The most crucial fact about sensor networks than traditional networks is that they are limited in resources, computing capabilities, and memory, which is the main reason for these networks popularity these days. Therefore, as wireless sensors become essential commodities in the electronic economy, new proposals for old technologies cause network solutions to be considered by engineers, analysts and IT specialists once they have been excluded[4].

In WSN, the topology is a crucial element that plays a vital role in minimizing various constraints like limited energy, latency, computational resource crisis, and communication quality. The amount of energy used by these networks is determined by the number of packets transmitted and received. The transmitting energy usage, on the other hand, is determined by the distance between the sender and destination nodes, with packet size frequently playing a key role. It can be managed using practical routing algorithms, but the network topology has set the initial stage[4]. The topology governs the protocol that allows each node to regulate energy transfer. Each node should be able to manage the amount of transmission power it uses. However, while having transmission power control, the algorithm should ensure that neighbouring nodes are reached that are instantly linked within a high transmission power range.

1.2 Problem Statement

The number of nodes, the power consumption, the life cycle of the sensors, the information to be detected and its timeliness, the position of the sensors, the environment, and the backdrop of the sensor all influence the development complexity of a WSN [6]. Currently, research in WSN clustering algorithms is focused on two aspects: clustering techniques and energy savings, with little emphasis devoted to future development [7]. Researchers only take into account the assessment of data obtained from sensor nodes that uses the least amount of energy and decreases energy consumption to improve performance [20],[9].

Besides, researchers focus on the current consumption, maximum throughput, packet error rate and the delay for each unit of WSN[10]. Therefore, it is important to look after few aspects of WSN system like optimizing the energy, ensuring the life longevity and efficiency of the energy used. Furthermore, the neighbour node table may be assessed and updated by gathering additional network nodes. The network name can be supplied to allow several WSNs to communicate with one another.

1.3 Objective

i. To stimulate the best WSN topology that can optimize the energy consumption for a system.
ii. To analyze the energy efficiency and life longevity of the WSN system.

1.4 Scope of Project

This study will be focusing on choosing the best topology for the wireless sensor network that can provide the best performance in a system. The topology proposed should satisfy the characteristics of optimizing energy, life longevity and efficient in energy. The parameters to be evaluated such as nodes, size of packet transmission (throughput), speed, maximum lifetime and energy consumption. The proposed topology also must be able to communicate among the sensor nodes reliably at the effective cost of deployment. This study is proposed using MATLAB to study the algorithm of the WSN topology and make some analysis on the performance of the proposed topology.

CHAPTER 2

BACKGROUND STUDY

This chapter presents a literature review of the relevant concept of this research and a summary of relevant recent researches.

2.1 Introduction

Wireless Sensor Network is broadly used to monitor physical and environmental conditions. Many researchers have been conducting advanced research to investigate the performance of different existing topologies of WSN. Since topology determines routing paths inherently, it indicates whether to use broadcast or unicast, deciding packet sizes and types and other overheads. Choosing the correct topology helps minimize the amount of contact necessary for a specific problem and saves resources. A useful topology that guarantees that neighbors are at a minimum distance. It decreases the possibility of a message being lost between sensors[4],[11]. Some researchers have suggested mesh, tree, and star topology are more suitable[12],[7],[13]. Each topology has its advantages and weakness in a specific working environment. Hence, it is essential to compare and evaluate each topology's effectiveness; a set of performance evaluation metrics is required[4]. Performance comparison and analyses of different topologies are made in throughput, end to end delay and packet drop rates. For a network with 250 nodes, it is found that up to around (230) nodes some topology is ideal for real time services in regarding the urgent healthcare signals with maximum stable[12]. It is stated that topology is stable and has the best optimization in the natural environment than other topology and presents no environmental problems.

This chapter reviews the concept of topology based WSN and the detailed study about the parameters. The WSN concepts, method and techniques are also discussed. Additionally, the research of best topology for WSN has included.

2.2 Introduction to WSN

WSN is a less cost, small-scale factor, smart sensor nodes, and receive great benefits. Not only can they be employed to track or manage the region in cumbersome and volatile areas of concern, but it can also be deployed to automate mundane activities. The sensing units were costly with lacking the computational and communication capability of current smart sensor nodes, both operated by a battery, which can detect, process, store and forward data. WSN applications demand different architectures and performance based on the parameters. Therefore, it must consider the intrinsic features of WSN and its smart sensor nodes for a detailed understanding of the various architecture and deployment techniques. This inherent WSN implementation's intrinsic design makes it difficult and inefficient to identify and delineate the taxonomy.

WSN are controlled with limited set of sensor device that distribute in indoor or outdoor environment. With all devices, network nodes can have real or logical communication; this communication forms a topology based on the application. For example, a WSN might have mesh, star, and other topologies with the same mesh, star, and other topologies. This may not always be the case anyway. The logical topology is primarily determined by the logical role or tasks of the nodes. It can be ad hoc or based on self-organization, clustering, and pheromone tracking as a technique. The network's available resources are used to define the strategy [6] [19].

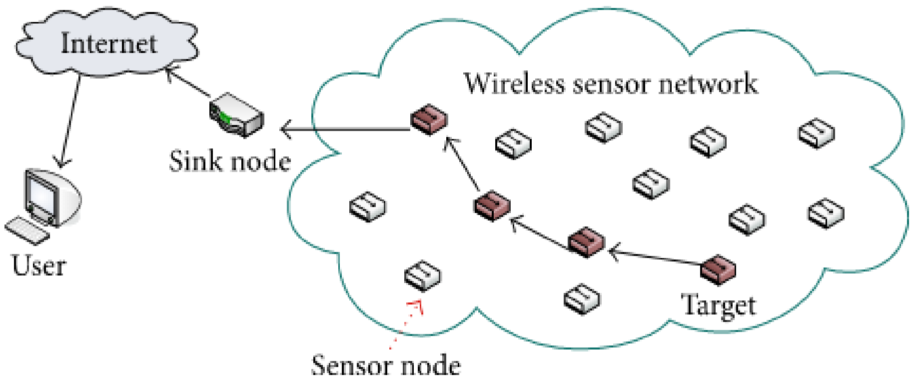

Figure 2.1: Wireless Sensor Network (WSN) architecture

2.3 Topology for WSN

Topology is introduced into Wireless Sensor Networks to reduce the power consumption in the nodes. Topology monitoring helps to remove long-distance connections without sacrificing the nodes access to the rest of the network too much[14]. Topologies for WSN are made with their descriptions. Previous research proved that star, mesh, chain, tree, and ring are the topologies that would be more suitable for WSN [5][12][18][21]. The best topology is analysed from the performance, parameter, and method/techniques of the topologies. Nodes are often dispersed at random, as the network architecture is determined by their location and connections. Nodes are the central topology divided into two main classes, which are Full Function Devices-FFD (Router node) and Reduced Function Devices-RFD (End node). The FFD supports a complete range of functions and could play a CN (Gateway) network coordinator or an ordinary computer. Besides, RFD is used as standard equipment at the same time. They also limited memory, computational power, and lower energy usage[15].

2.3.1 Parameters to measure the effective of Topology

Parameters are important in choosing the topology and the technique in creating a system. The parameters that should be considered are the network size (Area), number of nodes, packet size, packet interval time (PIT), initial energy and transmit power. It is important to identify the scalability, power consumption, fault tolerance, range and coverage of each topology.

2.3.1.1 Star Topology

Star topology based WSN is changed in a variety of factors, such as the number of nodes, packet size, and packet interval time, are used to assess the system. This is accomplished by raising the number of nodes and packet size to find the greatest performance while altering the packet interval time to find the best performance with the highest throughput. The best throughput for star is at 210 nodes number [16]. In star topology, communication takes place between end devices and the coordinator. The network size used is 100m x 100m with 230 numbers of nodes. Begin with 256 bytes of packet size and 1 second of packet interval time. The initial energy of 0.5J with transmits power of 0.1 Watt. Star topology is very suitable for biomedical applications which have fast delivery of information with a stable throughput and average power consumption [10].

2.3.1.2 Mesh Topology

Mesh is network with multi-hop local area networks (LAN) are networks in which each sensor node not only transmits and receives its own messages, but also acts as a router, relaying messages for its neighbours through the network. Multiple communication routes from the sensor nodes to the base station are also made possible [17]. The performance evaluation of mesh topology is done by measuring the parameters. The number of nodes used is 250 nodes with the initial energy of 0.5J. 176 bytes of packet size with the packet interval time of 0.1 second. Besides, the transmit power and transmission band of 0.1 Watt and 2.4GHz respectively. Has the most throughput stability and most flexible among the topologies [12]. Mesh topology approaches to minimize energy consumption and minimizing communication latency.

2.3.1.3 Tree Topology

Tree topology is will be constructed in pyramidal tree structure that varies from mesh and star topology. The coordinator is at the top of the network, while the other parent nodes are routers and the terminal nodes are end-devices. The performance evaluation of tree topology is done by measuring the parameters. The number of nodes used is 100 nodes with the initial energy of 0.5J. Therefore, 400 bits of packet size with the packet interval time of 0.1 second [5][8]. Researchers require to obtain in maximizing the network lifetime and optimize the coverage of WSN with its requirements.

2.3.2 Analysation of Parameters

The performance of topology is analysed with certain parameters. Firstly, the network size is very important to be chosen. 100m x 100m of network size is the most chosen in previous researches. The system nodes were distributed all over the chosen area. The number of nodes comes next. The number of nodes placed in a sensor field varies depending on the application and might range from a few to hundreds or thousands. Furthermore, node density can range from very sparse to very dense deployments. Furthermore, the node density of a WSN might vary dramatically owing to a variety of factors such as transitory or permanent node or connection failures, node mobility, or the redeployment of new nodes [17]. Data Packet Size will determine the performance and the stability of a network while the initial energy depends on the cases because the nodes are different in every scenario [22].

2.4 Review of WSN in a system

Sensor nodes in wireless network for communication are known as WSN. The sensor nodes are made by four components like radio, processor, sensors and battery. WSN is a network of Micro-Electro-Mechanical-System (MEMS) which contain the characteristics of self-computation, communication and sensing capabilities. By these capabilities WSN able to perform with all its functions that fits in certain application areas. WSN is mainly based on the wireless communication of data sensed by the sensor node to the administrations through internet with the channel of WSN technology. WSN is fully depends on the deployment method of sensor nodes with its architecture.

