SMART AND ENERGY AWARE ROUTING FOR THE INTERNET OF MOBILE THINGS

BY

BEH ZI XUAN

A PEPORT

SUBMITTED TO

Universiti Tunku Abdul Rahman

in partial fulfillment of the requirements

for the degree of

BACHELOR OF INFORMATION TECHNOLOGY (HONOURS)

COMMUNICATIONS AND NETWORKING

Faculty of Information and Communication Technology

(Kampar Campus)

JANUARY 2021

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Date: 9 April 2021

Date: 9/4/2021

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I declare that this report entitled **"SMART AND ENERGY AWARE ROUTING FOR THE INTERNET OF MOBILE THINGS"** is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

Signature : beh

Name : BEH ZI XUAN

Date : 9 April 2021

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Finally, I must say thanks to my mother for her love, support, and continuous encouragement throughout the course especially during this pandemic. Almost everyone is financially impacted by this pandemic but many thanks to my mother to have become my pillar of support and gone through all the ups and down to make this project a success.

ABSTRACT

This project is to design a smart and energy aware routing algorithm for the Internet of Mobile Things. Reason of doing this project is because the discovery of problem such as high occurrence in routing loop and unsuccessful packet routing under high mobility environment for Internet of Mobile Things. Therefore, a smart and energy efficient routing algorithm is necessary to be developed and the level of energy consumption is important to be improved and observed. In this project, we aim to design and develop a new routing algorithm entitled "SEA routing protocol" that is believed to resolve the problems mentioned which will lead to high energy consumption in IoMT devices. The network simulation process is run in the CupCarbon software which is known as a smart city & IoT wireless sensor network simulator. The routing algorithm are developed and coded in Sen Script. In this project, the routing algorithm can perform disqualify node detection and energy aware routing. To summarize, to solve the problem of high occurrence in routing loop and unsuccessful packet routing, two functions are designed and performed. First function will be to filter out the disqualify node in the network based on their respective battery capacity. Second, four different are generated based on the scenario detected. Hence, two scripts written in SenScript will be generated where one is call routing.csc and battery.csc files. Both version of scripts will be simulated and generate an energy consumption report. At the end of the project, packet delivery ratio and energy consumption report are generated which are the key elements to prove the SEA routing algorithm is smart and energy aware. Based on results obtained, the energy consumption level consumed by the network is 0.05 joule to 0.04 joule. Result also shows that when delay instruction is applied before routing message is generated can contributes in the energy efficient context. This can also be concluded that the SEA routing algorithm is smart and energy aware based on the results obtained.

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LIST OF ABBREVIATION

- AODV Ad hoc On-Demand Distance Vector Routing
- BGP Border Gateway Protocol
- DODAG Destination-Oriented Directed Acyclic Graph
- DSDV Destination-Sequenced Distance Vector
- DSDM Dynamic Systems Development Method
- EEDR Energy-Efficient Distance Routing Algorithm
- EIGRP Enhanced Interior Gateway Routing Protocol
- GRP Geographic Routing Protocol
- IoMT Internet of Mobile Things
- IoT Internet of Things
- LLN Low Power Data Easily Lost Network
- MFR Most Forwarded within R
- NFP Nearest with Forwarded Progress
- OSPF Open Shortest Path First
- RERR Route Error
- RIP Routing Information Protocol
- RPL Routing Protocol for Low-Power and Lossy Networks
- RREP Route Reply
- RREQ Route Request Packet
- SDLC System Development Life Cycle
- SEA Smart and Energy Aware Routing Protocol
- THD Topological Hole Detection
- UAV Unmanned aerial vehicle
- WSN Wireless Sensor Network

CHAPTER 1: INTRODUCTION

1.1 Problem Statement and Motivation

In this project, the packet routing process among the Internet of Mobile Things (IoMT) devices play a pivotal role. Many sensor nodes are embedded inside an IoMT devices which therefore form a wireless sensor network (WSN) to communicate with each other. However, the WSN is well known as a resource constrained and energy limitation network as well as surviving solely on the lifespan of the sensor nodes' battery. According to the findings done by Shaikh.R and Sayed.A (2015), one of the major reasons that lead to the degradation quality of services in the network is the lack of implementing dead node detection method. Not only that, the existing routing protocol could not support the nature of WSN which is high mobility then result in packet drop or loss of traceability. In line with the present demand, the formation of network devices has become larger and complex. From this, the problem statement can be concluded as the high occurrence in routing loop and unsuccessful packet routing under high mobility environment for Internet of Mobile Things which can also be found from many existing routing protocols. As a result, excessive energy is consumed by the IoMT devices.

In this study, it has given me the motivation and pleasure to develop a new routing algorithm that could possibly addressed the problems mentioned above. As the growing demand of the IoMT devices such as autonomous vehicle, the companies most concern area is about the energy consumption of the devices. When problem such as routing loop occur, the higher the occurrence of routing loop in the IoMT devices, the shorter the lifespan of the IoMT devices' battery as well as the poorer performance of the IoMT devices. When the lifespan of the sensor node's battery has come to an end, it will affect the overall network performance in terms of the quality of service. The motivation of this project is then followed by developing a routing protocol that supports mobility characteristic of IoMT devices. Several findings have proved that number of existing routing protocols nowadays cannot fully support the mobility characteristic of the IoMT devices which led the poor packet delivery experience. To address this issue, disqualify node detection feature is implemented in this project which can improve the quality of services by filtering out the disqualify node inside network.

1.2 Project Scope

Through the completion of this project, a routing protocol for the IoMT devices that work under the wireless communication with various simulation results on some scenarios will be delivered. The routing algorithm for that protocol will be designed in a way that can ensure energy efficiency, achieve smart context, and support mobility. Also, the routing protocol is smart in which it can determine the optimal path to route the data from one node to the destination node by detecting dead-end route, filtering disqualify node, analyse if the node has been visited before, and generate different types of messages based on different scenario. For the packet routing, we will have to identify the ID of the desire destination node such as sink node and input the ID into the script. By doing this, the source node will start to route the packet to the neighbour until the destination node is reached. It will determine the neighbour to route the packet by generating an index number that represent the sequence of who first receive the message sent by sender node. Not only that, the routing protocol can also perform the disqualify node detection which can improve the quality of service in the network by filtering out the disqualify node based on their respective battery power. Lastly, the algorithm built will be tested on different range of nodes in the network and determine the performance based on energy efficiency level and packet delivery ratio.

1.3 Project Objectives

The objectives of this project are as follows:

1. To develop a routing algorithm which allow a message to be routed from one node to another. At the same time, it is smart in a way that different types of routing messages are generated based on different scenario. For example, when a dead-end route is faced, a specific type of message will be generated to ask the sender node to elect a new node for parsing the message. Different number of sensor nodes will be placed in the network to do comparison. This study differs from other work as it will not maintain a routing table in every sensor node and delay instruction will be applied which is believed can contribute to the energy efficient context.
2. To develop a disqualify node detection that can analyse the sensor node placed in the network and filter out the disqualify node in the network based on their respective battery power. By doing this, it can improve the overall qualify of service in the network.

3. At the end of the simulation process, the comparison such as packet delivery ratio, energy consumption level that has been collected from different number of nodes will be determined and presented in a graph form. Besides, the suitability of the protocol to be deployed in simple, complex, large, or small network will be tested.

Apart from that, things that would not be covered in this project would be the external factors that would affect the overall network performance. External factors such as overload transmission of data packet, the network attacks and authenticity of the sensor node. Also, there will be no wired network communication.

1.4 Impact, Significance and Contribution

It is predicted that the Internet of Things (IoT) will become the future trend and popular to be employed around the world. By doing this project, it is expected to benefit the society or the world in terms of wireless communication for Internet of Things (IoT) domain. According to Low.TJ, Zaman.N and Yasin.MM (2016), many of the IoT devices is small and is built with finite battery capacity, limited computational capacity, and has lesser storage memory. Besides, the energy consumption is always the major concern to many of the company that own the IoT devices. Thus, the energy efficient context is always the major issue in WSN and always the main thing that many companies dream to achieve. It is also proven that the higher the energy consumption of the sensor the lesser the lifespan of the sensor nodes' battery. As a result, the IoMT devices is hard to last for several days and need frequent charging of battery which also can shorten the lifespan of the sensor node's battery. Many research papers have proven that the most energy consuming operation in a wireless communication network is always the routing process between one node to another (Low.TJ, Zaman.N and Yasin.MM., 2016).

With the points mentioned above, to maintain the energy efficiency during the data packet routing activity is extremely important. If the routing activity is built in an energy aware manner, the problems such as fast battery draining, short lifespan of the battery will be solved. Other than that, the mobility issue must be taken into consideration during the development of routing protocol. With mobility, the user can communicate and send data at any place without the network disruption. When the problems are solved, it will not affect the daily operation of people as the IoMT devices such as wearable fitness trackers is popularly to be used nowadays. From this, the user of the IoMT devices do not need to concern on the battery issue on whether to charge or change their devices frequently. When problem is resolved, lesser network disconnection or disruption issues will happen.

On the other hand, to achieve the mobility and energy efficiency are not enough. The routing algorithm must be able to ensure the packet delivery as much as possible. Therefore, the routing protocol must be developed in a way that it delivers the packet in a smart way. The smart term in the information technology field is known as the capability of the hardware to monitor and analyse itself (Christensson, P. 2006). However, when the smart term is applied in the routing protocol that is going to be developed at the end of this project, it refers that the capability of the routing algorithm to monitor and analyse the optimal path to reach the destination. In another words, the routing algorithm can calculate and compute the optimal path to the destination itself as well as choosing an alternate path in case a link failure had happened. An added feature of the routing protocol would be the ability to undergo the disqualify node detection as the network nowadays is growing larger and complex which result in poor network quality of service. By doing this, it can ensure high packet delivery and high quality of service for the communication between the IoMT devices. Thus, all the packet send from one region to another can be received and the daily operation of the user of IoMT devices will not be interrupted.

1.5 Background Information

Since the invention of IoT, it has benefited and improved the human daily operation in terms of effectiveness and accuracy. However, the engineer and scientist had contributed a lot so that the world can enjoy the beauty of IoT to human daily operation. The devices that had applied the IoT concept are communicate wirelessly and support mobility. But when time is back to the past decades, majority of the electronic devices were communicating under a wired network. For example, the communication between two computers were launched by connecting them via cable. Also, for a computer to talk to a printer, it must also be connected through a physical link in order to print a document. The term “wireless” is almost a crazy and impossible idea for the people over the past decade. Also, before the convergence of the computer technology, the people in the past were writing documents using pen or using the typewriter. Everything is documented on a paper and when unpredictable disaster has happened, the document is gone without leaving hardcopy of documents.

In the past, people will need to pay full attention to calculate an individual footstep, the humidity, the pressure when doing an experiment. All the data is required to be recorded from time to time. Once the data collector has overlooked one of the steps, the output for the experiment will become inaccurate and the experiment is messed up. Slowly, the people started to type documents using keyboards which then programmed the words to computer. People started to have a softcopy and hardcopy of document at the same time. They can save their work in a USB flash drive, send email, browse information on the Internet. Also, the sensor which can sense and collect data without human assist has been invented in the 90's by Eric Fossum. This is a great invention that helps the domain who need to do data collection from time to time. All these are the contribution of the engineer and scientist with the aim to ease the way of people doing things.

In the 80s, the router was invented and started to do the routing process. Routing is the process of traversing the packet from one IP interface on a network to the targeted IP interface on another network. It is the most important process where it allows the communication between different network as well as an important process for wireless communication nowadays. Router is solely operating at the network layer of the OSI model which perform the job of sending packets from one network to another network. Router is also a necessity for the Internet (Moore.F, 2017). Many forms of routing have been invented throughout the decades. The first form of routing was the static routing. It requires the network administrator to manually configure the routing entry to the routing table which is suitable for small scale network but not for a large-scale network. It is then followed by the second form of routing which is the dynamic routing. It is a form of routing where the router protocol will populate the routing tables in the network. It can also discover all the possible path to the destination and choose the best path to route the packet to destination. The job of populating the routing table is done by the software. Also, the dynamic routing can discover the alternate path to reach the destination when the best route has failed to send packet (Moore.F, 2017). There are few well known routings protocol that performs dynamic routing are Routing Information Protocol (RIP), Open Shortest Path First (OSPF), Enhanced Interior Gateway Routing Protocol (EIGRP) and Border Gateway Protocol (BGP). The dynamic routing is also widely to be used nowadays in large scale network or medium scale network.

In year 1994, BGP was invented and known as an exterior gateway protocol. With BGP, it is used throughout the Internet to do the task of exchanging routing information among autonomous system which then allow the communication between networks. BGP is important that could make the communication from one network to the internet a success rather than allow routing process in an organization or building. It was the first move that people finally can access the internet to communicate with people that is in another region.

As years passed by, the wired network is realised as not that convenient for human daily operation and cannot expand the business easily since to maintain a wired network is not cost effective. Then the concept of wireless communication started to gain the attention. It is because the wireless communication can be formed without the wired cable which can help the organization to reduce cost. Also, it is convenient and can support mobility. Therefore, many organizations had started to invest money to develop a reliable wireless communication. The wireless communication is continuing to be improved until now.

Apart from wireless communication, they found out that the sensor could be used to collect data without the human assist. Benefit of applying sensor are to help the company to reduce cost, high accuracy of data collected, minimum error, can be programmed to collect data at certain time. By using the sensors, it also eases the way people doing job as they can remotely access the data collected by sensor at another region. A WSN is formed when groups of dedicated sensors that used to monitor and record the physical conditions of the environment is spatially dispersed (Kamal.Z and Salahuddin, 2015). According to Low.TJ, Zaman.N and Yasin.MM (2016), the WSN is a resource constrained network and the most energy consuming operation is known as the data packet routing. The collected data is to be organized at a central location which is the at the sink node. The sink node will also route the data to the Internet which can be accessed by the requester. The data that it collects based on the physical condition of the environment are temperature, humidity, sound and so on. According to Kamal.Z and Salahuddin (2015), WSN does not has a static network topology and it rely on the wireless connectivity to ensure the sensor data can be delivered wirelessly. In WSN, it also allows the control of sensor activity. The WSN is built up by a group of sensor nodes and each node is connected to one another and routing algorithm is needed to be applied so that it can choose an optimal path to route packet to the destination. The WSN is widely employed in the health care monitoring, industrial monitoring and so on. Although WSN is a well-known solution for numerous applications, but implementations vary under different aspects which lead to the reduction in economies of scale (Lazarescu.M, 2017). As a result, both the hardware and software for WSN solutions are often application-specific prototypes which lead to significant non-recurrent engineering cost and risks such as reliability, development time and optimization (Lazarescu.M, 2017). Hence, the IoT concept has aroused. Besides, the concept of WSN plays an important role to the invention of the Internet of Things (IoT).

To differentiate WSN and IoT, WSN is built up by a group of dedicated sensors along with a communication infrastructure and it is also a foundation for the IoT application. While for the IoT concept, it is a network that consists of numerous physical objects which is used to connect and exchange the data over the Internet. Inside the physical objects, there are many built in sensors which constantly collecting the data of the physical object. For example, a drone has minimum 3 built in sensors to collect the data about the physical condition of the environment and one node is to be selected as the sink node to send data over the Internet. However, the IoT system sensors send the collected and monitored data directly to the Internet. In WSN, the sensors are required to send the information to the sink node then the sink node will upload the information to the Internet so that user can access data from another region. In simple words, the WSN is a one node in IoT or can be described as WSN is part of the IoT topology. Without WSN, the IoT platform is not existed.

According to GSM Association, several distinctive features are identified in IoT is believed to bring an enormous impact to the society and enterprises. The significant distinctive feature is the IoT can enable life-enhancing services. For example, apply IoT in the Health applications. Connected devices to capture the major health indicators and update the medical report in real time sending alerts to the doctors to ensure treatment is correctly followed, alert family members to ensure proper caretaking. Then move to the IoMT context, it refers to the mobile devices that apply the IoT context such as autonomous vehicle. For example, the self-driving autonomous vehicles will keep track the distance with the front vehicle, detect the problem in the vehicle and search the nearest car servicing centre immediately.

In a conclusion, the wireless routing protocol is the pivotal method to achieve all these things such as the IoT example mentioned above. However, to accomplish this, the design and routing challenges are needed to be addressed first. In this project, both the challenges in terms of energy efficiency, sensor location and mobility are the prior concern that needed to be solved. Also, this project is focuses on the wireless routing between the IoMT devices.

CHAPTER 2: LITERATURE REVIEW

2.1 A Survey: Ad-hoc on-Demand Distance Vector (AODV) Protocol

Ever since the convergence of wireless communication, the Ad hoc On-Demand Distance Vector Routing (AODV) has raised the researchers' attention for the Ad Hoc Network. According to Zanjireh.M and Larijani.H (2015), a network is defined as an ad hoc network when it is operating under a scenario that does not count on antecedent framework such as routers in a wireless network. Instead, every sensor node is responsible to do routing by forwarding the data to other nodes based on the routing algorithm that applied in the network. According to Liu.S, Yang.Y, Wang.W (2013), the classic routing protocol is not capable to meet the needs of the unpredictable and frequently changing of network topology in the multi-hop characteristic of ad hoc network. Thus, the AODV which is a reactive routing approach is invented. A reactive routing approach that is based on distance vector concept is also known as the on-demand routing. Reason of saying this is because a route is only be built or discovered when data packet is necessary to be forwarded to the destination. For example, when a source node forwards a packet to the destination, it started to examine the routing table to determine if there is any existing route to the destination. If there isn't an existing route, source node will start to do route discovery to look for possible path. Also, the reactive routing approach of AODV is believed to decrease the routing overhead and power consumption.