Besides, network is set up by deploying sensor nodes with similar or distinct features; the remainder of the operation is determined by the node's architecture and application mode. These networks feature sensor nodes that are specifically developed for a specific application based on the requirements and standards of the desired outcome. A sensor node's important functions include detecting data, conditioning the data, and then converting it to a format that can be sent to a processor. After that, the processor sends the processed data to another node for aggregation, and that node sends it to the base station, where it is sent to various destinations selected for it over the internet.

Therefore, due to many limitations, WSN allows innovative solutions and need non-traditional protocol design paradigms. Due to the requirement for minimal device complexity and low energy consumption, an acceptable balance between communication and signal/data processing capabilities must be found. The majority of WSN research is now focused on creating energy- and computationally efficient algorithms and protocols, with applications confined to simple data-oriented monitoring and reporting applications.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The fundamental of this project begins with the study of literature review and covers the method based on the topology. Literature studies have been conducted on WSN, topology, parameters that would be used in a WSN system and the related researches. Application and other related researches are framed in terms of all the journals, documents, books, articles and websites that are accessible.

The steps for choosing the best topology for WSN is into many part and it start from the theory before undergo the simulation as well as the parameters to be considered. Choosing topology by comparing it with referring to the parameters based on optimizing energy. Calculation based on parameters for the design is focused in this chapter. It is based on the configuration of the WSN in a system for design on software with specifications and simulation. The stages of designing the system are defined in this part, which started with modeling, simulation processes, and analysis using MATLAB software. The type of method for designing the system chose is mentioned in this chapter. The further procedure in determining the specified parameters and design of the system is outlined in this chapter including simulations and equations.

3.2 Flowchart

Project planning definitely a crucial action in carrying progress to the successive end. The proper project includes the workflow to be done before, in present and after in a sequential order. It creates a view and aware about the next step to take in proceeding the projects. The ways are drafting flowchart, or block diagram. The flowchart of this project is shown in the figure 3.1. The workflow is divided into five stages in designing this system. There are:

Stage 1: Literature Review

At the initial stage of this study, fundamental aspects WSN and the type of topology will be investigated. Performances of topology and the parameters will be studied include the techniques and algorithm for the system. The WSN system from relevant previous research has also been investigated in this stage. Simulation software such as Matrix Laboratory (MATLAB) will be familiarized during this stage.

Stage 2: Choosing Suitable Topology

The best topology will be choosing according to requirement based on the performance. The parameters of chosen topology will be discussed. The specification on the reference value of the parameters is investigated and will run the simulation in order to compare the performances of each topology. The parameter of the proposed system such packet transmission, number of nodes, and router nodes is specified. ACO (Ant Colony Optimization) algorithm is used.

Stage 3: Software Simulation

In this stage, simulation and optimization process using MATLAB software are performed for the proposed system. Optimization of the system is carried out using parametric study by performance of topology. Further optimization is done in this stage to obtain good response for the proposed system.

Stage 4: WSN Testing

The data should be accurate when testing with the WSN. Also require the criteria like optimize the energy consumption, longevity in the system and ensure the efficiency of energy. Verification and validation through simulation works will be implemented.

Stage 5: Analysis on the Result of Simulation

This final stage will focus on the data analysis with the theoretical verification of simulated results. The simulation result is the ideal result and it is the reference for the WSN designed system.

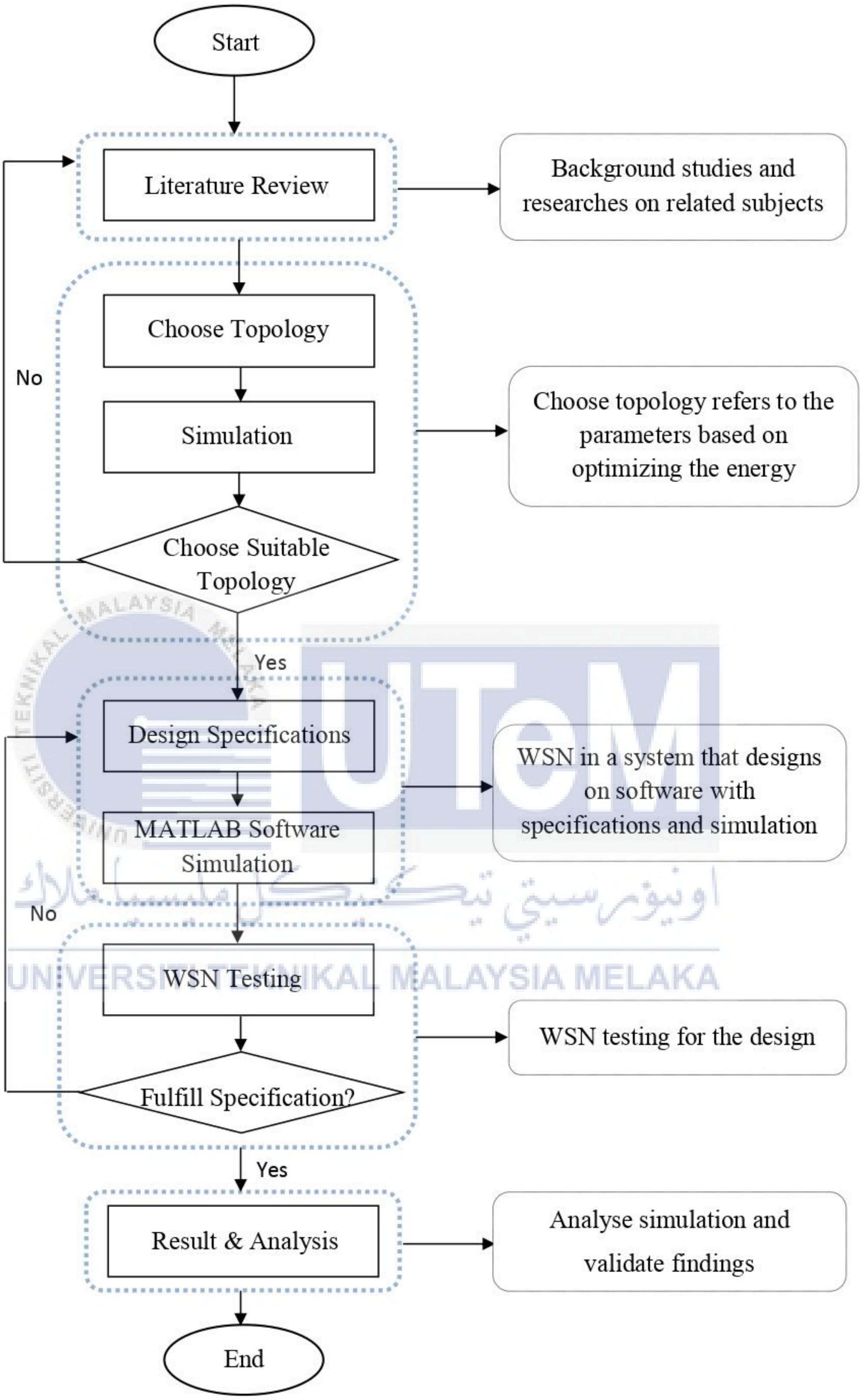

Figure 3.1: Flow chart of this study

3.3 Technique and protocol

There are various types of techniques and protocol for this design. PEGASIS (Power Efficient Gathering in Sensor Information Systems) is an example of protocol based chain topology. Every node in chain senses the data. Data from different sensors en- route to the base station is attempt to minimize the number and the size of data transmissions. Thus, save the energy in sensor. EECCPAR (Energy Efficient Clustered Chain based Power Aware Routing Protocol), by dividing the energy burden evenly across the sensor nodes, this protocol proposes to prevent transmission delay on long links, increase the network's lifetime, and reduce communication costs.

Besides, Energy-Efficient Routing Protocol is used to decrease power utilization and data latency which also has high stability and high throughput in network performance. Main goal of EECPL (Energy Efficient Clustering Protocol) is to distribute the energy load, to enhance the lifetime of sensor networks, and to reduce the energy consumption. Energy-Efficient Sensing Algorithm is use to prolong the operational lifetime of sensor network and energy efficiency should be consider in every design of sensor network. Clustering protocol based on energy efficient is going to be used in this system. In this project, Ant Colony Optimization algorithm (ACO) is used in order to compare and choose the best topology. ACO is approach to solve combinatorial optimization problems. It is also help in routing process with WSN. ACO has an effective way to maximize the life longevity in a WSN system and to optimize the energy consumption.

3.4 Calculation

The specification of the design based on the parameters which has some calculation to be calculated. Based on the results of testing throughput and packet loss, network performance is calculated. The amount of data that can be received by the coordinator in a particular amount of time is referred to as throughput. The throughput can be calculated by the following equation in 3.1

$$Tg\ (byte/s) = Db \times rx\ /\ T(s) \tag{3.1}$$

Where:

Tg = Throughput

s = Seconds

Db = Byte data

rx = Data received

T = Receipt time

Then Packet loss is the amount of data lost so that data packets are not received by the coordinator with the amount of data that the device has sent in a single measurement. The packet calculated by the following equation in 3.2

$$PLT = (1 - (nT\ recv/nT\ sent)) \times 100\% \tag{3.2}$$

Where:

PLT = Packet Loss

nT = Amount of data

Topology is introduced in Sensor Networks in order to reduce the power consumption in the nodes. Received signal expressed as in equation 3.3

$$P_{Rx} = P_{Tx} + G_{Tx} + G_{Rx} + L \tag{3.3}$$

where P_{Tx} is the transmitted power, G_{Tx} is the transmit gain, G_{Rx} is the receive gain and L is the path loss in dB.

3.5 Simulation Tool

Matrix Laboratory (MATLAB) is the most common tool used in developing programmes. MATLAB is a forum for programming created exclusively for engineers and scientists. The MATLAB language, a matrix-based language that enables computational mathematics to be represented more naturally, is the heart of MATLAB. Math Works is a proprietary programming language and numeric computation environment developed by multi-paradigm. MATLAB makes it possible to modify the matrix, to map functions and data, to apply algorithms, to construct user interfaces and to interface programmes written in other languages.

MATLAB has the capability to teach which an important trait in teaching purposes is. Other languages interpreted to provide interactive sessions. The consumer may type one or more commands at the prompt of the command and these commands are executed immediately after pressing return. This makes it easy to test small sections of the code interactively without any interruption resulting from compilation and promotes innovation. Interpreted languages also tend, using the interactive prompt, it is easier to debug compared to compiled executable.