In AODV, the sender will broadcast a route request packet (RREQ) in order to find a route to the destination. The broadcast message will propagate through the whole network until it found an intermediate node that can also communicate with the destination node or has the recent route information about the destination. During the forwarding of RREQ process in the intermediate nodes, the intermediate nodes will record all the collected data in their respective routing tables about which node the RREQ is initiated from. Through this, it is useful as it will be used to generate a reply path for the route reply packet since the AODV uses only the symmetric links. As the route reply packet forwarded back to the source, the nodes along the reverse path add the routing information into table. When the AODV detected a link failure, the sender node will be notified about the situation and the process of route discovery can be performed if needed. In AODV, the route discovery mechanism will be executed only when a route request to attain a new destination by advertising the RREQ in the network. The route error packet (RERR) will only be used with the aim of erasing the broken link.

The AODV is called to determine the next hop when a message is needed to be traverse from one network entity to another. AODV will then update the routing table whenever it receives a request to send a message, it will then check the existence of that specific route as well. The routing table contains the following fields which are the destination address, the next hop address, the hop count and lastly the destination sequence number. After checking the routing table, the router will simply forward the message to the next hop if the route exists. Else, it will save the message into the message queue and initiate the route request again to determine the route. The process of AODV can be illustrated by the figure 1.1 as shown below:

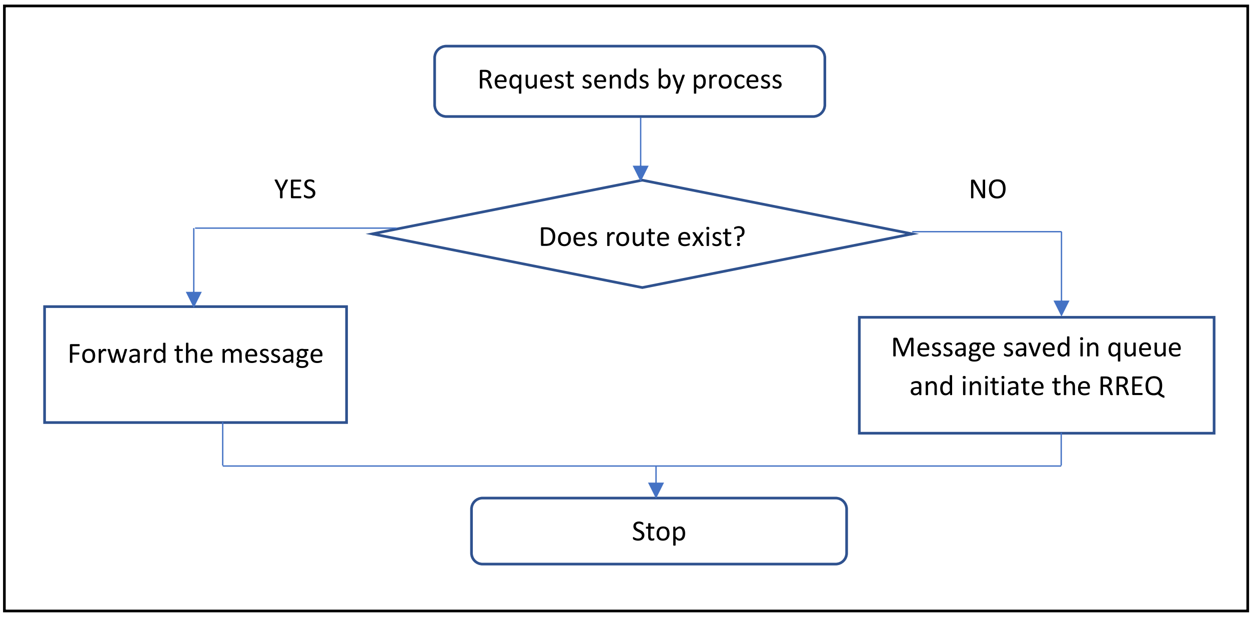


Figure 1.1 Process of AODV

Meanwhile, in AODV it uses four types of messages to communicate with each other. Messages such as RREQ message, Route Reply (RREP) message are used for route discovery while RERR messages and HELLO messages are used for route maintenance. To conclude, the AODV will need to carry out both the route discovery mechanism and route maintenance mechanism.

When it is carrying out the route discovery mechanism, when a node initiate or forward a RREQ message to the neighbour node, the node is likely to receive the same RREQ message back from its neighbours. Through this, it is likely that routing loop will occur. To prevent routing loop, every node will maintain a route request buffer. Inside the buffer, it holds list of advertised route requests which has been made recently. Before RREQ message is forwarded, the respective node will constantly inspect the buffer and ensure the request is not been forwarded before. The RREQ message will also be stored in the buffer by a node that initiate a RREP message. Every destination in the network will maintain an accumulating sequence number that present as a logical time at the respective node. At every route entry, it contains the sequence number of the destination which at the same time represent the amount of time the route was created by the destination sensor node. Purpose of using the sequence number in AODV is to ensure that the node only update route with a newer one. Link failure is possible to occur caused by the flexibility of the nodes in wireless network. When link failure has happened, the node that is shorter distance to the source node will invalidate in its routing table about all destination that become unreachable due to loss of link. A route error (RERR) message will be created that will lists each of the lost destinations.

While in the route maintenance mechanism of AODV, the node will send the route error (RERR) in a upstream format until it reaches the source node. If multiple previous hops that were utilizing the link are detected, node will advertise the RERR. When the RERR is received by a node in the network, it will check from the RERR list and verify if the sender of RERR is next hop to some of the destination node. Whenever a sending node is detected to be the next hop to any of the destinations, the route will be compromise in routing table and disseminate the RERR to the source. RERR is continuing to be sent in the method mentioned earlier until it is accepted by the source. Once RERR is accepted by source node, it can still commerce route discovery when it requires the route again. According to Singh.M and Kumar.S (2017), the propagation of RREQ and path of the RREP to the source can be illustrated by the figure 1.2.

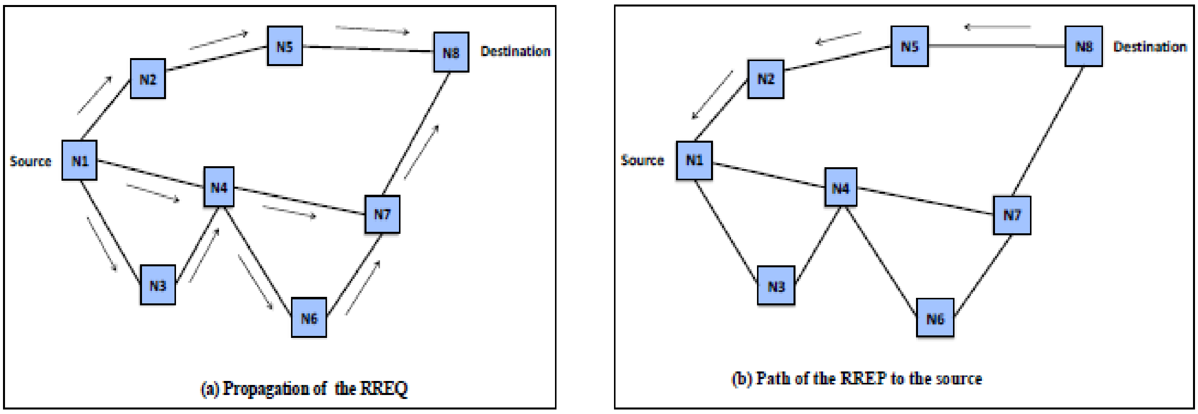


Figure 1.2 a) Propagation of RREQ message, b) Path of the RREP to the source by Meeta Singh and Sudeep Kumar (2017)

2.1.1 Advantages and disadvantages of AODV routing protocol

Apart from the workflow of AODV, there are still good and bad about this protocol. When talk about the advantages of AODV protocol, the protocol can quickly respond to the topological changes that is affected by mobility. AODV can support the unicast method and multicast method of packet transmissions even if the nodes in the network is in a constant movement. AODV does not rely on existing median of supervisory system to handle the routing process and has lower setup delay for both the connection and detection of the latest route to reach the destination. The protocol can ensure a loop-free, self-starting and high scalability to many mobile nodes. While for the disadvantages side of AODV, enormous number of control packets will be generated when a link failure has occurred which can increase the congestion in the active route. Besides, the AODV consumes a lot of bandwidth and takes longer time to build a routing table. Various performance metrics begin to decrease followed by the growing size of the network. It has high processing demand and has possibility that a valid route will become expired. In AODV, the determination of a reasonable expiry time is difficult to be concluded.

2.2 Energy-Efficient Distance Routing Algorithm (EEDR)

With the objective on ensuring the energy efficient in small- and large-scale network, Chan.HF and Rudolph.H (2015) had come out with their routing algorithm that is named as Energy-Efficient Distance Routing Algorithm. In this golden age of technology, WSN has been deployed popularly on a variety scale of network, so the scientist declared that will pivot more on the reduction of energy utilization on the extended distance transmission when building the algorithm. When applying hierarchical routing algorithms in multi-hop transmission, problem of energy misuse on redundant transmissions is discovered. To solve this, the energy efficient distance routing algorithm is proposed. As suggested by Chan.HF and Rudolph.H (2015), the network is spitted up into diverse cluster whereby all cluster head node of each cluster is supervised to combine and accumulate figures from the corresponding cluster member with the purpose of retaining energy. Then, an overview of the gathered information is distributed by discovering the next hop that is having the shortest distance to the base station. At the same time, it is also within the energy broadcasting range. By enforcing this, it is able to prevent unnecessary transmissions and retain the transmission costs. In the case that the sensor node is extremely near to the base station, data is straightly forwarded to the base station. This method is able to retain the energy utilization level as the information is forwarded by locating the nearest next hop to the base station rather than delivering the data one by one to the next cluster head until it reaches base station which is being deployed by the hierarchical routing algorithms during multi hop transmission.

As a final observation, the EEDR algorithm is utilizing the method of discovering the next hop that is having the shortest distance to the base station which is more superior than the method of forwarding data one after another to the next cluster head until base station is reached. The initial procedure on how it could discover the next hop nearest to the base station is by letting all the cluster heads to abide for an allotted period of time before commencing the transmission. Another method would be to abide for a specific size of message to be assembled before beginning the forwarding. The distances to base station are to be analyzed. Data is passed to the base station only when the distance to the base station is nearer than other cluster head. Else ways, the cluster heads details are to be withdrawn from the database. Conversely, the following targeted cluster is to be chosen within its energy efficient transmission range and closest to the base station. The energy utilized for the data forwarding of both cluster head will be examined. Consequently, the data is passed by the cluster head to another and renovate the cluster heads in the case that the remaining energy is adequate for both cluster heads.

The method has been simulated on small, medium, and large-scale network with network size of 100x100m, 300x300m and 400x400m. According to figure 1.3 (small scale network), for small scale of network, it is more suitable to use the single hop transmission as distance between nodes and base station is short. Hence, straight forwarding to the base station is considered sufficient to retain the energy without any redundant transmissions. While for the figure 1.4 (medium scale network) and figure 1.5 (large scale network), the energy efficient distance algorithm as suggested by Chan.HF and Rudolph.H (2015) is the most suitable method. It is because the cluster head itself will select the next hop that having shortest distance to the base station and is inside the energy transmission radius. It is proficient to diminish the energy utilization and the number of transmissions. While for the shortest distance to the next hop algorithm, it is not suitable to be used in medium and large-scale network. It is because energy probably be misused for superfluous transmissions. It may still have high possibility to generate lengthy path and consumed more energy compared to the energy efficient distance path even though the distance to the next cluster head is minimized.

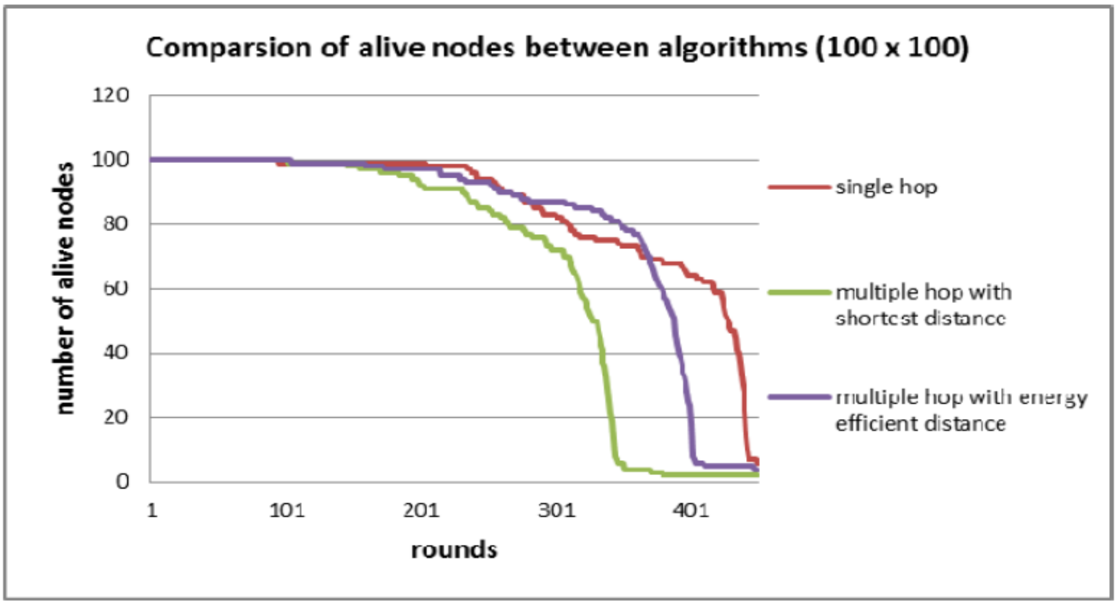


Figure 1.3 Simulation on small scale network by Chan.HF and Rudolph.H (2015)

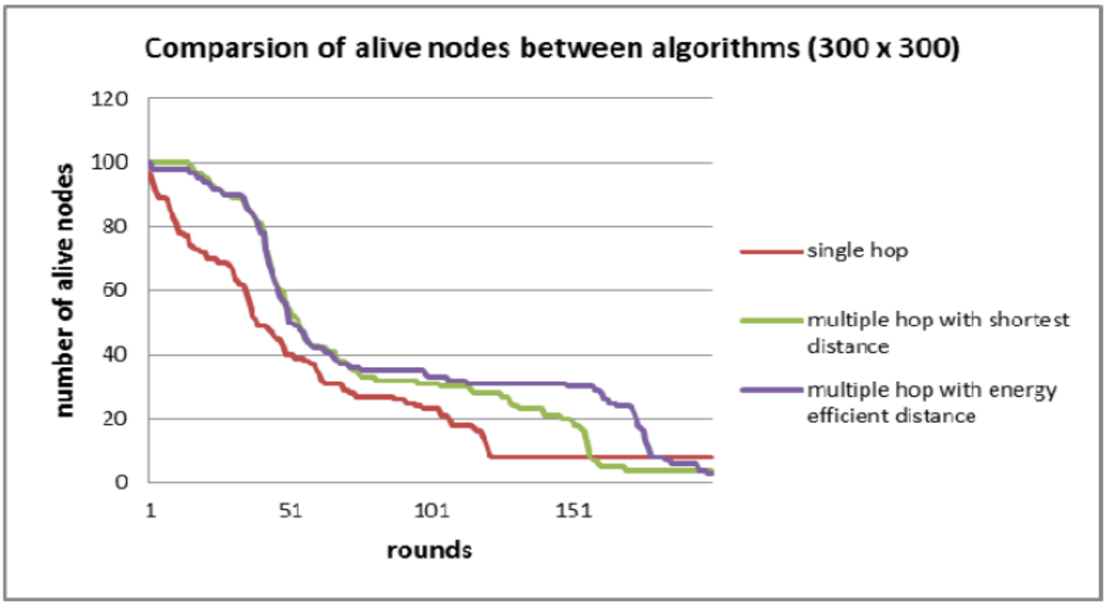


Figure 1.4 Simulation on medium scale network by Chan.HF and Rudolph.H (2015)

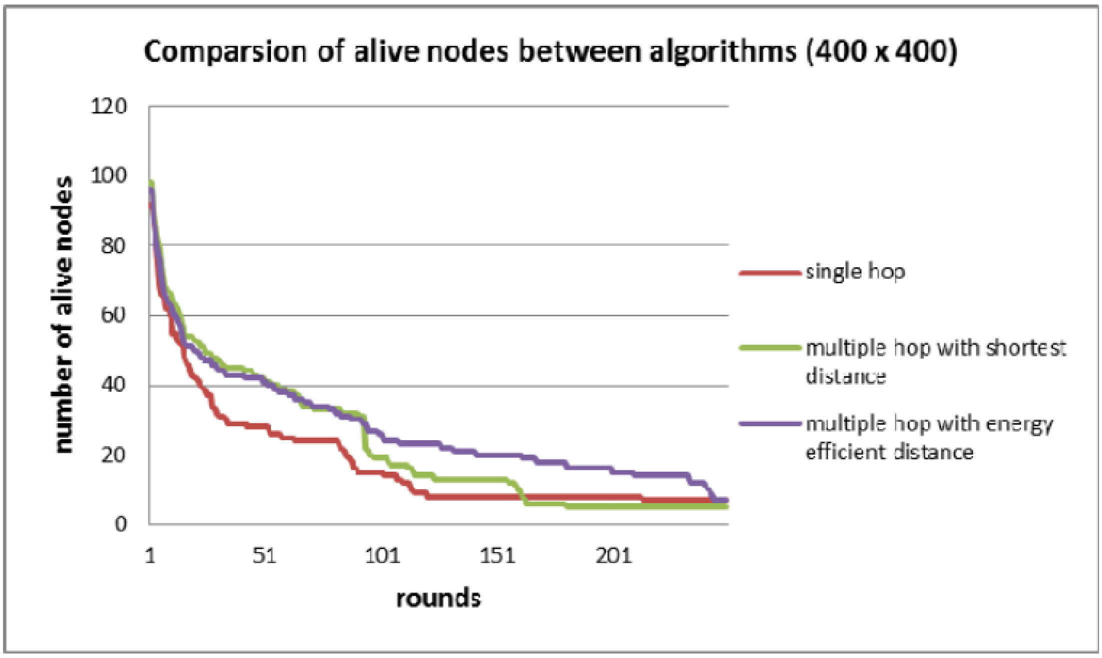


Figure 1.5 Simulation on large scale network by Chan.HF and Rudolph.H (2015)

2.2.1 Advantages and disadvantages EEDR Algorithm

To lighten the issue of energy inefficiency of WSN, the hierarchical routing algorithms had been proposed for WSN (Liu and XuXun, 2012). Hierarchical routing algorithms is a common data communication technique and it is commonly being deployed. According to Liu, XuXun (2012), claimed that hierarchical routing algorithms can be perceived as using the clustering method which is splitting the sensor nodes into diverse groups. It is a technique which can reduce the energy consumption whereby the cluster head is dispatching data from sensors to the base station. The hierarchical clustering is functioning in a way that the sensor network is separated into multiplex layers or either into different clusters. Each cluster head coordinates the transmission within cluster as well as handle the routing between the clusters and base stations. Hence, when the data to be sent carry from one level to another empowering it to carry longer distances with lower unsuccessful rate. This process contributes a faster and energy efficient data communication. With the point mentioned earlier, the hierarchical clustering provides the pros of data convergence between the cluster heads at distinct levels with the aim of optimizing the performance of the entire WSN.