MATLAB is an interactive environment and high-level technical computer language for algorithm creation, data visualisation, data analysis, and numeric calculation. Technical computer issues may be solved faster with the MATLAB software than with traditional programming languages like C, C++, and Fortran. Only a few of the applications include signal and image processing, communications, control design, test and measurement, and financial modelling and analysis. Add-on toolboxes are sets of MATLAB functions with a specific purpose that may be used to expand the MATLAB environment to tackle specific types of issues in these application areas. For documentary work, MATLAB has a variety of capabilities. MATLAB code may be used in conjunction with other languages and apps to create new algorithms and applications. It includes, among other things, a high-level language for technical computing, a development environment for managing code, files, and data, interactive problem-solving tools, and the ability to design custom graphical user interfaces. Simulations are conducted using MATLAB R2017b to get precise plots.

For this design system, first a program has been coded in comparing between three topologies and chooses the best topology using Ant Colony Optimization (ACO) algorithm. It recommends the best and efficient result. Then, programs are coded to run the chose topology in WSN system with its parameters. Simulating a WSN in MATLAB is not new; it consists of few functions in generating the results. In order to derive the model or obtain the simulated data that has already been collected from the archive, it is important to mention that real-time data from sensor nodes can be used here. The design requires with few parameters as discussed in Chapter 2. Figure 3.2 shows the MATLAB platform. The design requires the suitable function when the code is constructed.

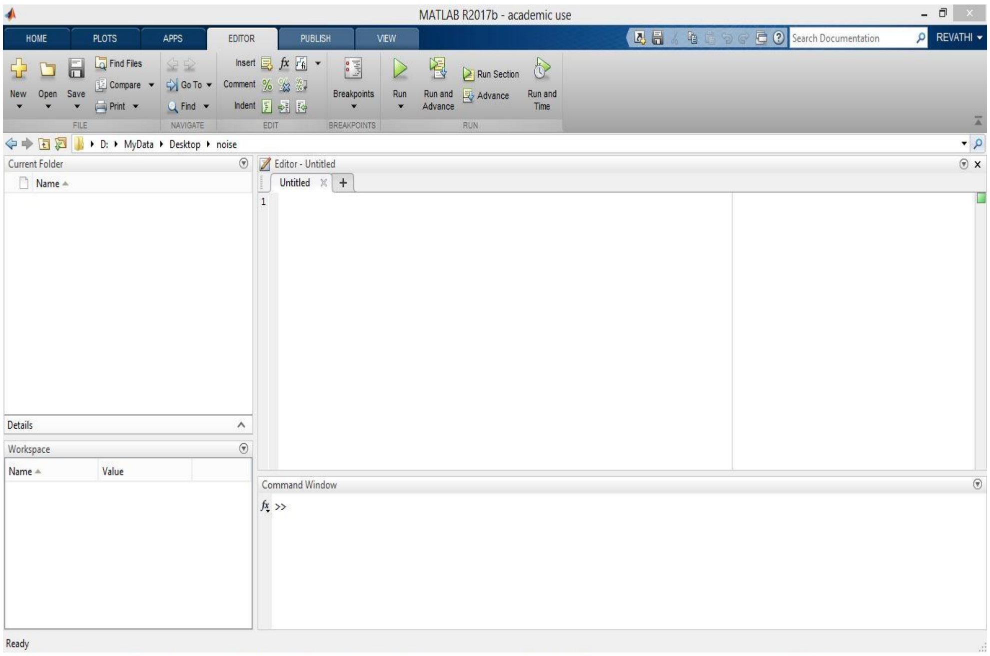

Figure 3.2: MATLAB Software Platform

CHAPTER 4

RESULTS AND DISCUSSION

The result and discussion exhibit the outcome of the investigated material and the analysis of the project summed into tables and graphs.

4.1 Introduction

In this chapter, the design of the WSN system is presented. The WSN system is designed with the chosen topology. The results from the simulation are analysed through parametric studies in order to get the optimum result. The comparison is made between simulations. The topology is compared then embedded with the WSN. The results which topology connected with WSN is analysed, and the analysis will focus on the parameters like number of nodes, transmission of packet, and routing nodes.

4.2 Design of the WSN

4.2.1 Comparing the Topology

The WSN is designed to create the mesh, star and tree topology for WSN in testing and evaluate the performance of network topology with few parameters. Table 4.1 summarizes the parameters used in the simulation.

Table 4.1: Parameters of Network Topology

Parameters	Value
Network Size	100m*100m
Number of Nodes	50
Dataset Range	250
Minimum Energy	80 (70% of energy in Milliwatt)
Maximum Energy	100 (Full energy)
Energy	0.35 J

The best performance of topology is evaluated by the number of packets sent. The parameters that have been used are shown in Table 4.1. The parameters considered during the simulation which have their own significance for the better performance of the network. The number of packet sent from the source to destination (target). The greater value of packet sent means better performance of the topology. Node 1 is set as source while Node 2 is seta as target as shown in Figure 4.1.

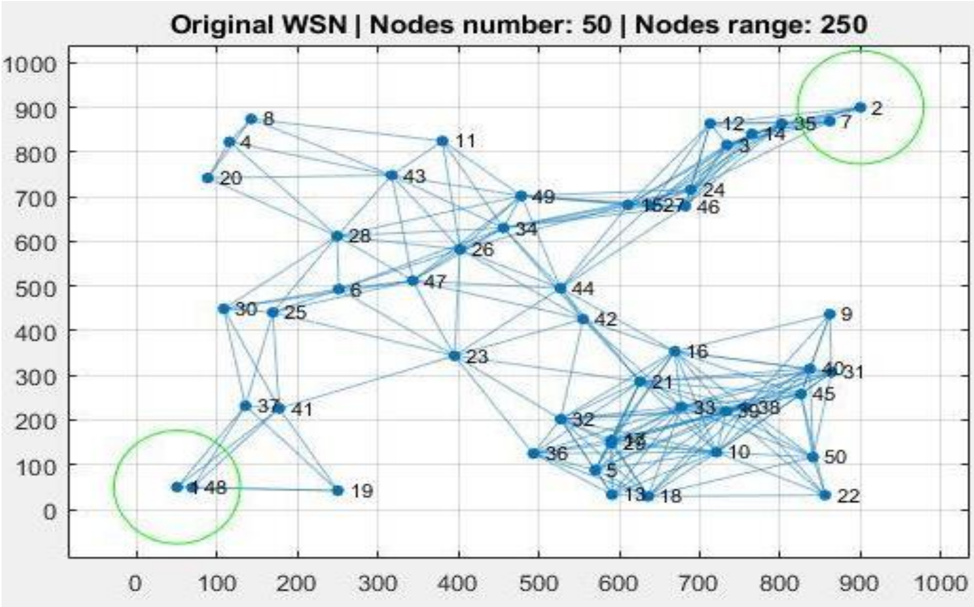

Figure 4.1: The original WSN

Ant Colony Optimization (ACO) algorithm is use in choosing the best topology for WSN in optimizing energy. Star, Tree and Mesh topology is compare by programmed code in MATLAB. The simulation assumed that there are sensor nodes randomly deployed. The result from the simulation is compared with the three topologies based on the packet sent.

The transmission of power varies depend on the distance between the node and receiver. Figure 4.2 shows the number of packets sent which is 4137. The dead node on this network is node number 26. The dead nodes always die in next router node of packet sending. The packet sent in seven hops with the router nodes of 1, 41, 23, 26, 15, 3 and 2. This network performance is on Star topology. The topology is decided by the router nodes in the network.

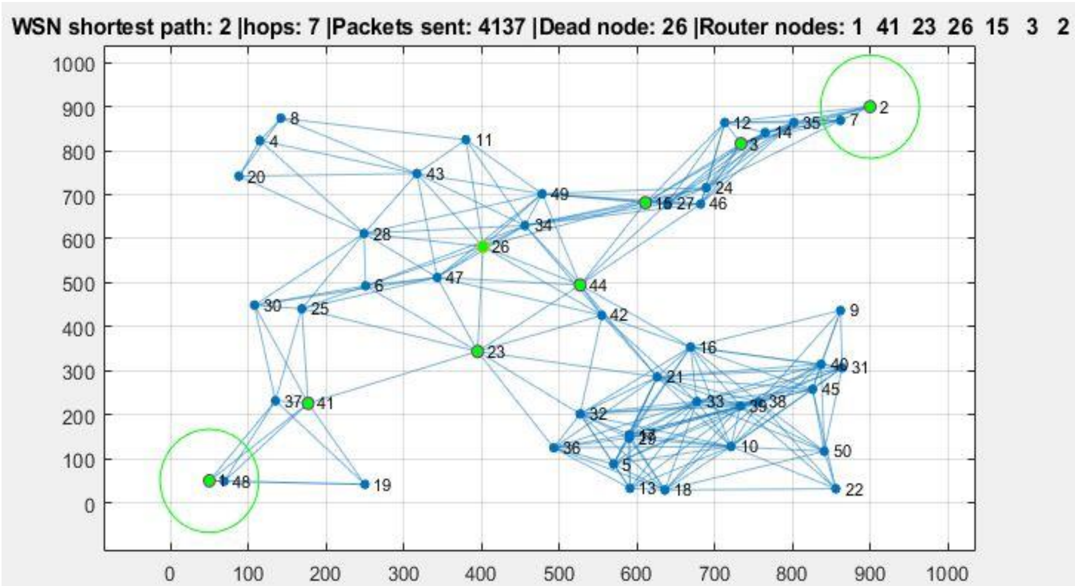

Figure 4.2: The WSN path 2

In Figure 4.3, the number of packets sent which is 5355 as shown below. The dead node on this network is node number 41. The packet sent in seven hops with the router nodes of 1, 41, 23, 44, 15, 3 and 2. This network performance is on Mesh topology. The topology is decided by the router nodes in the network.