Though many strengths in hierarchical routing algorithms, limitations occur during the transmission. According to Chan.HF and Rudolph.H (2015), limitations happened during the single hop transmission as well as the multiple hop transmission. During the single hop transmission, the cluster head will pass data straight away to the base station without forwarding through cluster head. It is considered the straightforward method to transmit data. However, problem arise when this method is applied in a large-scale network. Since sensors have transmission distance limitations, the data is not permitted to be sent to a particular range. If the data is successfully to be forwarded out, there's possibility that the cluster head is carrying a heavy burden as the energy utilization is equivalent to the distance that data is transmitted. In short, applying hierarchical routing algorithms in single hop transmission cannot ensure energy efficiency that directly shorten the lifetime of WSN. While in the multiple hop transmission, the cluster head will forward data to the base station by not flowing through every next cluster head. By using this method, it will split one long distance into multiplex shorter distances for the purpose of data transmissions. This method is suitable for large scale network as the cluster heads are sharing the loads among themselves. However, there is wastage of energy spent on unnecessary transmissions which again didn't achieve the energy efficiency.

2.3 RPL and P2P-RPL routing protocols: Implementation, challenges, and opportunities

The RPL which stands for Routing Protocol for Low-Power and Lossy Networks is a most commonly used routing protocol for the IoT domain. RPL is a distance vector protocol designed in 2012. A low power data easily lost network (LLN) refers to many embedded devices where it has limited processing and storage capabilities and connect with each other via Bluetooth, Wi-Fi or IEEE 802.15.4 and other wireless technology. LLN is widely used in environmental monitoring, smart home and other IoT based scenario. In February 2008. The ROLL Working Group compute the existing routing protocol such as the AODV, OLSR etc. Result shows that the existing routing protocol failed to meet the requirements of LLN which led to the development of RPL that can meet the low power requirement of LLN.

The RPL routing protocol is an IPv6 based distance vector routing protocol that can routed under the consideration of objective function along with the constraints. According to Yang.X (2014), The routing process will also re-establish a directed acyclic graph where every node except the root node contains the parent node as the directed acyclic graph up the default route. In RPL, when one of the nodes need an IPv6 addresses, it will exchange with the neighbour node that consists of three ICMPv6 messages to choose their respective parent node in order to join a goal-oriented directed acyclic graph. In RPL, data flow patterns are generated which are point to point and multipoint. There are also non-storing mode and storing mode in RPL. Moving to the data flow of point to point in non-storing mode, the data will be passed to the source node and the common parent node of destination node which is then followed by the parent node to transmit data to the destination node. While for the data flow of point to point in storing mode, the parent node will first transfer the data to the root node and the data collected by root node transfer to the destination node.

Meanwhile for the data flow of multipoint in non-storing mode, only the root node transfer data to following node and store the routing table at same time. Routing table of the root node is built under the guidance of the remaining nodes via the source route. However, for data flow of multipoint in non-storing mode, the root node has a routing table and the root node can only reach the destination by determining the next hop address without a source route to be built. In LLN, there is no static network topology and the RPL will need to connect the rest of the node automatically as well as discovering and maintaining the topological changes. The architecture of the RPL routing domain formulate by the Zhao.M et.al. (2016) can be illustrated by the figure 1.6.

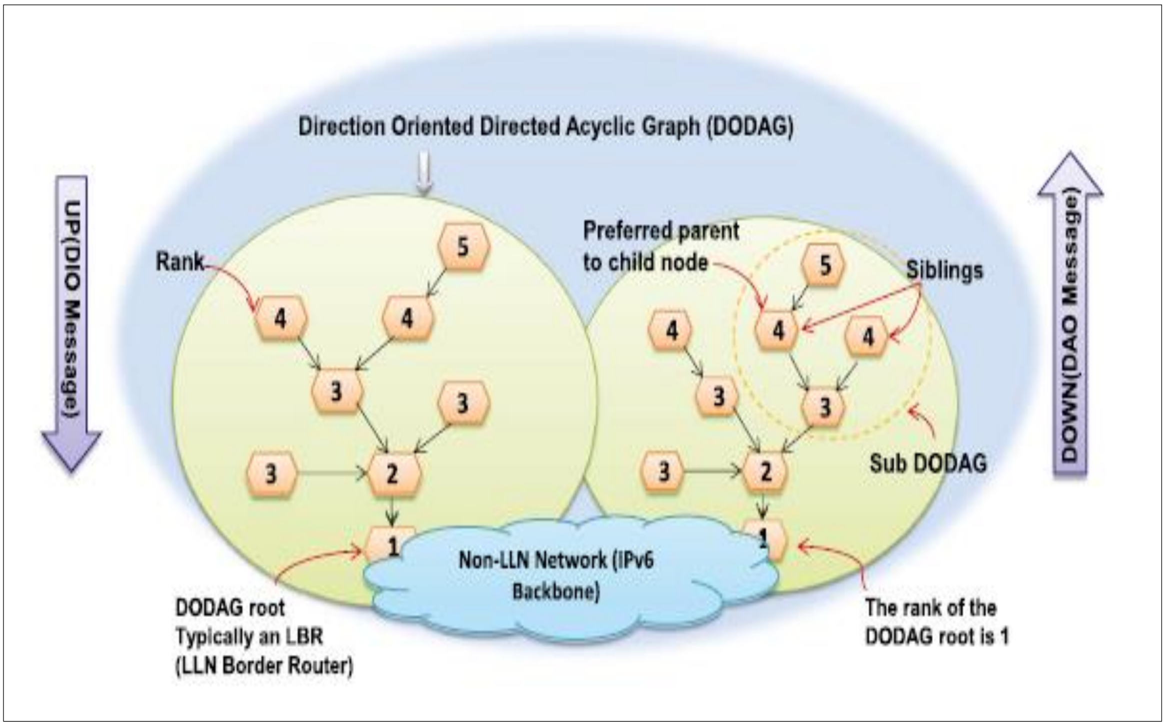


Figure 1.6 Architecture of RPL routing domain by Zhao.M et.al. (2016)

In RPL, it established a network in a tree topology format as a DODAG which is a destination-oriented directed acyclic graph. DODAG is rooted at a sink node that can be called as a root node that serves as a transit point bridging DAGs with the IPv6 network. By referring to the figure 2.6, it is clearly showing that one DAG is corresponding with other two of the DODAGs which are joined with the backbone link. The arrows as shown in the figure 1.6 are used to specify the rule from child node to their preferred parent node. In RPL, it has 4 sample values. Specifically, they are the instance ID, the DODAG ID, the DODAG version number and lastly the rank number. Four of these samples are the pivotal role which used to preserve a DODAG topology as well as uniquely identifying every node in RPL. The instances are also to be used to classify the DODAG sharing the identical service type such as the objective function. Besides, the common DODAG ID is owned by the nodes that are connecting with the identical root. For the DODAG version number, it is renovated every time when there are changes in the topology of DODAG. While for the rank instance value, it's purpose is to represent the distance from node to root node. The smaller the rank of the node the closer it is to its root node.

In RPL, the routes from root node to the other nodes are called the downward routes while the upward route is referring the routes from node to the root node. On the other hand, The RPL provides several features that make it so suitable for the LLN. Firstly, the RPL provides routing loops detection and routing loops prevention. It is done by every node's rank must be bigger than their parent node in order to obtain the open-chain nature of DODAG. It has the local recovery mechanism and global recovery mechanism that can catch the routing loop and recuperate the topology. The RPL has the capability to do self-configuration in a way that the paths of network are dynamically discovered during the IPv6 neighbour discovery mechanisms. The communication paradigms of RPL are multipoint to point, point to point and point to multipoint. The RPL is also widely used in LLN, 6LowPAN network and other IPv6 networks. It is then followed by the security mode of RPL which is when unsecure data is detection, it reinstalls and authenticate it. According to Zhao.M et.al. (2016), the mode of operation (MOP) in RPL are MOP (0) stands for no downward routes, MOP (1) stands for non-staring mode, MOP (2) stands for storing mode while MOP (3) stands for storing mode with multicast.

In LLN, two conflicting goals are needed to achieve which are in LLN require network topology is constructed efficiently and quickly, hence operative scheme of forwarder selection that provides rapid routing adjournment is necessary. Secondly, the network topology needed to be serviced via little routing cost in order to save energy. These goals are intricated by the low-power radios. Because of these, it results in network disconnection and high packet loss. To addressee all of these, trickle algorithm is adopted by RPL to ensure speedy broadcasting and little preservation fee for the whole network topography. The nature of the dribble algorithm is planned to broadcast the routing information in a fast manner and can maintain a low routing cost of network topology. According to Zhao.M (2016), a local "polite gossip" is used by the algorithm to do the self-regulate and exchange the packets with the neighbour nodes. Also, two potential states of the neighbour nodes are determined, which are all the routing data for every node in the network is up to date and another situation is existing nodes with older routing information. The trickle algorithm is unconstrained in terms of network density which make it extensible to be applied in many different networks.

2.4 Geographic Routing Protocol routing protocol

In both the mobile Ad Hoc network or in a wireless sensor network, they have the self-organized characteristic where connections are not initiated for interchange of information. Major issues of them is the scalability, high mobility, frequent change in network topology and the most energy consuming process known as the routing process. A routing process have high chances to become fail when there's an unexpected adjustment happen in the network topology. The mobility would be the major issue for the failure of routing under a wireless communication network. Hence, the geographic routing protocol (GRP) is best suited to be the routing protocol for devices work under wireless communication network. The GRP is more efficient and scalable for high mobility and frequent changes in the network topology environment. The GRP is under the hybrid routing approach which can solve the problems found in both proactive and reactive routing approach. Meanwhile, the hybrid routing approach is also the combination of the proactive and reactive routing approach. According to Singh. H, Kaur.H and Sharma. A. (2016), in hybrid routing approach the path is established using the concept in proactive routing while the routing process is done through the concept of reactive routing approach.

In GRP, it utilizes the idea of geographic routing during the exchanging of data between nodes in the network. The purpose of the geographic routing is utilized to eradicate the restriction of the topology-based routing. Through this, it contributes a good execution for the dynamic topology as the packets are passed to the destination corresponding to the location. Every node will confirm its own location and check the location of other nodes in the network by using several positioning strategies such as GPS etc. With the use of position-based routing, it eliminates the needs to establish or maintain the route connections. Routing table is not required to be stored or maintained in a up to date basis for every node when transmitting information. It is simple in a way that it identifies the position of the target node and conveys the information from sender node to the destination node. Way of passing the data in the GRP is depends on the site information of the target and the one hop neighbours.

In hybrid routing, two types of forwarding strategies which are the greedy forwarding and face-2 routing perimeter. In greedy forwarding method, sender node would know the estimated location of the receiver node in a way that message is passed to the closest neighbour of the destination node and message is obtained by the positioning strategy. The intermediate node that obtain the information to a neighbour two-faced in the way of the receiver node. This process is recurring whenever information is successfully delivered to the destination node and every node in the network will serves its own table that consists of the position of every node is listed. The major difficulty in the greedy forwarding method is to choose a reliable neighbour node to forward the information. To do this, different routing strategies are used defined as in terms of initiation, directions and space approaching the receiver node. Three different routing strategies are Most Forwarded within R (MFR), Compass Routing and Nearest with Forwarded Progress (NFP). Different routing scheme will lead the node to determine which neighbour node the data should be passed. Different routing strategies can be illustrated by the figure 1.7.

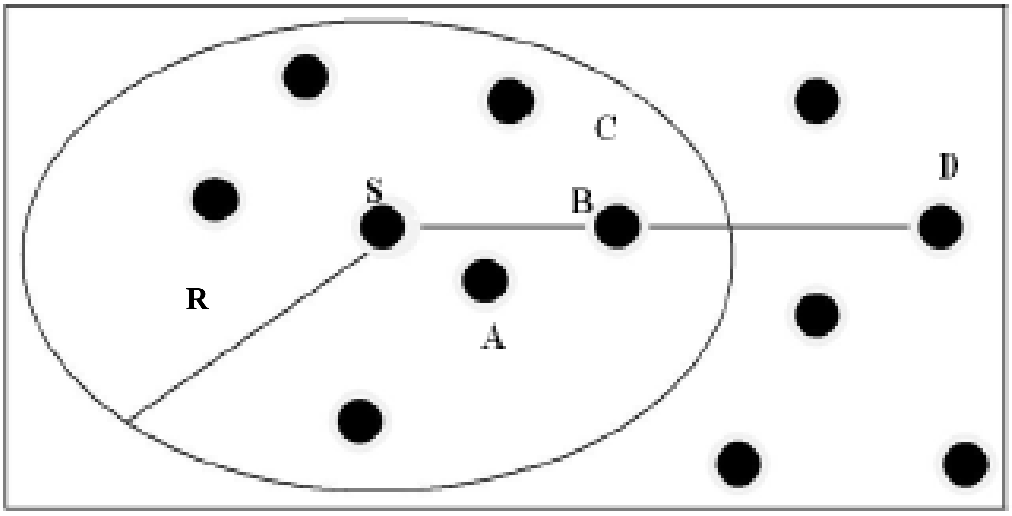


Figure 1.7 Greedy Routing Strategies by Singh. H, Kaur.H and Sharma. A. (2016).

In figure 1.7, S represent the source node, D represent the destination node and R represent the service area or utmost range of the S. The main motivation is to pass information from S node to the neighbour node and can reach the D node. Based on the figure 1.7, the C node can be the nearest towards the destination node at the same time inside the sender node S coverage area. This strategy is called the MFR aims to lower down the quantity of hops when sending the data from S node to D node. MFR is often used in a situation where the packet does not alter the signal strength for the communication between node S and node D. However, when packet altered its own signal strength, the NFP strategy will be utilized. In NFP, packet is forwarded to the closest neighbour of the sender node and able to reach to the destination node. The node for it would be the A node. Once, all the nodes in the network utilize the NFP strategy, collision between packets during transmission can be reduced a lot. While for the compass routing, it is a scenario where the sender node selects the neighbour node that is closest to the straight line between S node and D node. The example node for this strategy is the B node. Compass routing is utilized in order to reduce distance from source node to destination node during the packet traversal.

When packet arrived at a node where it failed to find the neighbour node that is near to the destination and at the same time achieve the criteria of greedy forwarding routing method, the Face-2 routing method will be used to determine the destination address. In Face-2 algorithm, packet is pass to the node that has the minimum backward progress when one of the nodes cannot discover the forward path. Disadvantage of this routing technique is that routing loop could occur. The nodes that utilize the Face-2 algorithm not necessary to save extra or even insufficient data as it is based on the planner graph traversal. It will proceed to the greedy forwarding mode when packet reaches closer to the destination where packet is in an improvement mode.

A planner graph has no intersecting circumference. Data is moved in an ad hoc network where nodes are apexes and circumference exist between the two apexes if they are nearer to communicate straight with each other node. During the planner graph traversal, packet is sent across the centre of the face by utilizing the right-hand rule. Right hand rule is about frontward the packet on the next hop by using the concept of anticlockwise from the circumference which it arrived.

2.5 Comparison table for AODV, DSDV, RPL and GRP.

Routing Protocol	AODV	EEDR	RPL	GRP
Routing Approach	Reactive/ On demand driven	Reactive/ On demand driven	Proactive/ Table driven	Hybrid
Feature	• Route is discovered and updated when needed. • The discovery of routes is initiated by the source node.	• Network is divided into multiple clusters. • Finding the next hop closest to the base station.	• Distance vector routing protocol. • Perform periodic route updates. • Highly flexible to network conditions, immediately give alternate routes when default one is failed.	• Integration of proactive and reactive routing approach. • Route is built using concept of proactive routing while routing process is achieved based on concept of reactive routing approach.
Advantages	• Lower routing overhead. • No routing loops. • Since on demand route discovery, it is more efficient in	• Lower fail rate. • Suitable for large scale network • Avoid wastage of energy spent on	• Low energy consumption.	• Recommended for large network since more efficient and higher scalability. • Up to date routing information.

	dynamic nature of WSN. • Low bandwidth requirement. • Low battery power requirement.	unnecessary transmissions		• Medium level of bandwidth requirement. • Medium level of battery power requirement.
Disadvantages	• High latency. • Transmission of data after route discovery result in delay.	• Result in a longer overall path and require more energy	• It has lossy links. • Generate different error rate. • High network instability.	• Require more resources for large size networks. • Results in inter-zone routing latency.
Energy Consumption	• Less energy consumption.	• High power consumption.	• Less energy consumption.	• Less energy consumption.