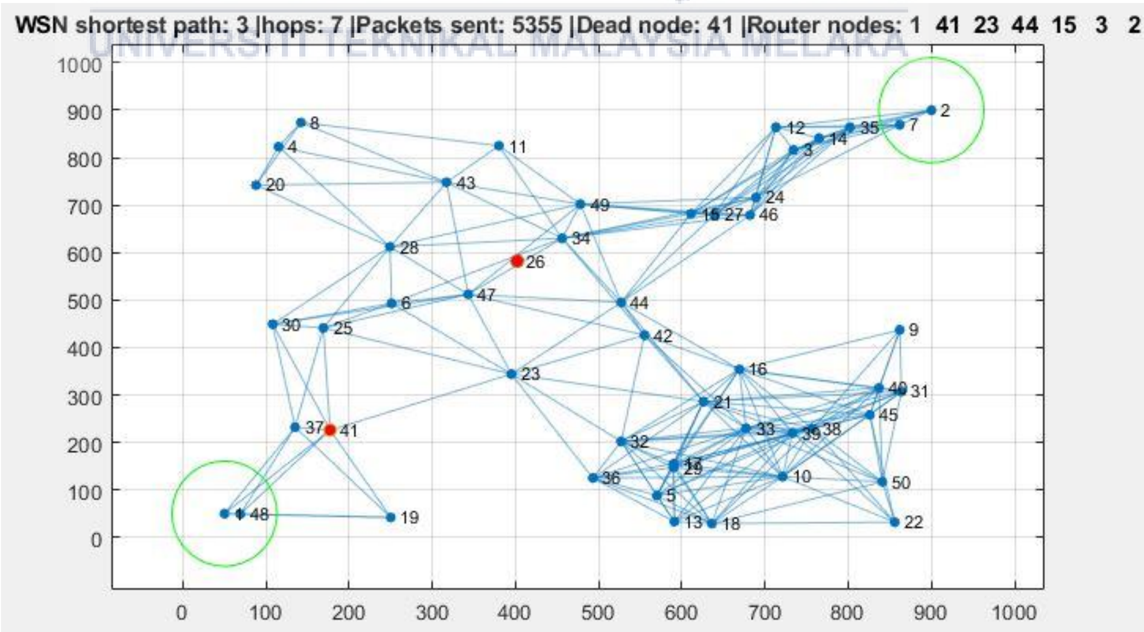

Figure 4.3: The WSN path 3

In Figure 4.4, the number of packets sent which is 5507 as shown below. The dead node on this network is node number 15. The packet sent in eight hops with the router nodes of 1, 37, 25, 6, 34, 15, 3 and 2. This network performance is on Mesh topology.

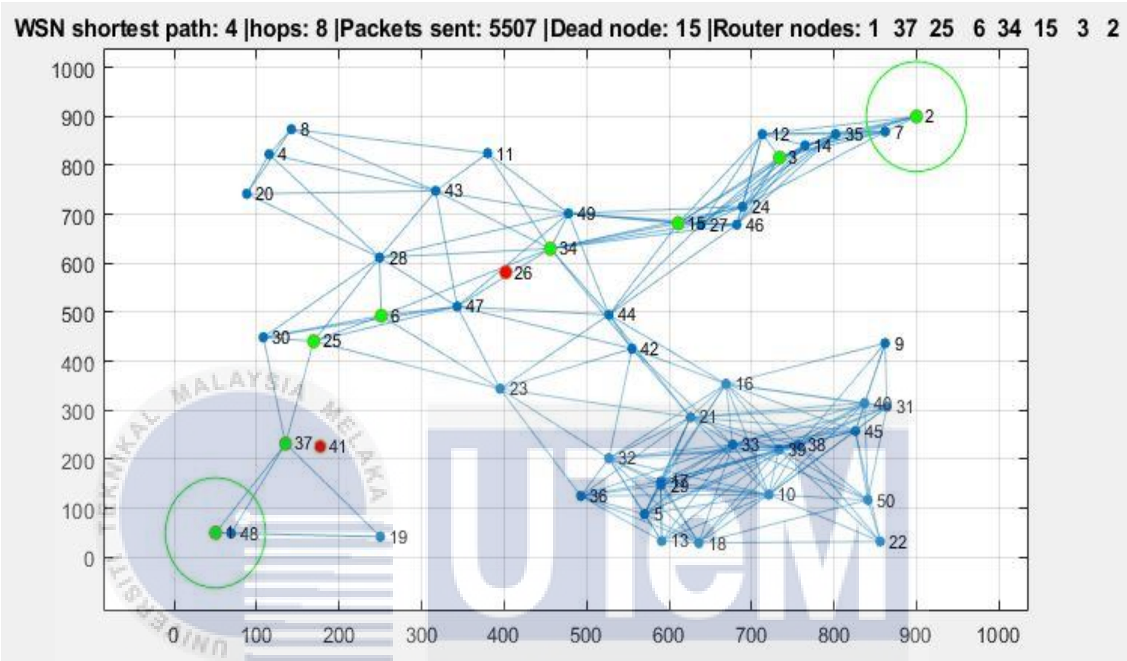

Figure 4.4: The WSN path 4

In Figure 4.5, the number of packets sent which are 10563 as shown below. The dead node on this network is node number 34. The packet sent in eight hops with the router nodes of 1, 37, 25, 6, 34, 24, 7 and 2. This network performance is on Star topology.

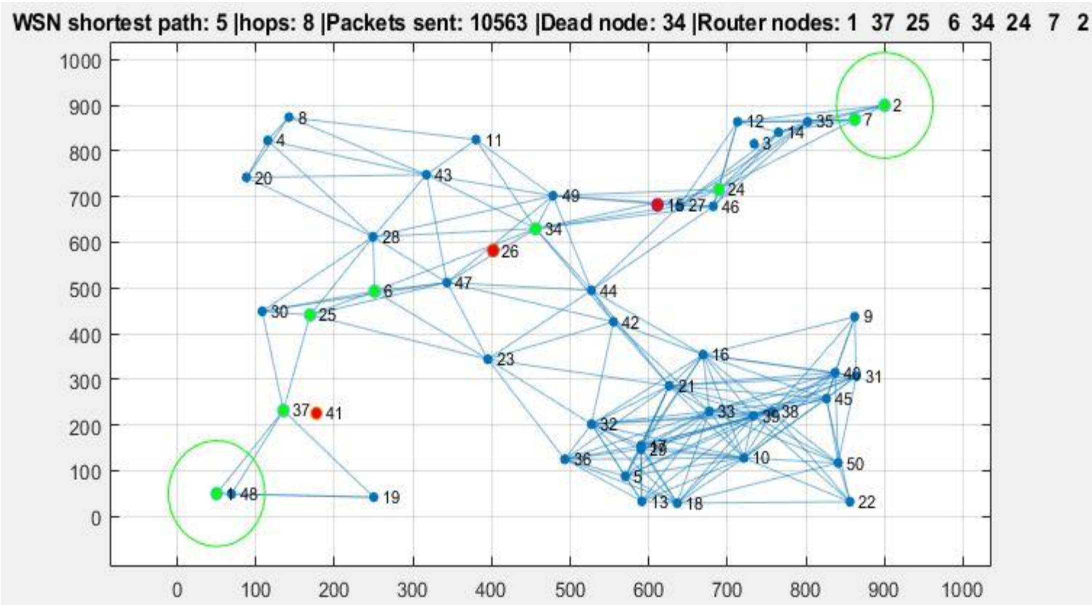

Figure 4.5: The WSN path 5

In Figure 4.6, the number of packets sent which are 10715 as shown below. The dead node on this network is node number 23. The packet sent in eight hops with the router nodes of 1, 37, 25, 23, 44, 27, 12 and 2. This network performance is on Star topology.

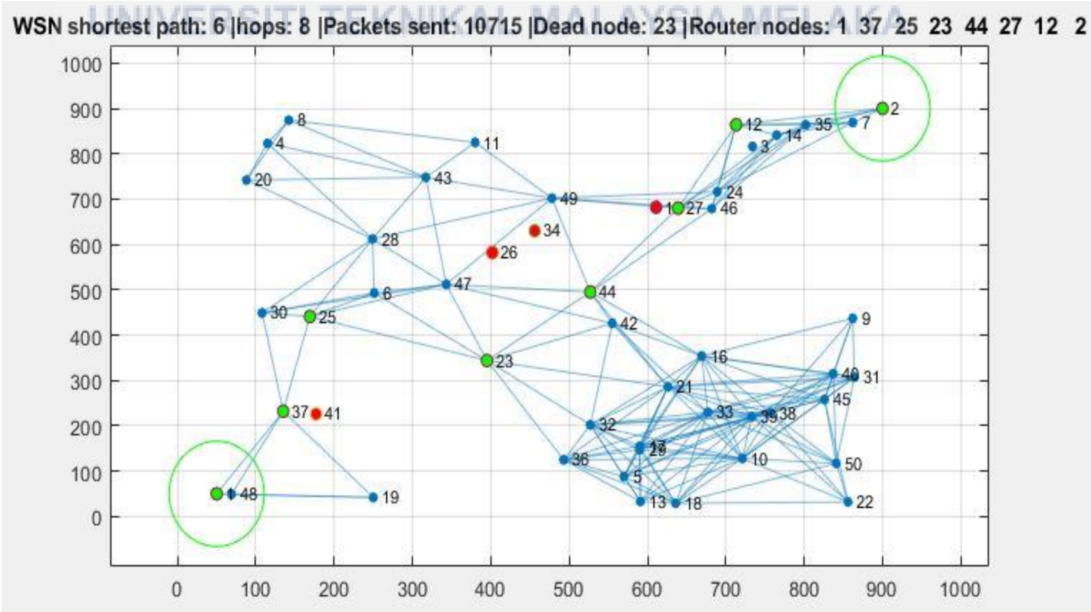

Figure 4.6: The WSN path 6

In Figure 4.7, the number of packets sent which are 11259 as shown below. The dead node on this network is node number 7. The packet sent in eight hops with the router nodes of 1, 37, 25, 28, 49, 24, 7 and 2. This network performance is on Mesh topology.

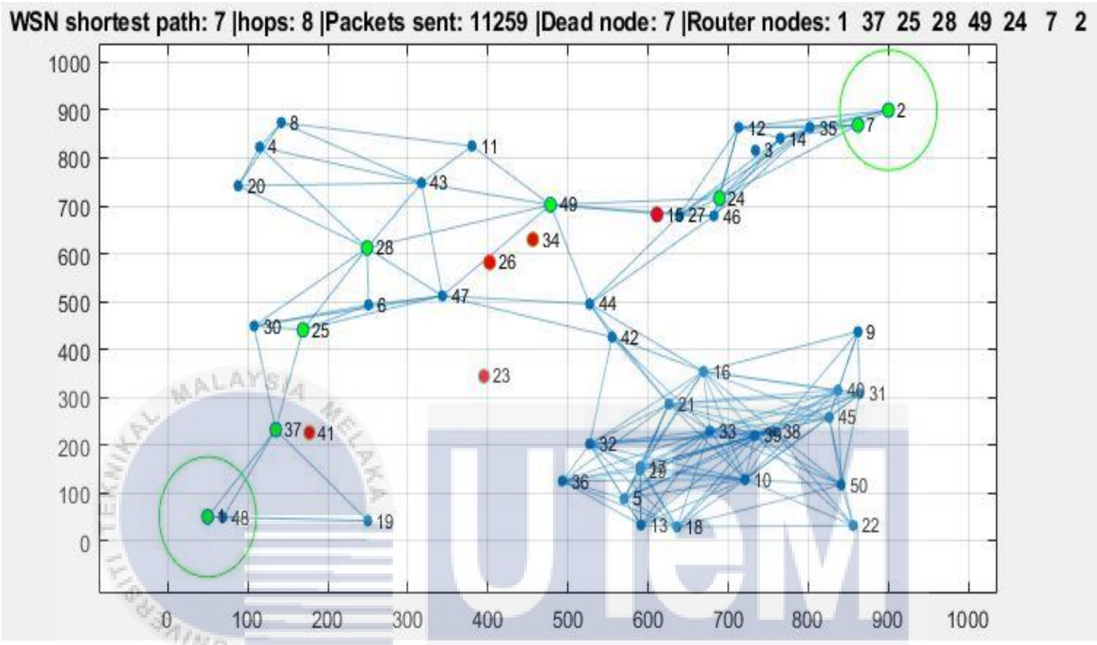

Figure 4.7: The WSN path 7

In Figure 4.8, the number of packets sent which are 11547 as shown below. The dead node on this network is node number 25. The packet sent in eight hops with the router nodes of 1, 37, 25, 28, 49, 24, 12 and 2. This network performance is on Tree topology.

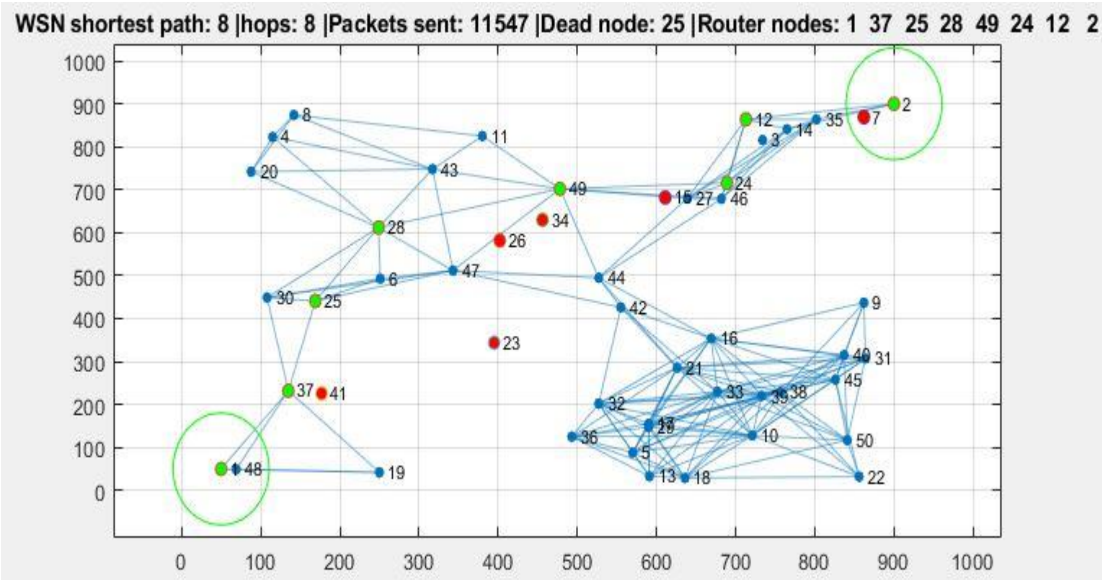

Figure 4.8: The WSN path 8

In Figure 4.9, the number of packets sent which are 12211 as shown below. The dead node on this network is node number 24. The packet sent in eight hops with the router nodes of 1, 37, 30, 28, 49, 24, 12 and 2. This network performance is on Mesh topology.

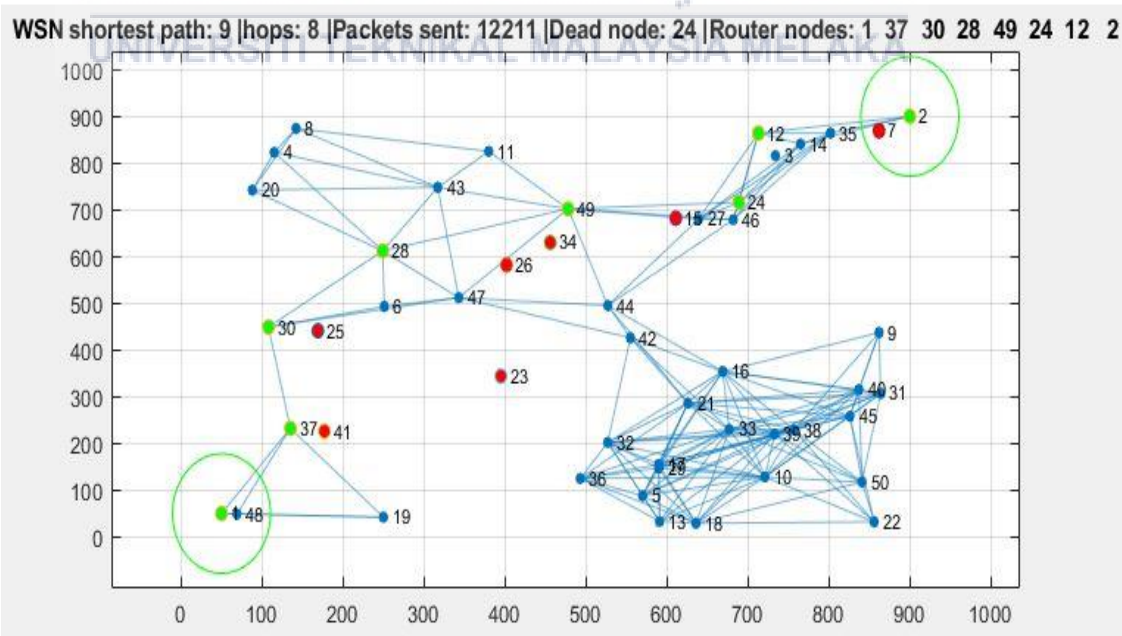

Figure 4.9: The WSN path 9

In Figure 4.10, the number of packets sent which are 12315 as shown below. The dead node on this network is node number 37. The packet sent in eight hops with the router nodes of 1, 37, 30, 28, 49, 24, 12 and 2. This network performance is on Tree topology. The packets not able sent due to unavailable of routes. The router nodes in sending the data to base station are unable to find through Tree topology.

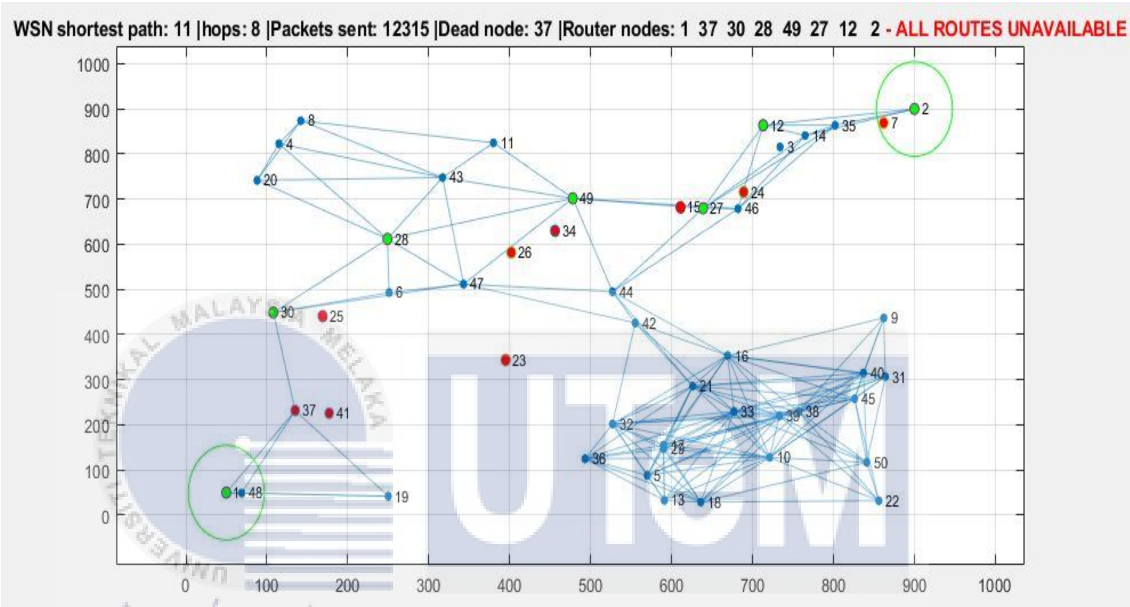

Figure 4.10: The WSN path 10

Table 4.2 below shows the analyzation of the simulation result of the network in comparing the topologies for WSN. Mesh topology is chose as the best topology for WSN from Figure 4.3, Figure 4.4, Figure 4.7 and Figure 4.9 as shown above because most of the packets are sent. So in mesh network, only selected nodes have the repeater/relaying function and are connected with more than one other node, while in a full mesh network, all nodes are homogeneous and fully interconnected to each other. There is assumption, transmitter and receiver are in free space and no obstructing objects in between. Mesh topology is intended to allow a very high level of redundancy by connecting each system within the network to every other system on the network. As it can compare the routes nodes decide the topology and the packet sends are more compare to other results. Hence, it is proved that Mesh topology is the best topology for WSN in optimizing energy.

Table 4.2: Analyzation of simulation result

Figures	Topology	Router Nodes	Dead Node	Packets Sent
Figure 4.2	Star	1, 41, 23, 26, 15, 3 & 2	26	4137
Figure 4.3	Mesh	1, 41, 23, 44, 15, 3 & 2	41	5355
Figure 4.4	Mesh	1, 37, 25, 6, 34, 15, 3 & 2	15	5507
Figure 4.5	Star	1, 37, 25, 6, 34, 24, 7 & 2	34	10563
Figure 4.6	Star	1, 37, 25, 23, 44, 27, 12 & 2	23	10715
Figure 4.7	Mesh	1, 37, 25, 28, 49, 24, 7 & 2	7	11259
Figure 4.8	Tree	1, 37, 25, 28, 49, 24, 12 & 2	25	11547
Figure 4.9	Mesh	1, 37, 30, 28, 49, 24, 12 & 2	24	12211
Figure 4.10	Tree	1, 37, 30, 28, 49, 24, 12 & 2	37	12315

4.2.2 Connect Mesh Topology with WSN

Mesh topology is connecting to WSN with the number of node of five in order to prove that mesh topology is able to connect with WSN. Figure 4.11 shows the connection and the data can be received from the nodes. Only 5 nodes are used to show a clear connection of routes.