Table 1.1 Comparison Table for AODV, DSDV, RPL, GRP.

2.6 Wireless Sensor Network (WSN)

As the fast growing of IoT or IoMT devices, the WSN topic is often a leading area of research. The routing challenge, and energy consumption level are always the hots topic that the companies are now trying to achieve or improve. The term sensor is always referring to a device that will respond and detect certain input collected such as pressure, humidity, heat, etc. Input is usually can be collected or detected from physical area or from the environmental conditions. Once there is an input, there will always be an output. The output commonly refers to an electrical wave that send to a controller for processing purpose. (Mancilla.M. et all, 2016)

2.6.1 Types of WSN

Since WSN technique has been widely deployed, there is many types of WSN is founded and deployed into use. Type of the WSN is chose and deployed based on the environment. For example, terrestrial WSNs, mobile WSNs, underwater WSNs, underground WSNs and multimedia WSNs.

For terrestrial WSNs, it is a technique that capable to allow efficient communication between the base station. In such network, it consists of hundreds to thousands of the wireless sensor nodes to be deployed either in unstructured or structured manner. In this study, the unstructured manner refers to the ad hoc network while the structure manner refers to the preplanned network. In unstructured mode, the sensor nodes are randomly distributed within the target area that is dropped from a fixed plane. While for the structure mode, it considers the optimal placement, grid placement and 2/3D placement models. In the terrestrial WSNs, the battery power is super limited but it has additional battery which equipped with a solar cell as the secondary power source. The energy conservation of terrestrial WSNs is achieved by implementing few functions which are low duty cycle operations, minimizing delays, optimal routing and many other.

Next, for the mobile WSNs it consists of a sets of sensor nodes that can be moved on their own. Besides, the sensor nodes can also be interacted with the physical environment. This technique allows the WSN to be more flexible compared to the static sensor network. An example for the comparison of mobile WSNs and static WSN would be mobile WSNs offers stronger coverage sensing area, better energy efficiency and superior channel capacity.

Underwater WSNs consists of numerous sensor nodes and autonomous vehicles deployed in the water. Then, the autonomous underwater vehicles are utilized for the function of data gathering from all the sensor nodes put under the water. This is an advanced and ecofriendly technique as 70% of the earth is occupied with water. However, it will lead to problems such as long propagation delay, bandwidth, and sensor failures. It is ten followed by the underground WSNs. The underground WSNs is way more expensive than the technique of terrestrial WSNs when it comes to deployment, maintenance, and cost for equipment. A more careful planning is needed to be undergone compared to terrestrial WSNs. The sensor nodes are hidden in the underground to monitor closely the condition in the underground. An additional sink node is located above the ground to efficiently relay the information from sensor nodes to the base station. Both the sensor nodes in underwater and underground WSNs are equipped with limited battery power which are difficult to be recharged and replaced. Drawback of underground WSNs is that effective and efficient wireless communication is difficult to be achieved as there's high level of attenuation and signal loss.

Lastly, the multimedia WSNs is widely used nowadays in which it enables the tracking and monitoring of events in the form of multimedia. Example like imaging, video, and audio. It includes the affordable cost of sensor nodes that equipped with microphones and cameras. All the nodes are interconnected for data compression, data retrieval, and correlation. However, there is still drawbacks found from multimedia WSNs. For example, it will consume high level of energy consumption, high bandwidth requirement, require data processing algorithm as well as the compressing techniques. By fulfilling all these criteria, it can deliver the content effectively and efficiently.

2.6.2 Advantages and disadvantages of WSN

As WSN is widely being deployed nowadays, there is still pros and cons that could be resulted from it. Firstly, WSN offers effective usage even under a harsh or hostile environment. According to Kishore.K and Sharma.S (2016), WSN were developed for the purpose of battlefield surveillance in military engagement. In that moment, it is impossible to have wired network of sensor devices as it easily exposes your location and is not convenient. Therefore, WSN technique is built for the purpose of communication as well as to relay important information to the headquarter for further analysis. Besides, WSN also offers easier scaling solution. The nature architecture of the WSN makes easier scaling solution for undergoing environmental surveillance. When expanding the area of surveillance, the only action needed is to configure and deploy the newly added sensor nodes to allow communication on same network. WSN also allow long-distance data transmission and long-distance data collection. Every sensor node plays as a relay station among other sensor nodes and plays as the main location for data to be transmitted. It solely relies on signal relays and cooperation from other nodes in the same network to route the data. Lastly, the most significant advantage of deploying WSN in the environment would be the capability of anticipate the natural disaster. Since it offers the ability to detect the environmental condition, thus, it can prevent the forest fire or earthquake by detecting the changes in temperature, humidity, movement of soil and many more.

Disadvantage of deploying the WSN is the security concern. Without careful configuration or a robust security system, the sensor node is vulnerable to the security attacks. With simple configuration, the attacker can easily break into the system and manipulate the system. Most dangerous part would be the retrieval of data stored inside the node. Next, the most significant drawback of WSN is the energy context. The sensor nodes are well-known with their limited battery power which will lead to shorter lifespan of the sensor node. Energy context is always the challenging domain that many companies target to improve.

CHAPTER 3: SYSTEM DESIGN

3.1 Proposed method

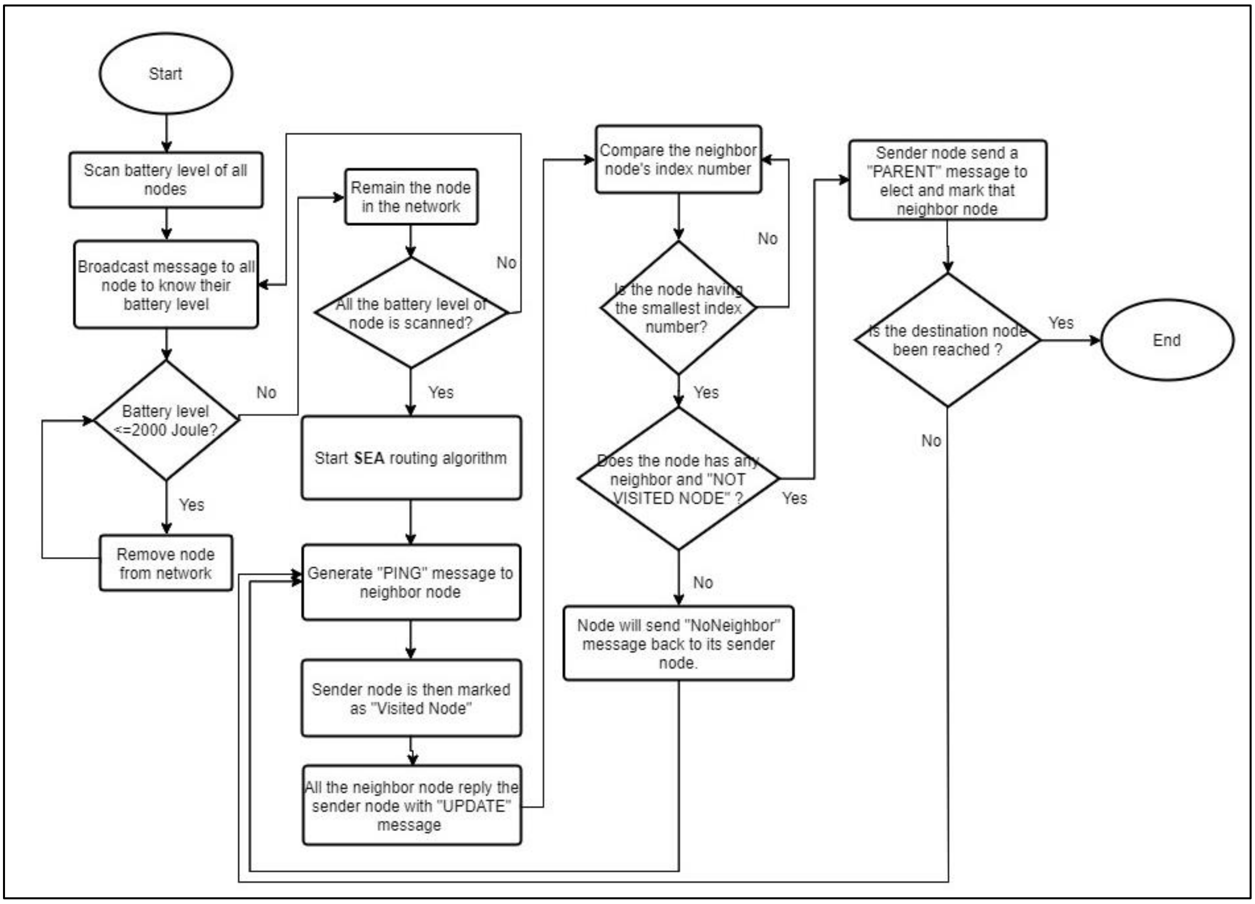


Figure 1.8 Flowchart for proposed method.

<u>3.1.1 Disqualify node detection</u>

Based on the flowchart in figure 1.8, it shows the flow of the proposed routing algorithm called "SEA". Before the routing process is began, it will first run the disqualified node detection. This feature is executed by removing all the node that is believed will affect the quality of service in the network. Also, the removal process is run based on the battery power of every sensor node in the network. If the battery power of the node is lesser or equal to 2000 joules, the node will be removed from the network immediately. Question comes on why it must be 2000 joules? The answer for it is because research shows that when number of sensor node is added to 200 under the WSN environment, at least 1500 joules of the energy is consumed during the simulation (Gavalas.D et al., 2014). With this, the algorithm is planned to set a threshold at 2000 joules since approximately 200 nodes will be added in this project for determining the energy efficiency level. The lesser battery power the node has, it means the sensor node would not be able to support the routing process once the number of sensor node is increased. After all the disqualify node has been detected, they are no longer in the network and will not be part of the routing process. By doing this disqualify node detection, it is believed to add extra credit to this project as it is smart in a way that can remove all the disqualify node for the purpose of improving the overall quality of service.

3.1.2 SEA routing process.

During the routing process, four types of messages will be generated. The four types of messages are “PING”, “UPDATE”, “PARENT”, “NoNeighbor”. Given a scenario whereby a IoMT device such as unnamed aerial vehicle (UAV) wanted to send a message to their respective management platform. Thus, the sensor node will art as the router to pass the message until the destination or gateway such as base station is reached. When base station is reached, the message is then passed to the internet. Scenario is illustrated in figure 1.9. While the explanation and illustration of the routing process is shown in figure 2.0, 2.1, 2.2, and 2.3 respectively.

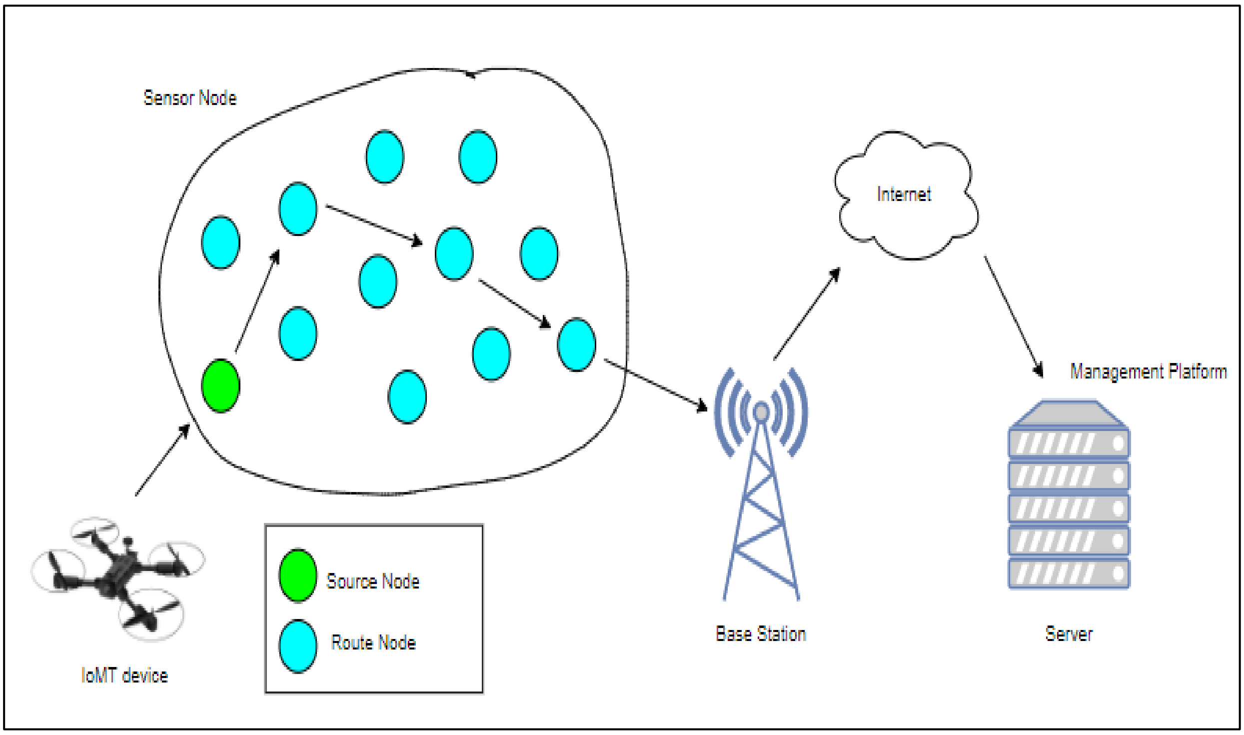


Figure 1.9 Network diagram of the routing scenario.

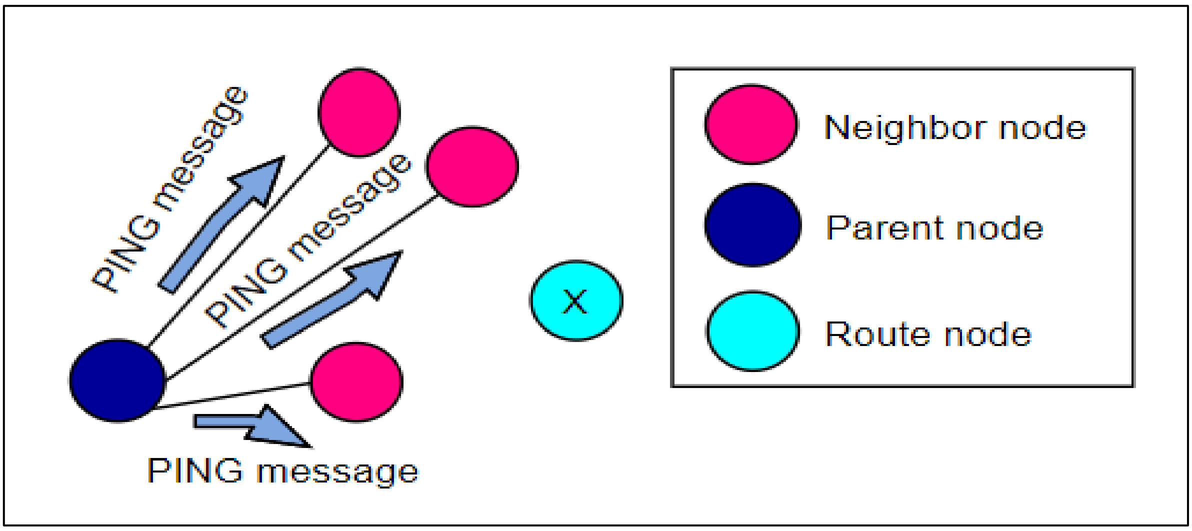


Figure 2.0 Illustration for PING message.

In figure 2.0, it illustrates the very first step of the SEA routing algorithm. To initiate this process, a IoMT device such as UAV is needed to send a message and have passed by one of the nodes in the network. When the signal from the IoMT device is detected, the parent node or can be called as the sender node will start to send a "PING" message to its neighbor node. However, need to take note that the neighbor nodes needed to be wirelessly connecting to the parent node. In this project, all the node that is within the sensing area of the parent node are directly connecting to their respective parent node. From the figure, the route node with label 'X', it is to shows that the node is not within the sensing area of the parent node so is not directly connecting to the parent node. As a result, the parent node will not send a "PING" message to the route node with label 'X'.

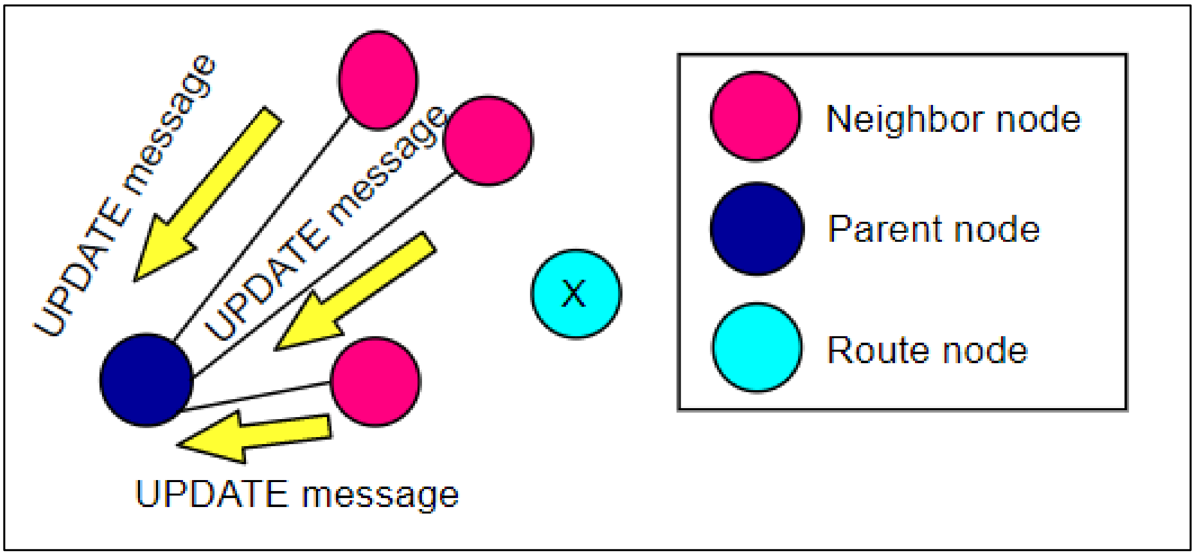


Figure 2.1 Illustration for UPDATE message.

Based on figure 2.1, it shows the continuity of the routing process. To continue, when all the neighbor nodes have received the PING message, they will reply their parent node with an UPDATE message along with their respective index number. So, question comes on what is their respective index number? The index number that is replied to the parent node is the order that neighbor node first receive the "PING" message. For example, if neighbor node with ID '5' first receive the "PING message", it will reply its parent node with index number '1', then the ID '7' second receive the "PING" message, it will reply its parent node with index number '2'. In short, the sequence of index number is generated based on the speed that neighbor node first receives the "PING" message and react to it. Based on this concept, it is believed to achieve the energy efficient context at the end of the project. Therefore, the neighbor node will send an UPDATE message which contains their respective index number. In this project, every node in the simulation tool is distributed and placed randomly. No fixed position for every node to match the nature of WSN.

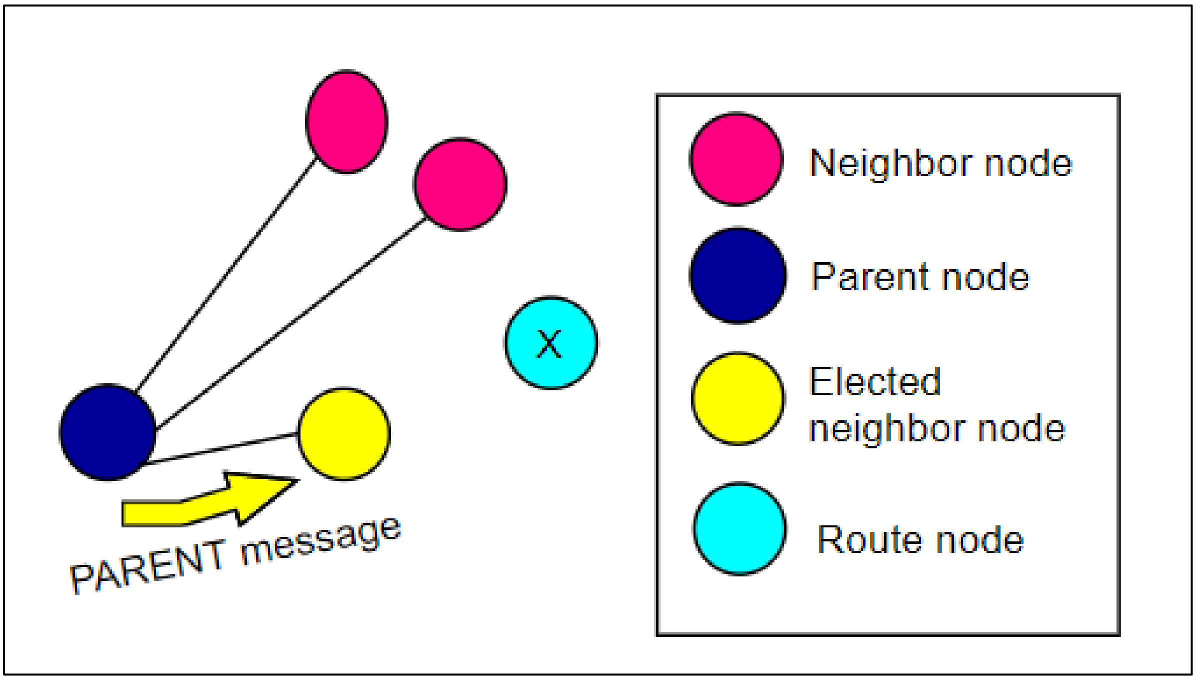


Figure 2.2 Illustration for PARENT message.

During this process, it is all about doing the comparison work. When the parent node has received the "UPDATE" messages replied by its neighbor nodes, the parent node will start to do comparison on the index number accordingly. The parent node will compare and choose the smallest index number received. Again, the sequence of index number is generated based on the speed the neighbor node received the "PING" message. If index number equal to '1', it means the node is the first node that receive the "PING" message. Therefore, when smallest index number is found, the parent node will make a reply message back to its respective neighbor node which is called "PARENT" message. It is like informing the neighbor node that "I am your sender node.". When the desired neighbor node is found that neighbor node will be marked in the simulation tool.

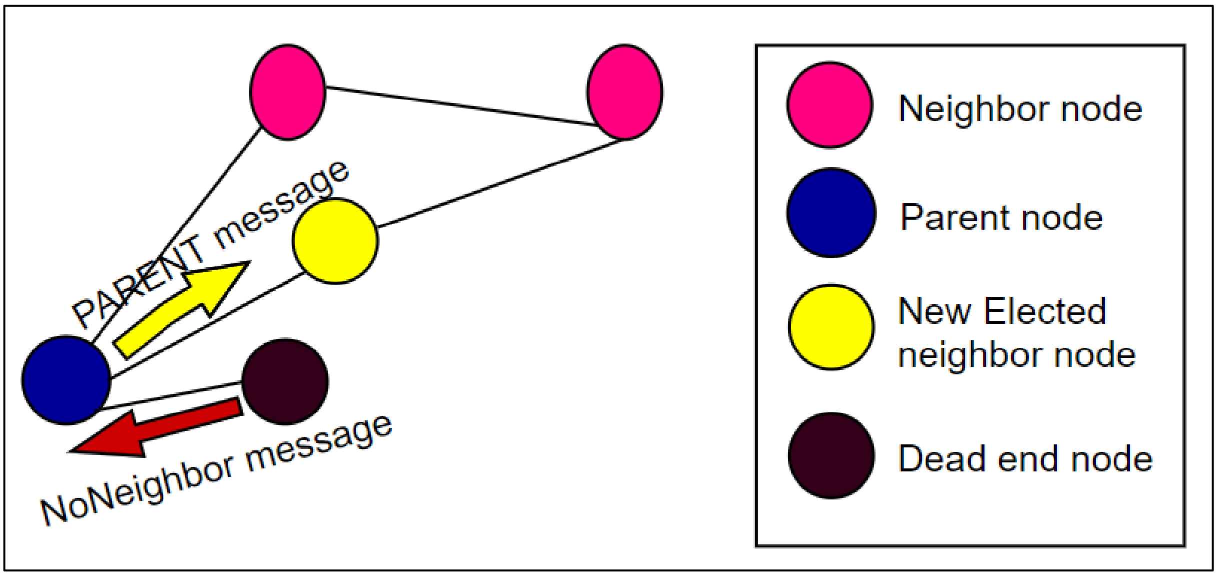


Figure 2.3 Illustration for NoNeighbor message.

Other than doing the neighbor node electing task, the SEA algorithm is designed in a way that can detect the dead end. In this project, the dead end is referring to no more neighbor node to continue the routing process. Based on the figure 2.3, it shows that no more neighbor node is connecting the dead-end node. With this, it means the routing process cannot be continued anymore and no more route can be formed even though the dead-end node having the smallest index number among other nodes. Besides, even if there is neighbor node connecting to it, this "NoNeighbor" message will still be sent when all its neighbor node already been visited previously. This is to avoid routing loop occur. Therefore, the dead-end node will generate a new message type which is called "NoNeighbor" message. By implementing this to the algorithm, it is also believed that this SEA routing algorithm is smart in a way can detect dead end and generate a new message to inform its parent node about it so that it would reach a blocked stage. After the parent node receive this message, it will then elect the node that has the second smallest index number to parse the message and form a new route. As a result, the "PARENT" message is generated to the node that is having the second smallest index number.

Whole procedure is repeated and stopped until the destination node is reached. In this project, the destination node will be the base station or so-called sink node. Energy consumption level will also be generated at the end of the simulation. Number of sensors such as 100, 150, 200 and 250 will be placed inside the network. After all the nodes are distributed in the network randomly, the simulation will be executed to generate the desire result. In this project, result such as packet delivery ratio and energy consumption level are generated, observed, and compared. Reason of doing this is to know if this SEA routing algorithm is suitable in WSN based on several aspects. Aspects such as the reliability, suitability, and energy efficiency are determined.

3.2 Table for routing messages in SEA routing algorithm

Type of messages	Description
PING	• This message is sent when IoMT device request to send a packet to the base station. • The IoMT device can send a message at anywhere to any node. • This message only sent to the neighbor node that is wirelessly connecting to the sender node. • Neighbor node is connected when they are within the sensing area of the sender node.
UPDATE	• This message is generated by the neighbor node to the sender node. • All the neighbor node will reply the source node with this message. • The message contains their respective index number. • Index number is determined based on which node manage to receive the PING message first. • If node A first receive the PING message, it will reply its sender node with index number 1. • If the sender node has 3 neighbor nodes, then 3 of its neighbor nodes will reply the sender node with their respective index number.
PARENT	• This part, it will do comparison and only sent to the neighbor node that has the smallest index number. • This message is to elect the neighbor node with smallest index number and inform that node that it is its sender node.
NoNeighbor	• This message will be sent only when there is no more neighbor node connecting to the sender node so-called dead-end route and the neighbor node is also been visited before to avoid routing loop.

Table 1.2 Table for the summary of routing messages.

3.3 Software Setup

CupCarbon network simulation tool is a free of charge software which can be downloaded from this link https://cupcarbon.com/. The first view that comes into the eyesight is shown in the figure 2.4. Before the installation process, do make sure the computer is equipped with the latest version of Java which can also be installed from https://www.java.com/en/. The software CupCarbon could not be executed without the latest version of Java. Also, the version of Java must be installed according to the specification of the computer. Thus, specification of your computer is needed to be checked to ensure the correct Java version is installed in the computer. For example, install the 64-bit Java for Window operating system. The interface of Java installation website is as shown in figure 2.5.

Figure 2.4 Interface to download CupCarbon.

Figure 2.5 Interface to download latest version of Java.

After the installation process, the software is embedded inside a Zip file. After extracted all the file inside the Zip file, several folders will be shown and just clicked on the file named "cupcarbon.jar" as shown in figure 2.6. Technically, the software can be successfully executed smoothly. However, Java issue is faced which causes the CupCarbon program could not be executed. Thus, extra step is needed to be done. Solution for it is to include one command line in the terminal which is "java -jar cupcarbon.jar". The solution is shown in figure 2.7. When all these processes have been undergone, the CupCarbon software is now executed successfully.

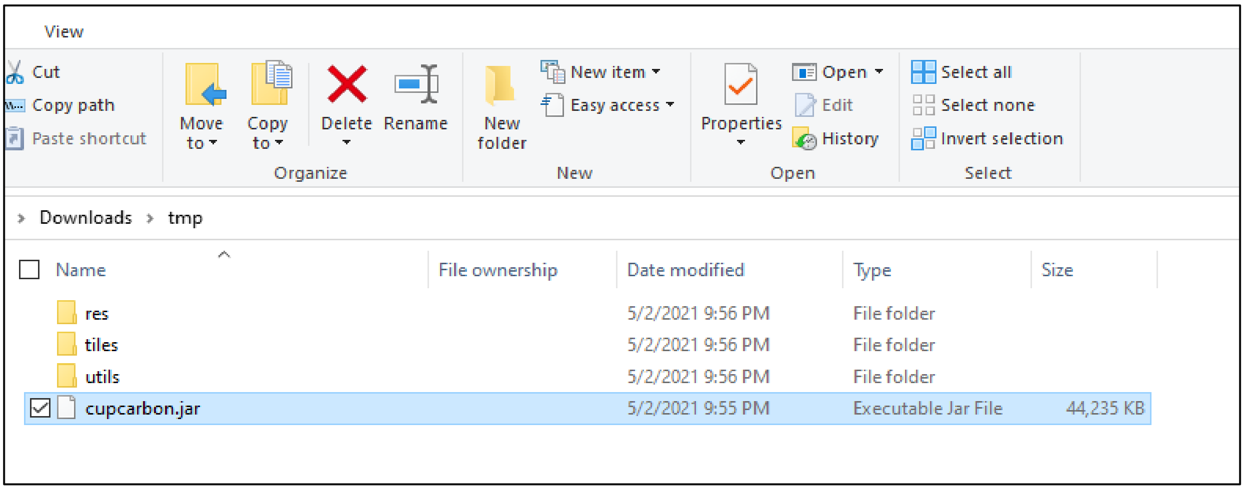


Figure 2.6 Files contains inside Zip file of CupCarbon.

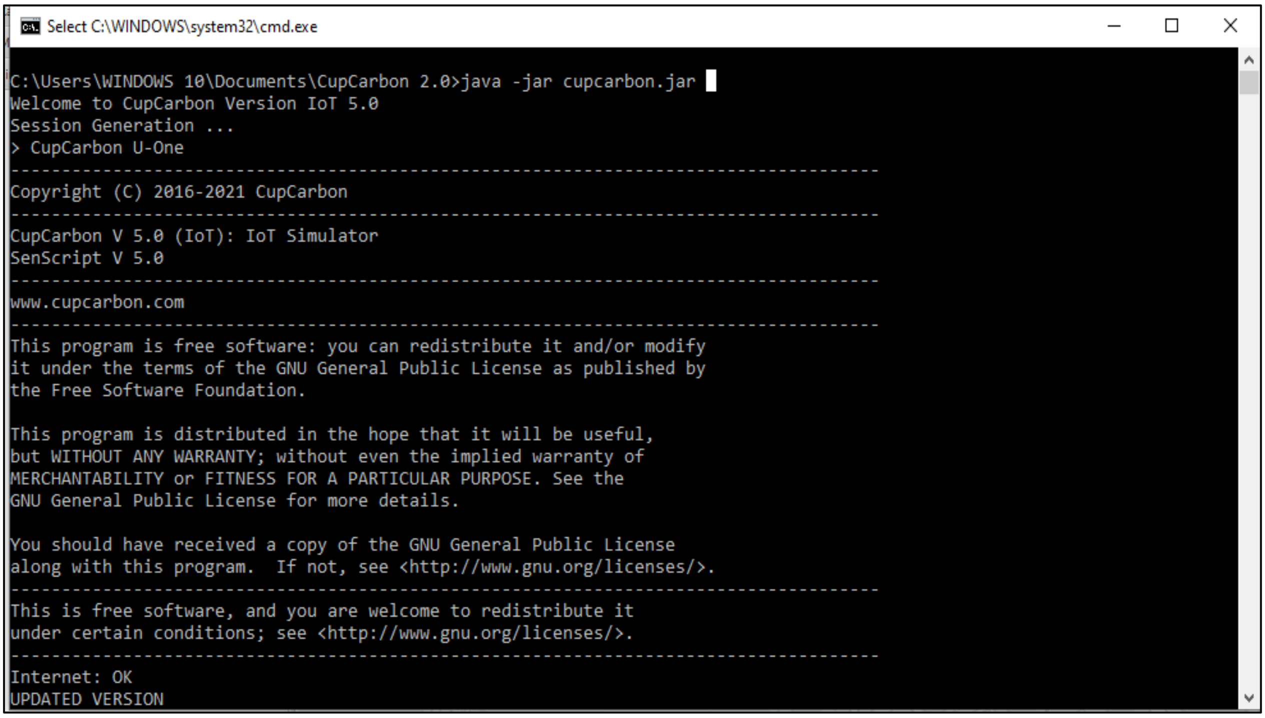


Figure 2.7 Command line to execute CupCarbon.

Upon completion, the CupCarbon is successfully executed and the interface of CupCarbon is as shown in figure 2.8. Besides, the console tab of CupCarbon is in a separated tab for a more precise and easy reference. Once simulation process is completed, all the necessary information will be shown in the console tab.

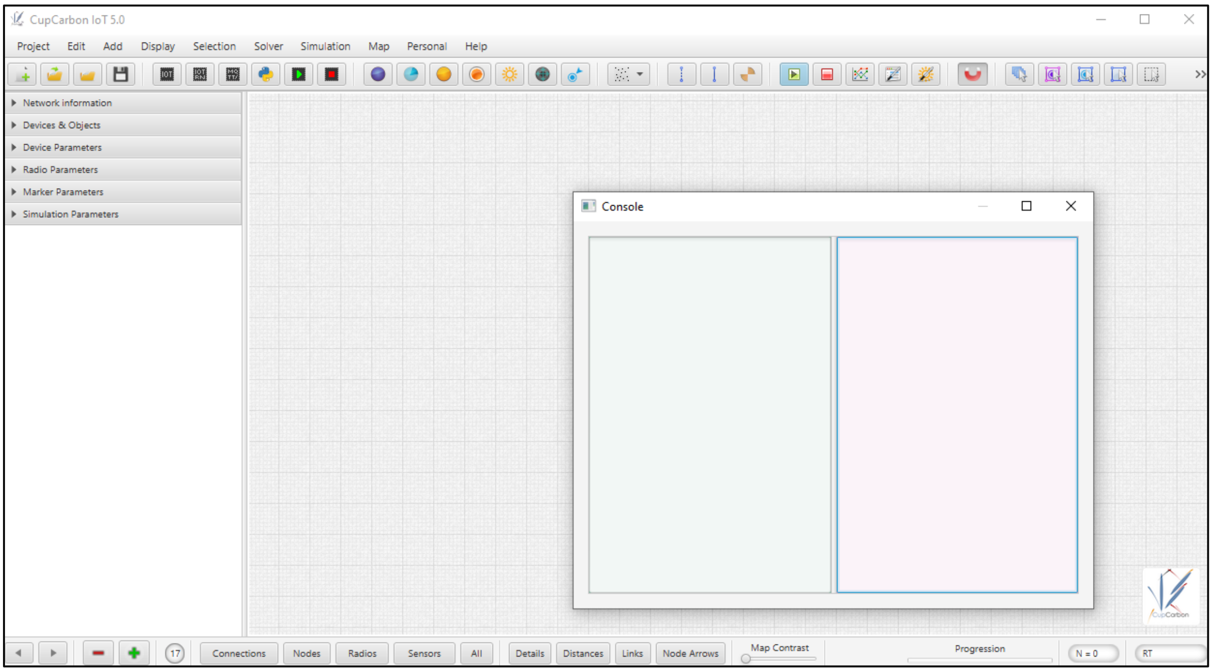


Figure 2.8 Interface and Console of CupCarbon.