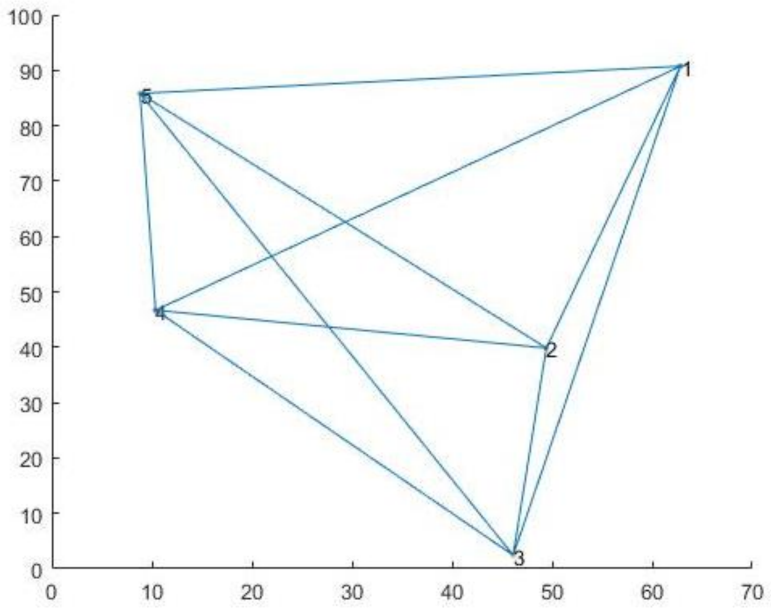

Figure 4.11: Connection of Mesh

4.2.3 Mesh Topology in WSN system

Nodes are set for WSN with the network size of 100m*100m and 50 numbers of nodes respectively. The wireless sensor nodes are deployed randomly. The sensor node senses the data and sends it to the base station with transmitter and receiver. The network performance is analyzed by nodes vs throughput, energy used vs throughput, speed vs throughput and number of nodes vs maximum lifetime in order to observe the energy efficiency and longevity of network in WSN. The total number of packets received at the base station and the average rate of successful packet delivery are referred to as throughput. The most essential metric for analyzing network performance is throughput; to improve throughput, the error should be rectified; there is no need to retransmit the packet. Congestion will not arise if transmission traffic is decreased. There is no packet loss if there is no congestion, which is a mistake. When there are more packets in the network, the performance of the network declines, causing congestion and packet loss. It enhances performance if there is an error correction mechanism that corrects the error instead of retransmission. This network's performance is based on mesh topology. Figure 4.12 shows the simulation of network in WSN for the transmission of data in system through their source and destination.

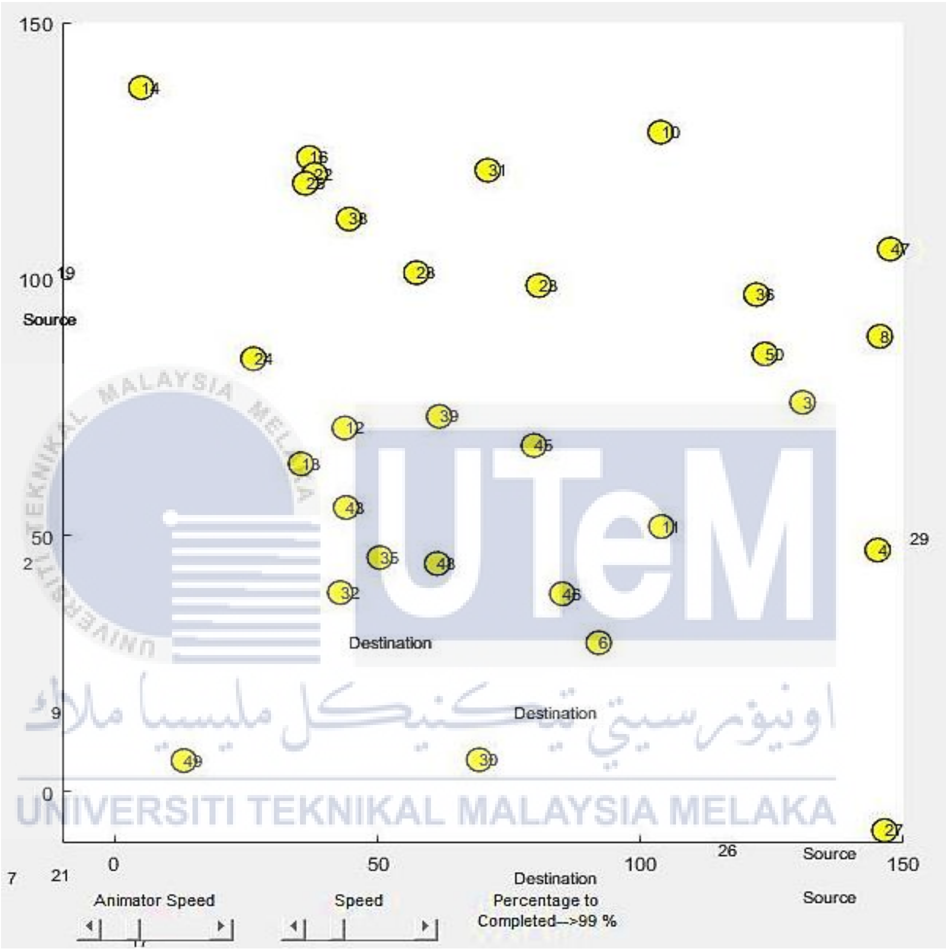

Figure 4.12: Source and destination of network runs using Animator speed

4.2.3.1 Number of nodes vs Throughput

Network performance is evaluated by the number of nodes and the throughput in this system. The result is shown in Figure 4.13 below. The packets received are stable when the number of nodes is from 20 to 30 and from 50 to 60 respectively. There is a sharp decline when the number of node is from 30 to 40. It might due to the increased of probability of packet collision by increases the number of nodes. The maximum throughput is obtained when the number of node is at 30 and after 50.

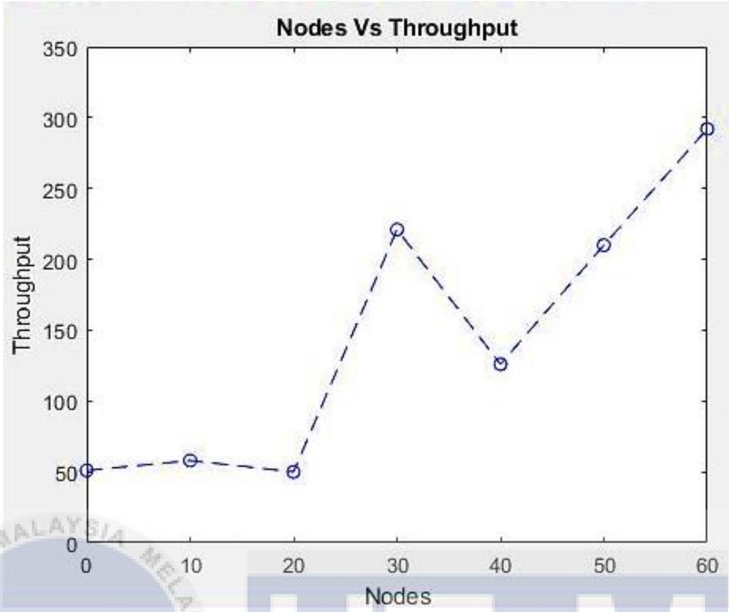

Figure 4.13: Nodes vs Throughput

4.2.3.2 Energy used vs Throughput

The energy consumption in the system is important in order to maintain the energy efficiency and life longevity in WSN system. Figure 4.14 below shows the output result. When less energy is consumed, the throughput increases. The most packets are transmit and received when the energy used is from 0 to 10. When more energy is use which is from 30 to 40, the throughput decreases and slightly increase when the energy use is from 40 to 50.

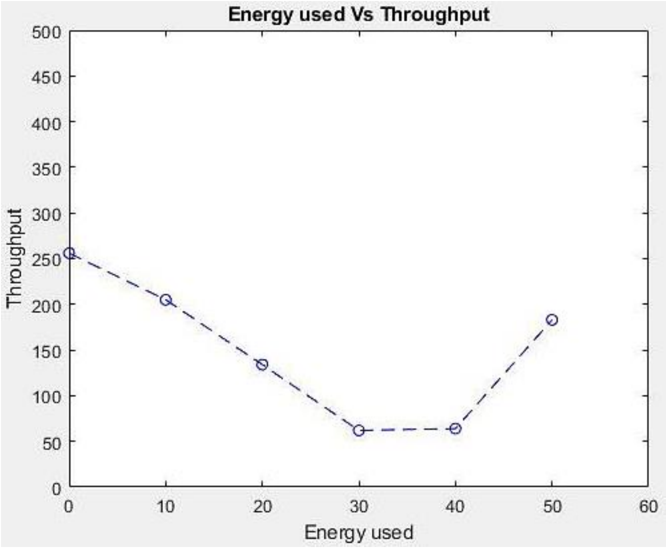

Figure 4.14: Energy used vs Throughput

4.2.3.3 Speed vs Throughput

The speed in network is to observe the transmission of packet in the network. As shown in Figure 4.15, there are no much changes in the throughput when the speed is increases in transmitting the data it just maintains and the throughput increases when the speed is from 40 to 50.

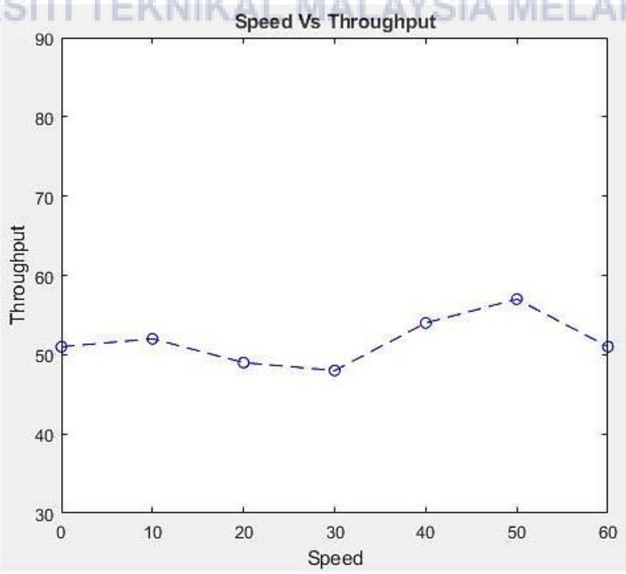

Figure 4.15: Speed vs Throughput

4.2.3.4 Nodes vs Maximum Lifetime

The maximum lifetime in network is for the first node of sensor nodes to run out the power on its time interval is from the start of operation of the sensor network until the death of the first alive node. The network lifetime is to judge the efficiency of energy in the network. It always depends on the throughput where the base station is receiving more data packets to confirm the efficiency and the network lifetime. Considering the simulated results as shown in Figure 4.16 when the number of node increases, the maximum lifetime increases. The maximum lifetime decreases when the node is at 30. It might due to packet collision when the transmission of data. Hence, from the simulated result as shown in Figure 4.13, Figure 4.14, Figure 4.15 and Figure 4.16. The second objective is achieved by proving that Mesh topology in WSN system has ensure the energy efficiency and life longevity.