3.4 SenScript setup for Disqualify node detection

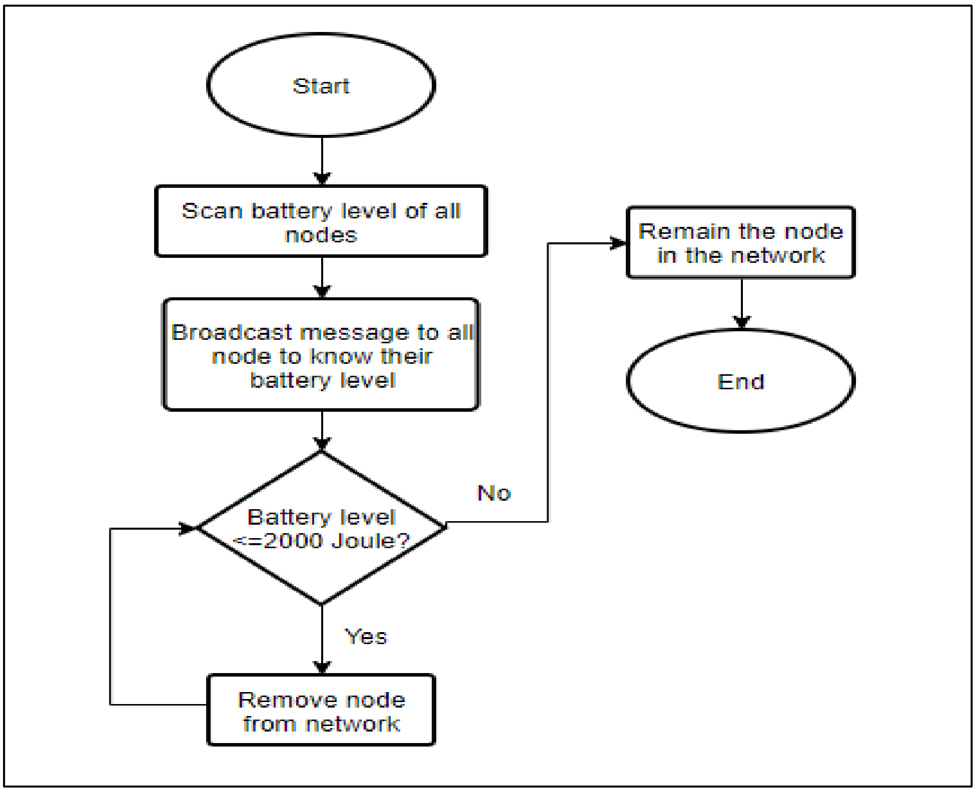


Figure 2.9 Flowchart for disqualify node detection.

In figure 2.9, it describes the design of disqualify node detection. Again, all the node placed in the network will be scanned through to check their battery power. Once a node is found having a battery power below or equal to 2000 joules, the node will be removed from the network. They are no longer in the network to help in routing process. Reason of inputting 2000 joules as a threshold is because research shows that when number of sensor node is added to 200 under the WSN environment, at least 1500 joules of the energy is consumed during the simulation (Gavalas.D et al., 2014). Then, in this project a maximum of 250 number of sensors will be placed to run all the testing and generate report. Therefore, it is considered safe to place 2000 joules as the threshold. Figure 3.0 shows the SenScript code to build up this algorithm.

In this project, SenScript will be utilized to build all the algorithm. It is slightly different than many of the existing programming language or script. However, the programming concept is the same. SenScript is specifically built to program the sensor node in CupCarbon. Thus, it requires to learn how to code using SenScript. The following part will explain how SenScript is used to build the algorithm in this project.

```
loop
send "ping..."
battery x      //read node's battery power
print "Battery level: " x
if (x <= 2000)
  println "Killed"
  kill 1       //remove the node in the network
end
delay 1
stop        //stop after determining all node battery
```

Figure 3.0 SenScript for disqualify node detection.

3.5 SenScript setup for SEA routing algorithm

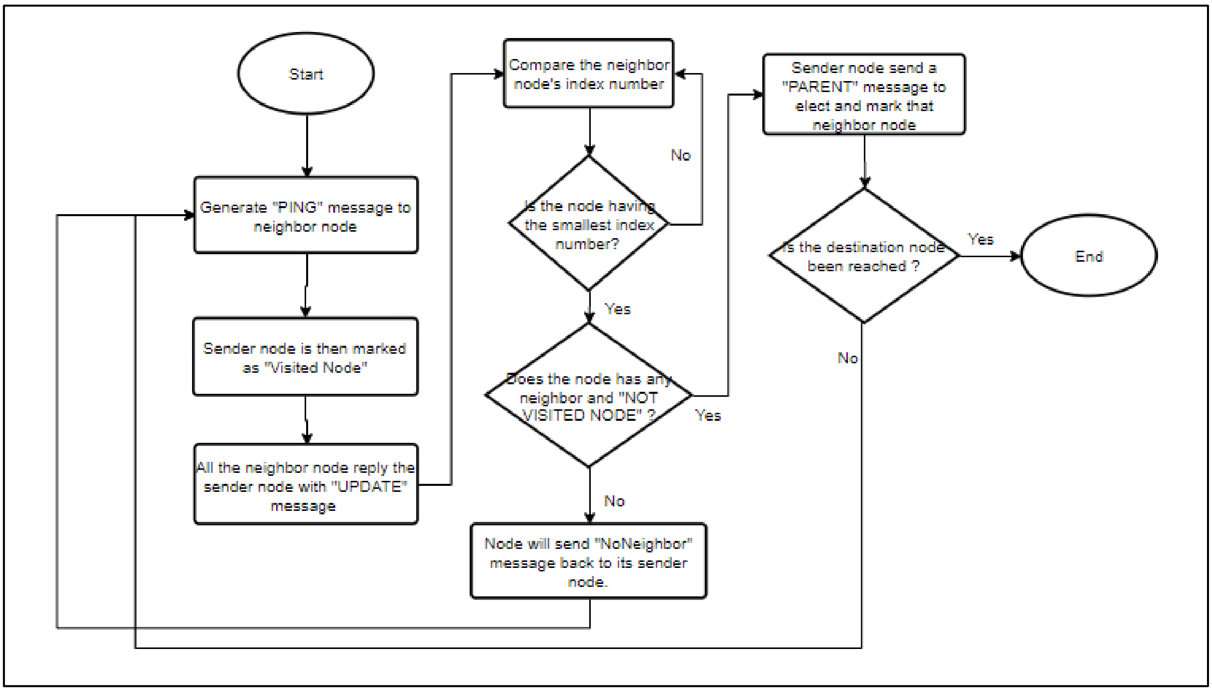


Figure 3.1 Flowchart for SEA routing algorithm.

Figure 3.1 shows the flowchart for SEA routing algorithm and this is the main part for this project. To explain, the algorithm is designed in a way that can detect dead-end and visited node. Besides, the message is generated based on the scenario detected. One of the examples is that NoNeighbor message is generate once there is no more neighbor node connecting to the sender node or all the neighbor node connecting to it are already visited in earlier process. When this NoNeighbor message is generated, the routing process is start over again.

```
set targetsink 443
atget id c_index
set elect 0
set once 0
set parent 0
set in_mission 1
set detection 0
```

Figure 3.2 Declare all the variables using SenScript.

In SenScript, it just like other programming language whereby declaration of variable is needed to be initialized at the beginning of code.

```
loop
if(detection==0)
        dreadsensor signal_IOMT
        if(signal_IOMT==1)
                set detection 1
                set elect 1
                data message "ping" c_index
                send message
        end
        delay 100
end
mark elect
if(in_mission==0)
        wait
else
        wait 500
end
read message
```

Figure 3.3 Process to detect message from IoMT device using SenScript.

In figure 3.3, it shows the way to detect dead-end route. Method of this is to detect any message sent by its neighbor node, if no respond receives, the “NoNeighbor” message is then be generated. Besides, it also detects if all of the neighbor node been visited before, if yes, that also means dead-end route, so the “NoNeighbor” message will be generated. The message is then sent it back to its parent node.

```
else
          set detection 1
          rdata message type r_index
          if((type=="ping") && (elect==0))
                    data message "update" c_index
                    delay 100
                    send message r_index
          end
          if((type=="update") && (once==0))
                    set in_mission 0
                    set once 1
                    data message "parent" c_index
                    delay 100
                    send message r_index
          end
          if(type=="parent")
                    edge 1 r_index
                    set in_mission 1
                    set parent r_index
                    set elect 1
                    if(c_index==targetsink)
                              led 20 4
                              stop
                    else
                              data message "ping" c_index
                              delay 100
                              send message
                    end
          end
          if(type=="NoNeighbour")
                    set once 0
                    set in_mission 1
                    data message "ping" c_index
                    delay 100
                    send message
          end
end
```

Figure 3.4 Process to send different types of messages based on different scenarios using SenScript.

In figure 3.4, it shows the process to generate different types of messages according to the scenarios. In this part, it is also built to form a route using a color such as blue to link all the route. At the same time, the elected neighbor node will be marked in the network with color such as green to better distinguish the node with rest of the sensor node. Therefore, a better visualization is shown. Other than that, the routing process is stopped when the base station so-called sink node is reached. During the whole process, the delay message is also included as in our previous project, it proved that it could help in the energy efficient context.

3.6 Setup for WSN environment

sIn this project, there are 3 types of materials needed to be placed in CupCarbon. They are i) Sink node, ii) Sensor node and iii) IoMT device. All these 3 materials are as shown in figure 3.5.

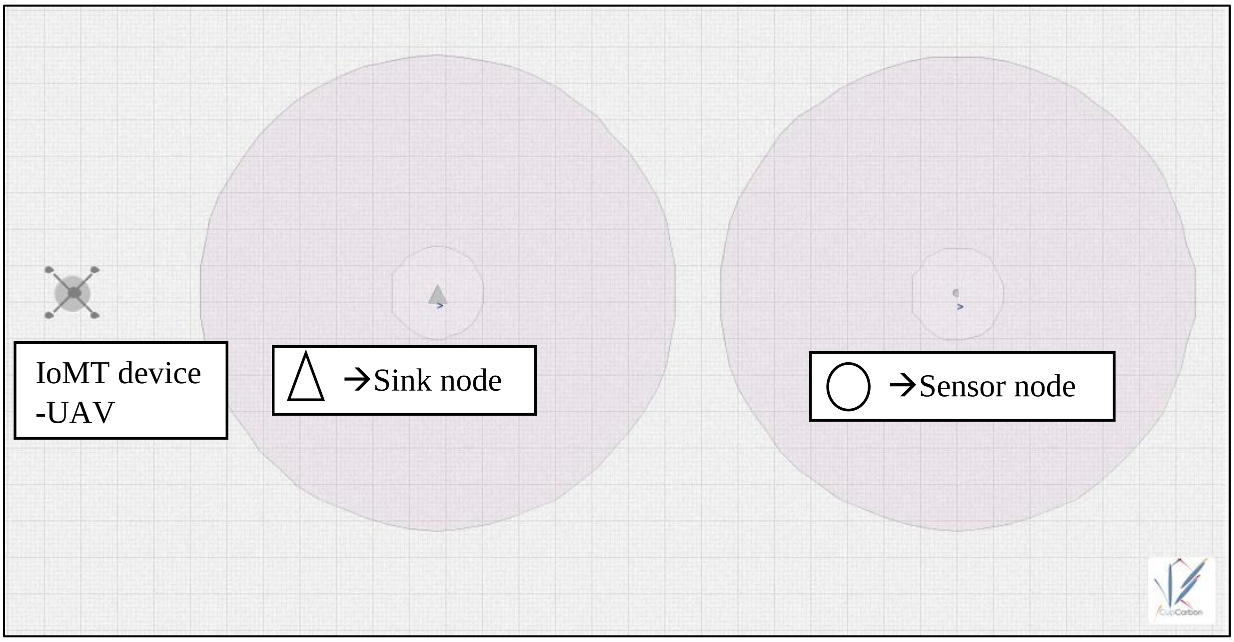


Figure 3.5 Sink node, sensor node and UAV in CupCarbon.

In this project, number of sensor node 100, 150, 200, 250 will be distributed randomly in the network. The result collected will be used to do comparison to determine the suitability of SEA routing algorithm in different aspect. Apart from that, they are wireless connecting to each other via Long Range (LoRa). Although in CupCarbon, it offers 3 types of wireless radio frequency technology such as WiFi, Zigbee and LoRa. However, according to Liang.R, Wang.P and Zhao.L (2020), LoRa offers greater capability and functionality as compared with other 2 technologies. LoRa known as a wireless radio frequency technology that offers long range and low power wireless platform which nowadays popularly deployed in the Internet of Things (IoT) networks globally. The comparison of WiFI, Zigbee and LoRa done by researchers Liang.R, Wang.P and Zhao.L (2020) is shown in table X.X.

Parameters	Wi-Fi	LR-WPAN	LoRa
Standard	IEEE 802.11 a/c/b/d/g/n	IEEE 802.15.4 (Zigbee)	LoRaWAN R1.0
Frequency band	5–60 GHz	868/915 MHz, 2.4 GHz	868/900 MHz
Data rate	1–6.75 Gb/s	40–250 Kb/s	0.3–50 Kb/s
Transmission range	20–100 m	10–20 m	<30 km
Energy consumption	High	Low	Very low

Table 1.3 Comparison of typical wireless communication technologies done by Liang.R, Wang.P and Zhao.L (2020)

Hence, we decided to deploy LoRa as the wireless communication technology for all the nodes in the network as many of the papers and real-life example already proven the benefits of deploying LoRa. The node in CupCarbon is running the Zigbee by default. So, it is necessary to change all the node to LoRa. After applied LoRa, the background of node goes light blue. The illustration of it is described in figure 3.6.

As mentioned, every node placed in the network is non-functional without assigning of SenScript. Thus, need to assign every node with a SenScript to be functional. Figure 3.6 shows how the sensor node going to look like when SenScript is assigned inside. The “routing” is the file name of SenScript and is already inserted into the node.

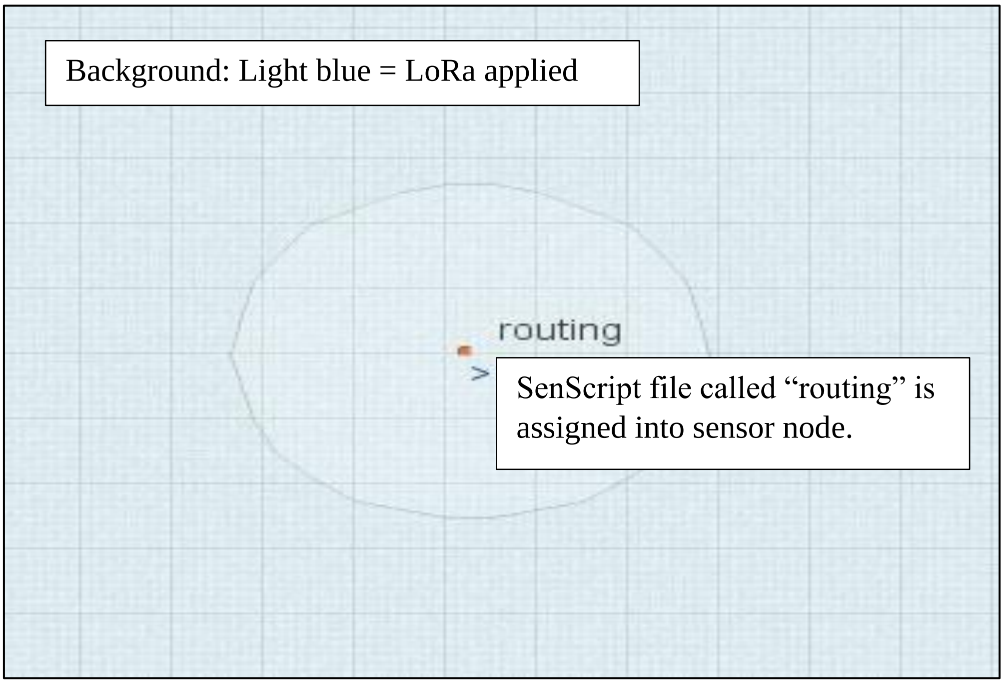


Figure 3.6 LoRa applied and SenScript assigned.

As mentioned earlier, there will be 100, 150, 200 and 250 nodes applied in the network. In figure 3.7, it demonstrates how the network is going to look like. In figure 3.7, all the nodes are distributed randomly, the base station as well as the UAV can be placed at anywhere. When a UAV passed by any of the sensor node, the sensing range of sensor node will turn into orange color. In figure 3.7, there is a total of 202 sensor node distributed in network. 200 are the sensor node while another 2 nodes are sink node and UAV. The link between every node is to show that they are wirelessly connecting to one another.