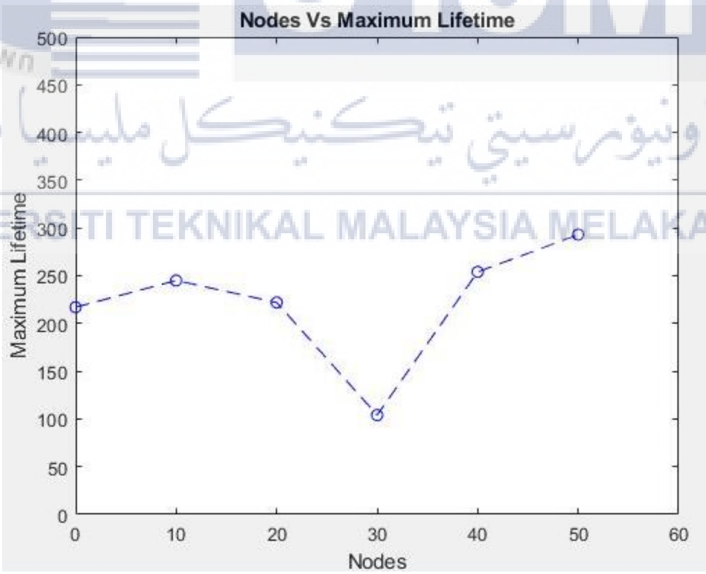

Figure 4.16: Nodes vs Maximum Lifetime

CHAPTER 5

CONCLUSION AND FUTURE WORKS

This chapter concludes the results obtained and the project accomplishments concerning the project's objectives and scope. The future studies proposed for life long approach to this project since potent to expand the research.

5.1 Conclusion

In this study, the Mesh topology is chose as the best topology for WSN system. Wireless Sensor Network became the most use network due to the multi-disciplinary approach. When observe the WSN system, it is not sufficient to have technological knowledge only but the knowledge of ecosystem is also necessary. The Mesh topology is evaluated and optimize in this WSN system. When compared to Star and Tree topology, Mesh topology have the capability to provide the extension of network coverage without increasing the transmit power or receive sensitivity. It also has a better reliability through the router nodes and easy network configuration. Mesh topology also minimize the communication latency and throughput is more stable.

As comparing the topology for WSN, Star, Tree and Mesh topology is chose. The simulation illustrates with few parameters which are network size, number of nodes, dataset range, minimum energy, maximum energy and initial energy. The simulated performance of the topologies in network is observed by the number of packets sent. The more number of packets are sent by Mesh topology which is 5355, 5507, 11259 and 12211 packets respectively. The outcome of Star topology in the simulated performance is 4137, 10563 and 10715. The least number of packets are sent by Tree topology. In Tree topology, about 12315 numbers of packets are not able to send due to unavailable of routes. Tree topology unable to find the router node to send the data to the base station. Mesh topology is proved by connecting in WSN system.

Part of the Mesh topology in WSN system with observing through number of nodes vs throughput, energy used vs throughput, speed vs throughput and number of nodes vs maximum lifetime. Each performance is observed where the packet is able to transmit and receive at the base station. There is little constraint in the performance when simulated, it might due to the packet collision when increased the probability of packet. The throughput in WSN system confirms the efficiency of energy and life longevity in network.

The WSN is indeed by Mesh topology in this system. The WSN is incorporated with Mesh topology and it is effectively accounted in this project. Respect to the design and concepts were successfully presented with the simulation results. The initiative of this system was limited only for WSN system. The additional method can be extended for any other WSN system.

5.2 Future Work

There are several viable accomplishments to the field of research practice in which for future progress. This research is carried out on choosing best topology for WSN system and studies can be examined on packets sent for better performance.

Besides, the WSN can be connected in any other system like waste monitoring, detect gas leakage, biological system and others. WSN has flexible enhancement properties that can manipulate in any system.

Even more, research can be done in the field of Wireless Sensor Network because it is a very large system where can be used in a lot of work. Due to need of an extra sensitive and improvement in architecture, the mobility and acoustic with application for specific sensor areas are untouched. The WSN can be functioning in small sensors but requires high and complex architecture with energy efficient secure algorithm development of technology is needed.

Finally, the WSN system also can be used in medical application as nowadays it is very important. WSN in medicine can be enlarged in future where it can create a system that able to detect and prevent health problems. WSN system can also enhance in agriculture and space system. In agriculture, it can be used for smart farming to improve the quality and productivity of farming as agriculture will be important in the near future.

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APPENDIX A

Comparing between topologies

%Choosing the best topology for WSN that can enhance the power consumption between three topologies such us Tree topology, Star topology and Mesh Topology

dataset.nodeNo = 50; %Number of nodes

dataset.nodePosition(1,:) = [1 50 50]; %Sending node fixed position (source)

dataset.nodePosition(2,:) = [2 900 900]; %Receiver node fixed position (target)

dataset.NeighborsNo=5;

dataset.range = 250; %Tolerance distance to became neighbor of one node

dataset.atenuationFactor = 1.8; %Atenuation factor in freespace - ranges from 1.8 to 4 due to environment

dataset.minEnergy = 80; %Miliwatts (70% of energy)

dataset.maxEnergy = 100; %Miliwatts (Full energy (100%) - 1 mAh charge capacity within 1 Volt energy)

dataset.energyconsumptionperCicle=0.35;

dataset.energyrecoveryperCicle=0.2;

dataset.energyfactor=0.001;

STenergy=10000;

packet=0;

```
iterationcounter=1;

for a = 3 : dataset.nodeNo

dataset.nodeId = a;
garbage.x = randi([1 900]);
garbage.y = randi([1 900]);
dataset.nodePosition(a,:) = [dataset.nodeId garbage.x garbage.y];
end
for i = 1 : dataset.nodeNo
for j = 1: dataset.nodeNo
garbage.x1 = dataset.nodePosition(i,2);
garbage.x2 = dataset.nodePosition(j,2);
garbage.y1 = dataset.nodePosition(i,3);
garbage.y2 = dataset.nodePosition(j,3);
dataset.euclidiana(i,j) = sqrt( (garbage.x1 - garbage.x2) ^2 + (garbage.y1-
garbage.y2)^2 );
end
end
dataset.weights = lt(dataset.euclidiana,dataset.range);
G=graph(dataset.weights,'omitselfloops');
for a = 1 : height(G.Edges)
garbage.s = G.Edges.EndNodes(a,1);
garbage.t = G.Edges.EndNodes(a,2);
garbage.Z(a,:) = dataset.euclidiana(garbage.s,garbage.t);
end
```

```
G.Edges.Euclidiana = garbage.Z(:,1);
[dataset.nodePosition(:,4)] = dataset.maxEnergy -(dataset.maxEnergy-dataset.minEnergy)*rand(dataset.nodeNo,1);
dataset.nodePosition(1:2,4)=STenergy;
for a = 1: length(dataset.nodePosition(:,1))
dataset.nodePosition(a,5) = degree(G,dataset.nodePosition(a,1));

end
[G.Edges.Pathloss] = (10*dataset.atenuationFactor)*log10(G.Edges.Euclidiana);
for a = 1 : height(G.Edges)
garbage.Sourcenode = G.Edges.EndNodes(a,1);
garbage.Targetnode = G.Edges.EndNodes(a,2);
G.Edges.SourcenodeXpos(a) = dataset.nodePosition(garbage.Sourcenode,2);
G.Edges.SourcenodeYpos(a) = dataset.nodePosition(garbage.Sourcenode,3);
G.Edges.TargetnodeXpos(a) = dataset.nodePosition(garbage.Targetnode,2);
G.Edges.TargetnodeYpos(a) = dataset.nodePosition(garbage.Targetnode,3);
G.Edges.ActiveEdge(a) = 1;
end
figure('units','normalized','innerposition',[0 0 1 1],'MenuBar','none')
subplot(1,1,1)
garbage.Xmax = 1500;
garbage.Xmin = 0;
garbage.Ymax = 1500;
garbage.Ymin = 0;
p = plot(G,'XData',(dataset.nodePosition(:,2)),'YData',(dataset.nodePosition(:,3)));
```

```
line(dataset.nodePosition(1:2,2),dataset.nodePosition(1:2,3),'color','green','marker','o'
,'linestyle','none','markersize',50)
garbage.ax = gca;
garbage.ax.XAxis.TickValues = 0:100:1000;
garbage.ax.YAxis.TickValues = 0:100:1000;
grid on
hold on
title(['Original WSN | ','Nodes number: ',num2str(dataset.nodeNo),' | Nodes range: ',
num2str(dataset.range)])
pause(2)
garbage.deadnodelist=[];
garbage.deadnodeneighbors=[];
G2 = shortestpathtree(G,1,2);
fileID = fopen('report-simulation.txt','w');
fprintf(fileID,'%6s    %20s    %20s    %20s    %20s\r\n','|NodeNo|','|No    ACO
Scene|','|Hops|','|Packets sent|','|Dead node|');
while ~isempty(G2.Edges)
G2 = shortestpathtree(G,1,2);
 iterationcounter=iterationcounter+1;
 % Test if there is connection between node 1 and 2. If not, terminate!
  if isempty(G2.Edges)
  break
  end
  for a = 1 : height(G2.Edges)
  source = G2.Edges.EndNodes(a,1);
```

```
target = G2.Edges.EndNodes(a,2);
garbage.edgesrow(a,:) = findedge(G,source,target);
end
garbage.routingnodes = unique(G2.Edges.EndNodes);
garbage.routepath = shortestpath(G,1,2);
for a = 1 : length(garbage.routingnodes)
garbage.b=garbage.routingnodes(a,1);
dataset.routingnodesPosition(a,:)=dataset.nodePosition(garbage.b,:);
end
[garbage.Outroutenodes, garbage.Outroutenodesidx] =
setdiff(dataset.nodePosition(:,1),garbage.routingnodes(:,1),'stable');
while min(dataset.nodePosition(:,4))>0

for a = 1 : length(garbage.routingnodes)
node=garbage.routingnodes(a,1);
dataset.nodePosition(node,4)=dataset.nodePosition(node,4)-
dataset.energyconsumptionperCicle^rand()+dataset.energyrecoveryperCicle^rand();
 packet=packet+1;
 end
 end
 [garbage.deadnoderow] = find(dataset.nodePosition(:,4)<=0);
 for a = 1 : length(garbage.deadnoderow)
 deadnode=garbage.deadnoderow(a,1);
 for b = 1 : height(G.Edges)
 if ismember(G.Edges.EndNodes(b,1),deadnode) == 1 ||
 ismember(G.Edges.EndNodes(b,2),deadnode) == 1
```

```
  G.Edges.ActiveEdge(b)=0;
  deadnode;
  pause(2)
  end
  end
  end
  garbage.deadnodelist(length(garbage.deadnodelist)+1,1)=deadnode;
  [garbage.deadedgerow]=find(G.Edges.ActiveEdge==0);
  [garbage.deaddatasetnoderow]=find(dataset.nodePosition(:,4)<=0);
  for a = 1 : length(garbage.deaddatasetnoderow)
  b=garbage.deaddatasetnoderow(a,1);
  dataset.nodePosition(b,4)=NaN;
  end
hopsnumber=length(garbage.routingnodes);
msg=['Without ACO - Scene #: ',num2str(iterationcounter),' | Hops :
',num2str(hopsnumber),' | Packets sent: ', num2str(packet),' | Dead node: ',
num2str(deadnode),' | Routing nodes: ', num2str(garbage.routepath)];
disp(msg)
%plot for every dead edges iteration's result
figure('units','normalized','innerposition',[0 0 1 1],'MenuBar','none')
p = plot(G,'XData',(dataset.nodePosition(:,2)),'YData',(dataset.nodePosition(:,3)));
line(dataset.nodePosition(1:2,2),dataset.nodePosition(1:2,3),'color','green','marker','o'
,'linestyle','none','markersize',50)
garbage.ax = gca;
garbage.ax.XAxis.TickValues = 0:100:1000;
```

```
garbage.ax.YAxis.TickValues = 0:100:1000;
hold on
for a = 1 : length(garbage.deadnodelist)
garbage.b=garbage.deadnodelist(a,1);
scatter(dataset.nodePosition(garbage.b,2),dataset.nodePosition(garbage.b,3),'Marker
FaceColor','red');
end
title(['WSN shortest path: ',num2str(iterationcounter),' |hops:
',num2str(hopsnumber),' |Packets sent: ',num2str(packet),' |Dead node:
',num2str(deadnode),' |Router nodes: ', num2str(garbage.routepath)])
grid on
pause(2)
report1=[dataset.nodeNo;iterationcounter;hopsnumber;packet;deadnode];
fprintf(fileID,'%6.0f %20.0f %20.0f %20.0f %20.0f\r\n',report1);
G = rmedge(G,garbage.deadedgerow(:,1));
scatter(dataset.routingnodesPosition(:,2),dataset.routingnodesPosition(:,3),'MarkerFa
ceColor','green');
pause(0.2)
clear dataset.routingnodesPosition
end
fclose(fileID);
for a = 1 : length(garbage.deadnodelist)
garbage.b=garbage.deadnodelist(a,1);
scatter(dataset.nodePosition(garbage.b,2),dataset.nodePosition(garbage.b,3),'Marker
FaceColor','red');
```

```
end
title(['WSN shortest path: ',num2str(iterationcounter),' |hops: ',num2str(hopsnumber),' |Packets sent: ',num2str(packet),' |Dead node: ',num2str(deadnode),' |Router nodes: ', num2str(garbage.routepath),'{\color{red} - ALL ROUTES UNAVAILABLE}'])
disp('NO ROUTES BETWEEN SOURCE (NODE1) AND TARGET (NODE2)')
```