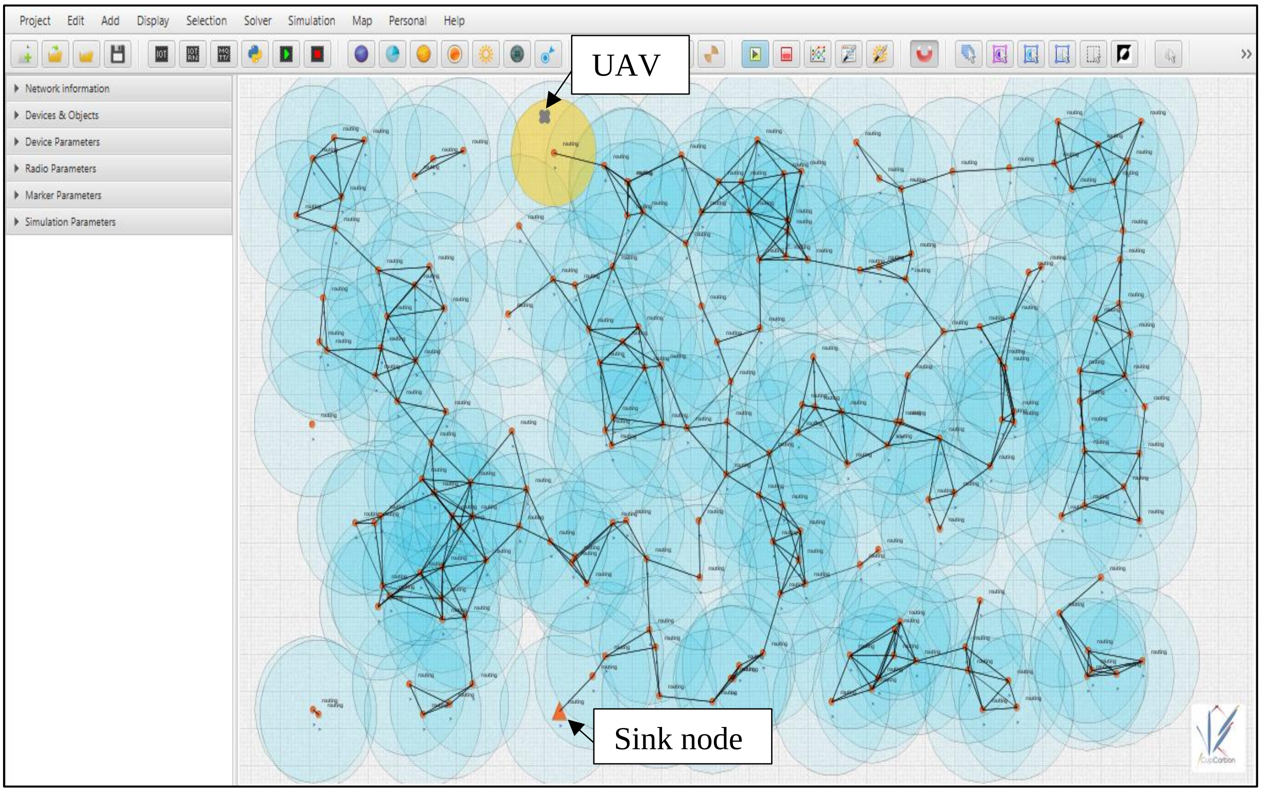


Figure 3.7 *Network design in CupCarbon.*

CHAPTER 4: METHODOLOGY AND TOOLS

4.1 Methodology

In this project, the methodology adopted along the way is called Agile Methodology. The agile methodology has been adopted by many of the project development for many years since it was first introduced on year 2001. Agile methodology is widely known as an iterative and incremental approach. It is also a methodology that is utilized in System Development Life Cycle (SDLC) process in Software Project Development. Examples of agile methodology is the Scrum, Dynamic Systems Development Method (DSDM) and so on. Steps involved in agile methodology are i) Define, ii) Design, iii) Build, iv) Test, v) Release and vi) Feedback. Reason of adopting this methodology is due to the short timeframe for this project. Total of 11 weeks are given to accomplish this project; thus, agile methodology would be the best way for this project. Besides, some of the benefits of adopting this methodology are i) it encourage rapid changes along the steps, ii) it is easy to be managed, iii) it offers flexibility to the whole team, iv) it is very suitable for smaller project.

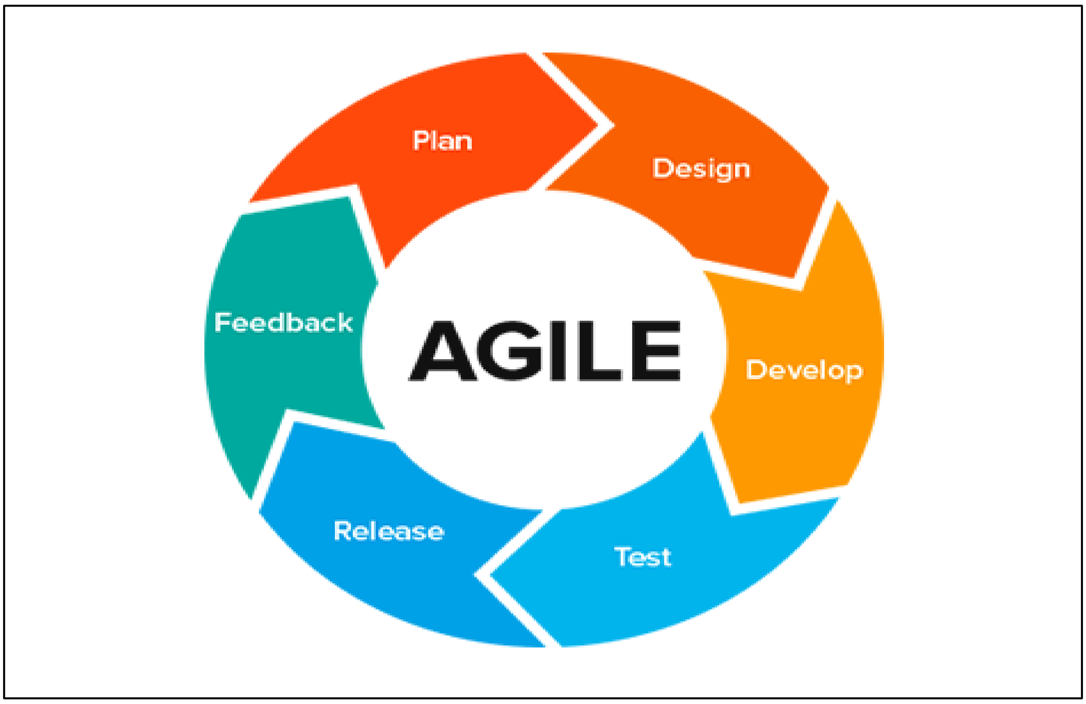


Figure 3.8 Agile Methodology Iterative and Incremental Phrases.

Define phase → From the initial phase, we will have to define all the requirements such as what we need to achieve in this project. After determining the requirements, it comes to the design phase where we will need to identify tools or equipment to achieve the requirement. In our proposed network, devices such as sensor nodes, drones, base station will be included and software tool such as CupCarbon is installed.

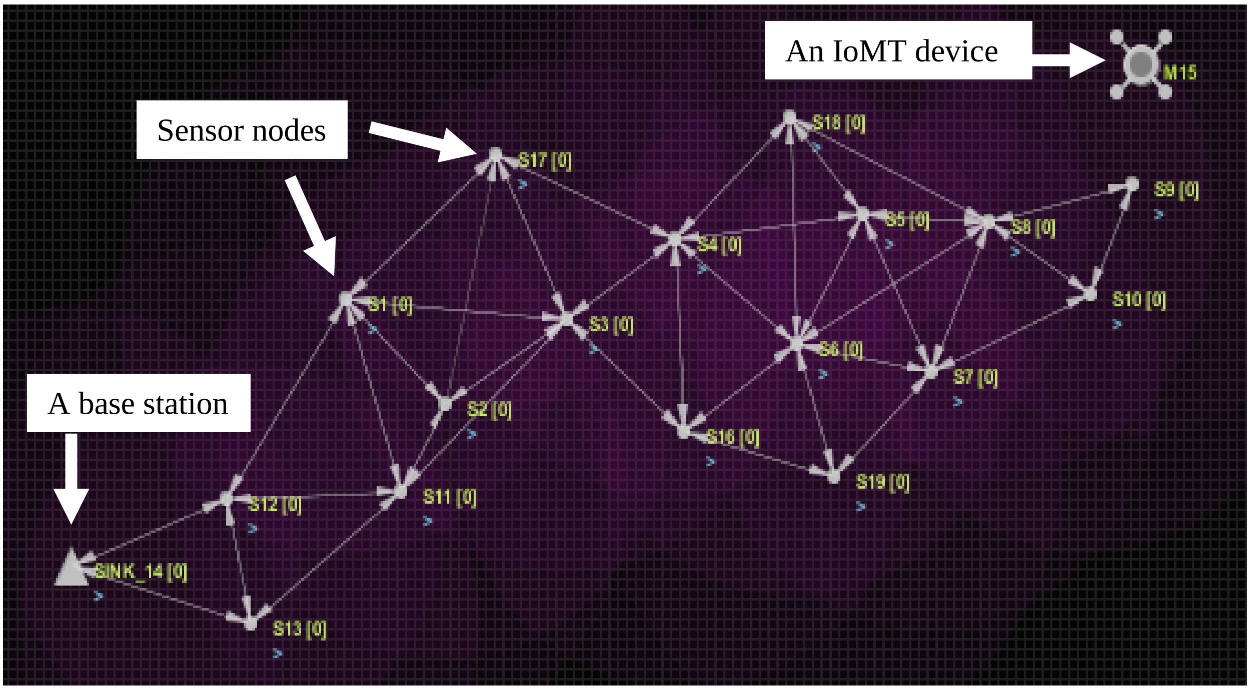


Figure 3.9 Proposed network architecture diagram.

Design phase → In the design phase, the network to perform routing algorithm, dead node detection, network segmentation is as shown in figure X.X. In the figure, the devices with label "M15" is referring to an IoMT device which is a drone. The device labeled with "SINK_14" is the base station in the network. The rest of the devices with label "S16" and many more are referring the sensor nodes in the network. All the sensor nodes are distributed in the network randomly. Along the way, whether the routing protocol, dead node detector and network segmentation algorithm will be tested once they are built. They are tested on different amount of sensor nodes and different complexity of the network. Then, feedback will be gotten from the supervisor of this project to further enhance the whole project.

Develop phase → In develop phase, all the nodes will be configured properly. Node specification such as battery level, sensing radius, radio parameter and so on will be configured accordingly. Besides, scripts are coded and assign to the node respectively. By doing so, it could allow all the nodes or devices in the network to be functional. It also allows us to build our own algorithm and features using script. In CupCarbon, we will need to power all the nodes with script called SenScript.

Test phase → In this phase, the packet delivery ratio, energy consumption level, battery level will be tested under different situation. For example, 30, 50, 70 number of sensor nodes will be added. After simulation, their packet delivery ratio, energy consumption and battery level will be generated into graph format and used it to do comparison. Lastly, the complexity level of the network topology will be enforced to see whether all the features built are suitable to complex or simple network environment.

Release phase → In this phase, the graph for packet delivery ratio, energy consumption level, battery level will be released. The result is in CSV file, so will need to convert it to graph form to have a better data visualization result.

Feedback phase → Along the way, feedback of the supervisor will be gained and determine if changes needed. If yes, then changes can be done in any phases as we are adopting the agile methodology where rapid changes are encouraged. Changes and improvement is made along the project development.

4.2 Tools

In this project, it heavily relies on software components which is CupCarbon. Besides, it is the SenScript that plays a very important role to power every node and the way the algorithm should run.

Software components

CupCarbon

CupCarbon is well known as a Smart City and Internet of Things Wireless Sensor Network (SCI-WSN) simulator. Objective of this software is to sketch, forecast, amend, and authenticate distributed algorithms for keeping track of the environmental data collection. CupCarbon offers a user-friendly and straightforward environment for depicting scenarios for conveyance, portability, and standard events. This software is developed and coded according to the new framework called JavaFX. It provides a new professional ergonomic design and better graphical user interface. CupCarbon simulation is laid on the application layer of the nodes. Through this, it contributes an existent supplement to nowadays existing simulators. However, it didn't manage to imitate all the protocol layers because of the multiplex nature of citified networks which need to consolidate other complex and assets consuming figures such as buildings, etc. Apart from the introduction of CupCarbon, the CupCarbon version that is used in this project is "CupCarbon Version IoT 5.0".

Figure 4.0 Logo of CupCarbon.

SenScript

In CupCarbon, SenScript plays an essential role in powering all the devices and nodes in the network. Without assigning a SenScript to the nodes, the node cannot perform any action. It is almost the same as Python script but it is specifically built for the node raised in CupCarbon. It adopts a special sign which is ‘$’ for its variable. For example, “add z a b” is equal to “z=a+b” in Python. After declaring the ‘z’, it is compulsory to put $z in the next line when we want to call the variable. For example, “add z a b”, “if ($z > 2) print “Value for Z is more than 2””. Apart from the introduction of SenScript, the SenScript version that I used in this project is “SenScript Version 5.0”.

Figure 4.1 Logo of SenScript.

4.3 Requirement

Desktop Computer

System Type	Window 10 64-bit operating system.
Processor	Intel(R) Core (TM) i5-7200U CPU @ 2.50GHz
RAM	8GB
GPU	Intel® HD Graphics
Operating System	Window 8 or above

Table 1.4 Details for Desktop Computer.

4.4 Implementation Issues and Challenges

In the making of this project, the most challenging implementation is the routing process. It is because an innovative routing algorithm is needed to be built which at the same time can ensure the energy efficiency for the IoMT devices. Although there are many existing routing algorithms proposed nowadays, but many of them still contains the hidden issues such as routing loop. Therefore, the propose routing algorithm SEA in this project is needed to be built in a way it can eliminate the routing loop problem, suitable for the communication in WSN and many more. Unfortunately, things turned out to be bad whereby the routing loop still occur in the initial development of the SEA algorithm. Because of this, improvement and modification in the routing algorithm is needed to be made to solve the routing loop problem. This issue needed to be focused heavily to match with the objective of this project.

Apart from that, the challenge of this project is the software tool called CupCarbon. Generally, this tool provides a very good interface for the simulation of both network and IoT environment. However, a SenScript that is specifically created by the founder is needed to be learned to program all the sensor nodes, IoMT devices, base stations, and many more. SenScript is different from other programming script such as Python and other programming script. Therefore, the way to do program every node using SenScript is a new challenge in this project. It does not contain any built-in function, thus many of the function require to build steps by steps to convey the message successfully. Also, when there’s a bug in the program, it will not tell in which line or what error. It requires self-discovery to find out the hidden bug else the program cannot be run. Sometimes, it may also lead to software not responding error once the SenScript is not coded properly. Thus, it is the biggest challenge in this project.

Lastly, the resource for this tool is limited. Although number of researches already leveraged CupCarbon as their simulation tool but the SenScript they used to build their algorithm is remained private. Thus, limited resources can be referred and reviewed. Therefore, self-discovery and self-learning are extremely important to complete this project. With all these factors, many efforts are needed to be placed in this project to complete it.

4.5 Timeline

Task	Project Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project kick off and data collection														
Identify problem statements and motivation														
Identify project objectives														
Look for suitable Network and IoT Simulation Software														
Gather and read research papers														
Identify and design the element to achieve project objectives														
Summarize what to implement for Project I and Project II														
Design the network architecture														
Construct the network using CupCarbon														
Do testing on the implementation made														
Obtain the energy consumption reading														
Make conclusion														
Design Poster														
Presentation														
Gain feedback and make correction														
Documentation														

Table 1.5 Timeline for Project I.

Task	Project Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Confirm on the design for network architecture														
Finalizing the functionalities to perform in this project.														
Identify project methodology														
Build the code and algorithm to run the identified functionalities														
Do testing on the implementation made														
Arrange and analyze the energy consumption reading after all the testing														
Make comparison on the result obtained														
Make conclusion and discussion														
Design Poster														
Documentation														
Gain feedback and make correction														
Presentation														

Table 1.6 Timeline for Project II.

CHAPTER 5: RESULT AND DISCUSSION

In this chapter, it will demonstrate all the testing and simulation that have been done. Results are also obtained which manage to prove that the SEA routing protocol is able to resolve the problem of high occurrence in routing loop and unsuccessful packet routing under high mobility environment for Internet of Mobile Things.

5.1 Simulation result for disqualify node detection

In this section, it presents the result generated by the disqualify node detection. The algorithm built will perform the job of filtering all the disqualify node hidden inside the network. The node that is having 2000 joules and below of battery power will be filtered out and removed from the network. Reason of applying 2000 joules as the threshold is because maximum of 250 number of sensor nodes are placed in the network. According to Gavalas.D et al. (2014), there was around 1500 joules of battery power consumed at the end of the simulation result when 200 number of sensors were placed in the network. Therefore, an assumption can be made whereby it will be safe to put 2000 joules as the threshold when perform our simulation. In figure 4.2, it shows the design of network to execute the disqualify node detection. Before performing the simulation process, the simulation speed in this project is set to 1000ms, arrow speed 200ms and simulation time is set to 86400.0s.