APPENDIX B

Connect Mesh with WSN

```
%connect Mesh topology with WSN
noOfNodes=5;
figure(1);
clf;
hold on;
L=100;
R=150;
netXloc=rand(1,noOfNodes)*L;
netYloc=rand(1,noOfNodes)*L;
for i=1:noOfNodes
plot(netXloc(i), netYloc(i), '.');
text(netXloc(i), netYloc(i), num2str(i));
for j=1:noOfNodes
distance=sqrt((netXloc(i)-netYloc(j))^2+(netYloc(i)-netYloc(j))^2);
if distance<=R
line([netXloc(i) netXloc(j)],[netYloc(i) netYloc(j)],'linestyle','-');
end
end
end
```

APPENDIX C

Mesh topology in WSN system

```
% Mesh topology for WSN in a system with the network size of 100m*100m
clear all;
close all;
clc;
nr_fr=10; %frames = moviein(nr_fr);
N=50;
Color='b';
Totalnodes='50'
n11=str2num(Totalnodes); %distance of nodes
min1=20;
max1=120;
ca=20; %Coverage Range
o1 = floor(min1 + (max1-min1).*rand(1,n11));
o2 = floor(min1 + (max1-min1).*rand(1,n11));
oint1=10;
oint2=10;
global slider_data slider1_data
slider_data.val = 25;
```

```
slider1_data.val = 25;
global fh
fh = figure('Position',[200 200 400 400],...
'MenuBar','none','NumberTitle','off',...'Name','WSN');
sh = uicontrol(fh,'Style','slider',...'Max',100,'Min',0,'Value',25,... 'SliderStep',[0.05
0.2],...'Position',[10+90 10 100 20],... 'Callback',@slider_callback);
sh1 = uicontrol(fh,'Style','slider',...'Max',100,'Min',0,'Value',25,...
'SliderStep',[0.05 0.2],...'Position',[150+80 10 100 20],...
'Callback',@slider1_callback);
sth = uicontrol(fh,'Style','text','String',...'Animator Speed',... 'Position',[10+90 25 100
20]);
sth1 = uicontrol(fh,'Style','text','String',...'Speed',... 'Position',[150+80 25 100 20]);
setappdata(fh,'slider',slider_data);
setappdata(fh,'slider',slider1_data);
for i=1:400 %coverage range
cla;
axis([min1-30 max1+30 min1-30 max1+30])
hold on
int=[1 2 3 4 5 6 7 8 9 10];
okgc1=40;
okgc2=40;
% plot(okgc1,okgc2,'s','LineWidth',1,...
%'MarkerEdgeColor','k',...
%'MarkerFaceColor','r',...
%'MarkerSize',16);
```

```
%text(okgc1,okgc2,'AP','FontSize',8);
hold on
m1=0.01+(slider1_data.val/50);   %Range
aa=-1;
ba=1;
m=3;
n=2;
x = aa + (ba-aa)*rand(1,numel(o1));
x1 = aa + (ba-aa)*rand(1,numel(o1));
o11=o1+i.*x.*m1;
o21=o2+i.*x1.*m1;
hold on

plot(o11,o21,'o','LineWidth',1,...'MarkerEdgeColor','k',...
'MarkerFaceColor','y',...'MarkerSize',12);

for j=1:n11
text(o11(j),o21(j),int2str(j),'FontSize',8);
end
hold on
%plotpoint(i,[oint1 okgc1],[oint2 okgc2],'b');
d=sqrt((oint1-okgc1)^2+(oint2-okgc2)^2);
d2=max(sqrt((o1-okgc1).^2+(o2-okgc2).^2));
da=[];
for j=1:n11
da(:,j)=(sqrt((o11-o11(j)).^2+(o21-o21(j)).^2));
```

```
end
k=d;
for j=1:3
%[v1 ind]=find(da(:,j)<ca & da(:,j~=0));
%for v=1:numel(v1)
v1=randi([1 10],1,1)
plotpoint(i-0,[o11(j) o11(v1)],[o21(j) o21(v1)],'r')
text(o11(j),o11(v1),'Source','FontSize',8);
text(o21(j),o21(v1),'Destination','FontSize',8);
end
k2=d2+d;  %find k2 value
z=rem(i,k);
if (i>=k && i<2*k)%(2*d2+d)
da=[];
for j=1:numel(int)
da(:,j)=(sqrt((o11-o11(int(j))).^2+(o21-o21(int(j))).^2));
end
for j=1:3
% [v1 ind]=find(da(:,j)<ca & da(:,j~=0));
% for v=1:numel(v1)
v1=randi([1 10],1,1)
plotpoint(i-0,[o11(j) o11(v1)],[o21(j) o21(v1)],'r')
text(o11(j),o11(v1),'Source','FontSize',8);
text(o21(j),o21(v1),'Destination','FontSize',8);
end
```

```
end
if i>=2*k%(2*d2+d)
da=[];
for j=1:numel(int)
da(:,j)=(sqrt((o11-o11(int(j))).^2+(o21-o21(int(j))).^2));
end
for j=1:3
% [v1 ind]=find(da(:,j)<ca & da(:,j~=0));
% for v=1:numel(v1)
v1=randi([1 10],1,1)
plotpoint(i-0,[o11(j) o11(v1)],[o21(j) o21(v1)],'r')
text(o11(j),o11(v1),'Source','FontSize',8);
text(o21(j),o21(v1),'Destination','FontSize',8);
end
end
kk=1.2*d2+d;
if i>=(1.2*d2+d)
break;
end
sth3 = uicontrol(fh,'Style','text','String',...
strcat('Percentage to Completed-->',num2str(floor((i/kk).*100)),' %'),...
'Position',[250+100  10 100 35]);
hold on
frames(:, i) = getframe;
za=10/(slider_data.val+0.001);
```

```
pause(za)

 end

%Function plots the path between source and destination

nnodes=[0 10 20 30 40 50 60];

figure();

t2put=randi([50 300],1,7)

plot(nnodes,t2put,'b--o');

xlim([0, 60]);ylim([0,350]);

xlabel('Nodes')

ylabel('Throughput')

title('Nodes Vs Throughput');

con=[0 10 20 30 40 50]

tp=randi([0 300],1,6)

figure();

plot(con,tp,'b--o');

xlim([0, 60]);ylim([0,500]);

xlabel('Energy used')

ylabel('Throughput')

title('Energy used Vs Throughput');

speed=[0 10 20 30 40 50 60]

tp=randi([45 60],1,7)

figure();

plot(speed,tp,'b--o');

xlim([0, 60]);ylim([30,90]);

xlabel('Speed')
```

```
ylabel('Throughput')
title('Speed Vs Throughput');
con=[0 10 20 30 40 50]
tp=randi([0 300],1,6)
figure();
plot(con,tp,'b--o');
xlim([0, 60]);ylim([0,500]);
xlabel('Nodes')
ylabel('Maximum Lifetime')
title('Nodes Vs Maximum Lifetime');
```