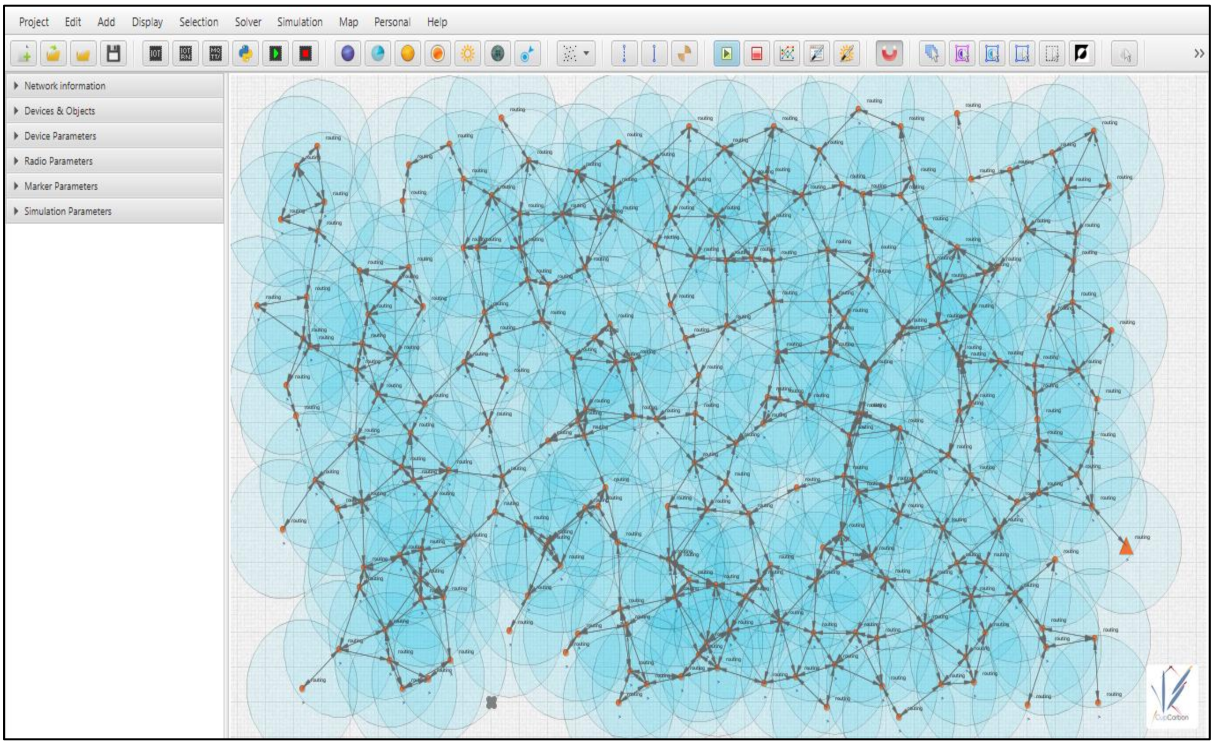


Figure 4.2 Network diagram before filtering the disqualify node.

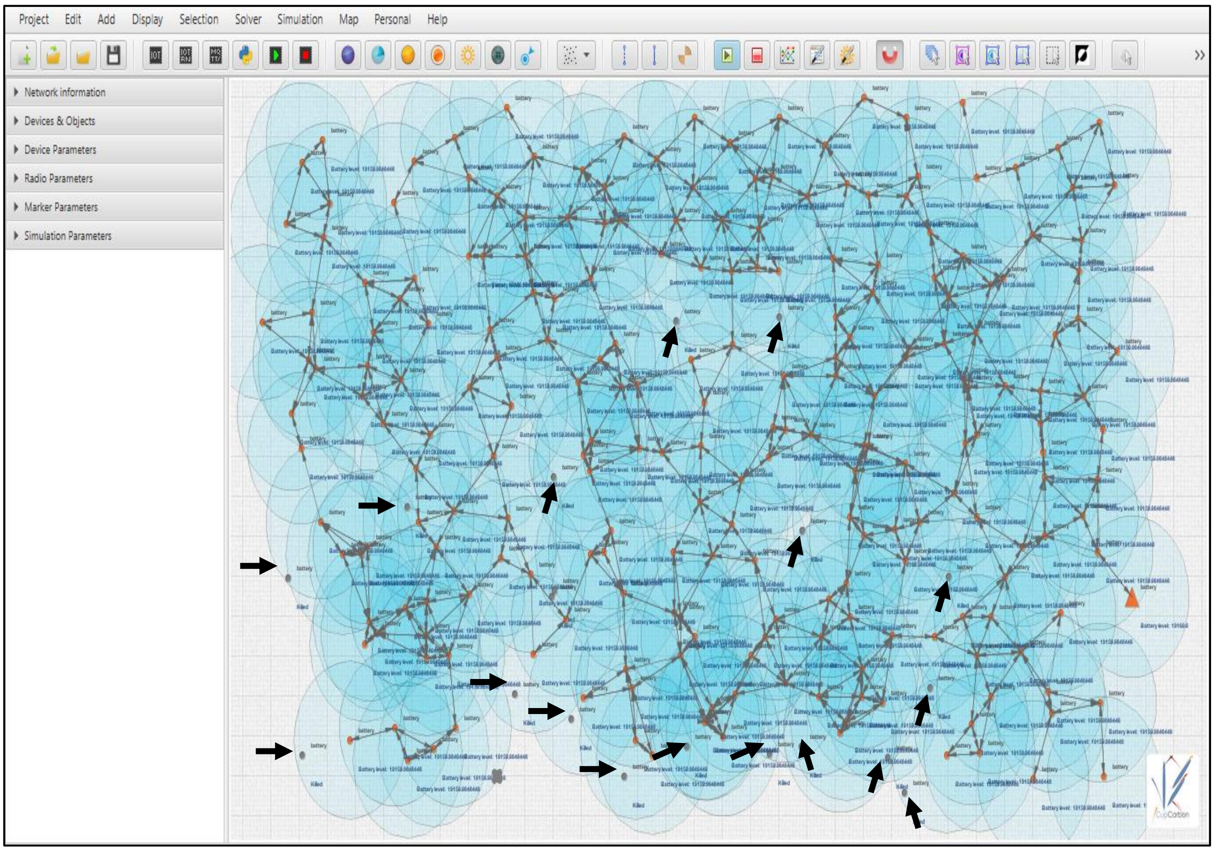


Figure 4.3 Network diagram after filtering the disqualify node.

In figure 4.3, all the disqualify is pointed by a black arrow. For better understanding, the qualified node will output their respective battery power while for the disqualify node they will output a “Killed” word to allow user to better distinguishing them. In our simulation process, 16 sensor nodes are filtered out from 250 number of sensor nodes in the network. Once the disqualify node is identified, they will then be removed from the network and no longer playing as a route node to pass the message. The routing process will be done among all the qualified node.

5.2 Simulation results for SEA routing algorithm

Before proceeding to the result, it shall begin with a process generated from a very small network. In this section, 10 number of sensor nodes is placed in the network just for a small demonstration purpose. It is to allow user to better understand the routing flow in detail.

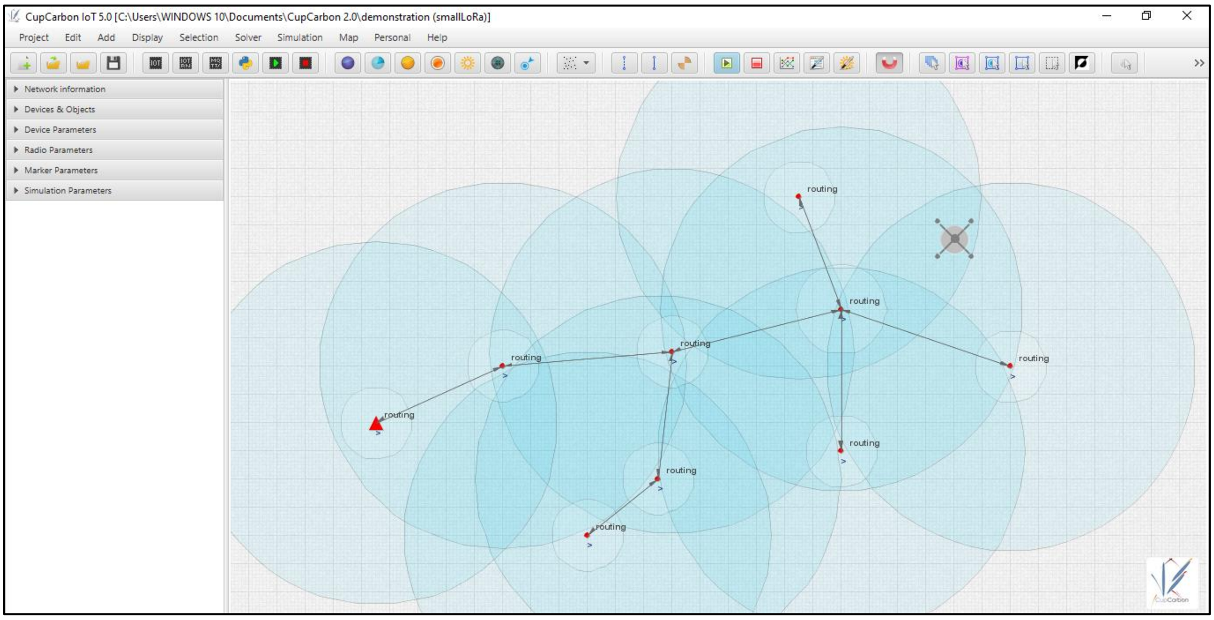


Figure 4.4 Small routing flow demonstration network.

The flow of the routing process is as shown in the following figures:

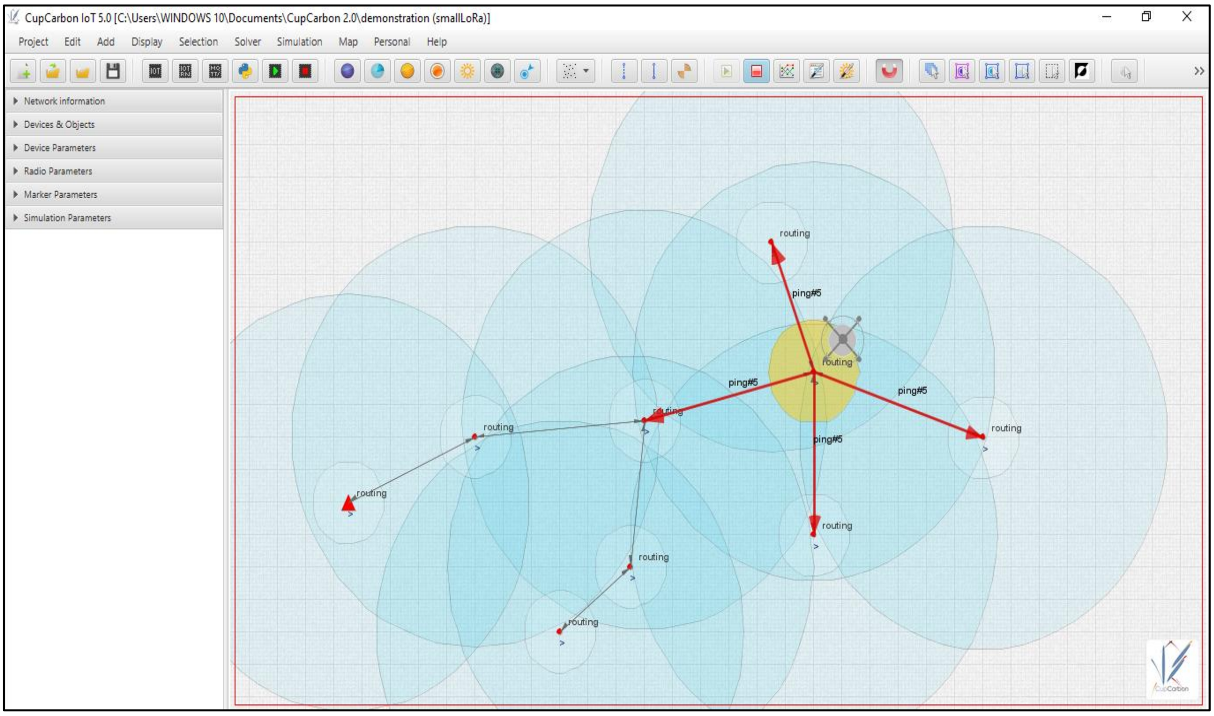
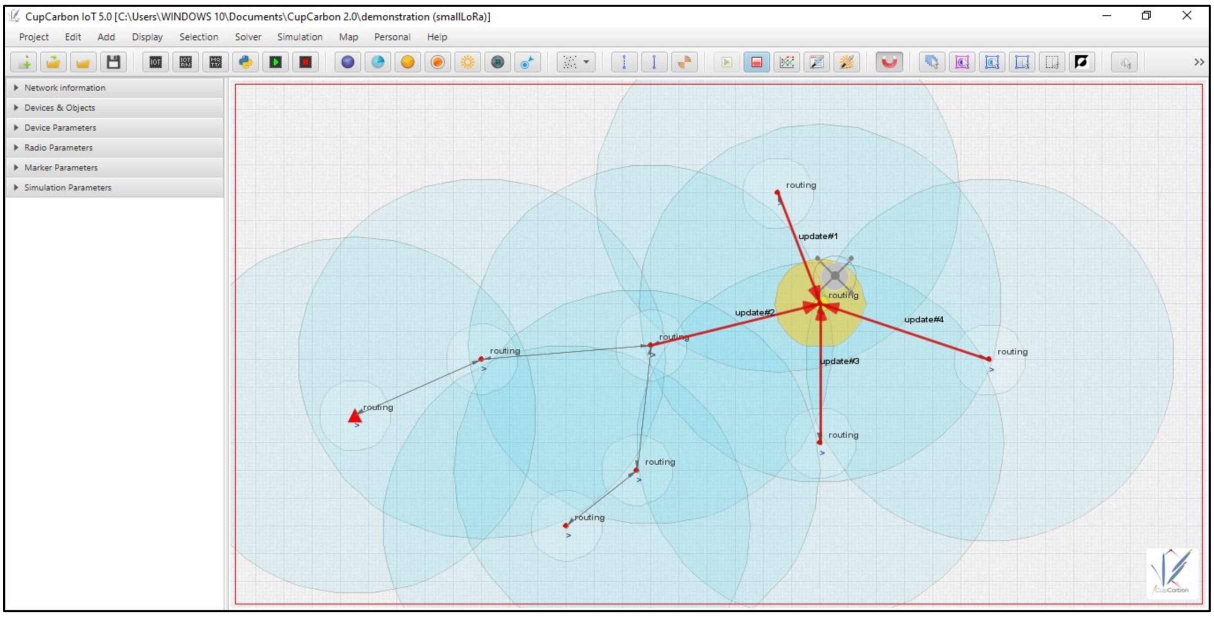


Figure 4.5 Routing process step 1.

Figure 4.5: It shows that when an IoMT device → UAV passes through the sensing unit of one of the nodes, the sensing area became orange color to represent its existence. The node is then become the sender node. It will send a “PING” message to its neighbor nodes. In this case, it has 4 neighbor nodes.



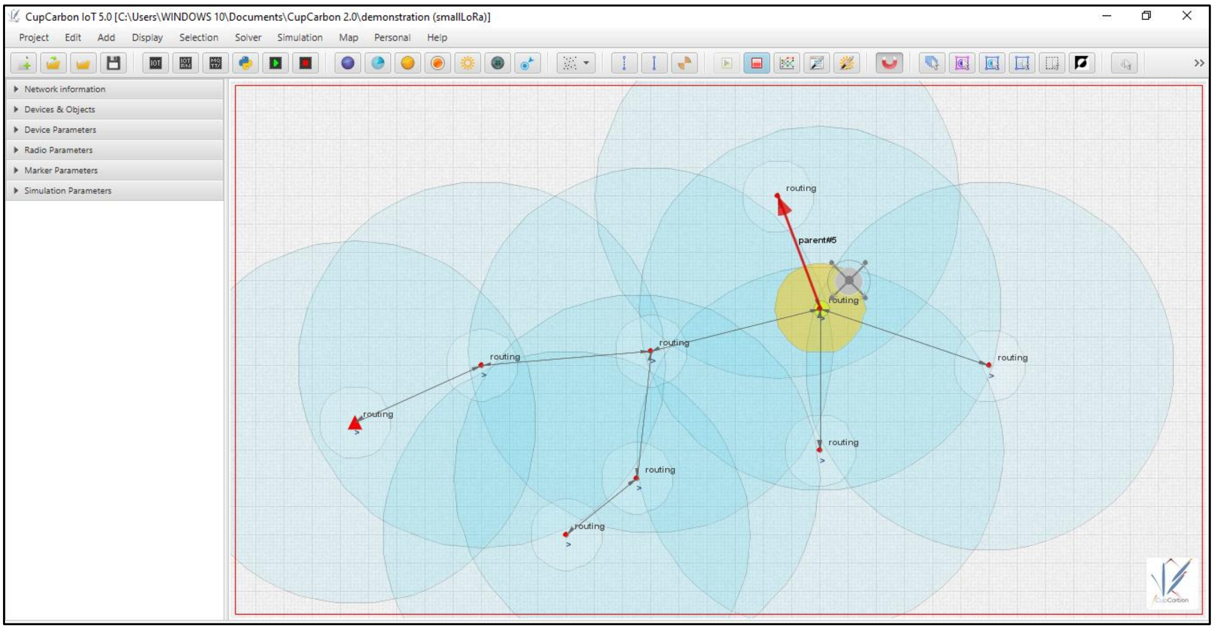


Figure 4.6 Routing process step 2.

Figure 4.6: It shows that when the neighbor nodes received the “PING” message, it then replied with an “UPDATE” message which contains their respective index number. As mentioned earlier, the index number represent which node first receive the “PING” message, generate the

index number, and inform its sender node. In this case, it is obvious that the index number with 1 will be elected as the node to perform routing.

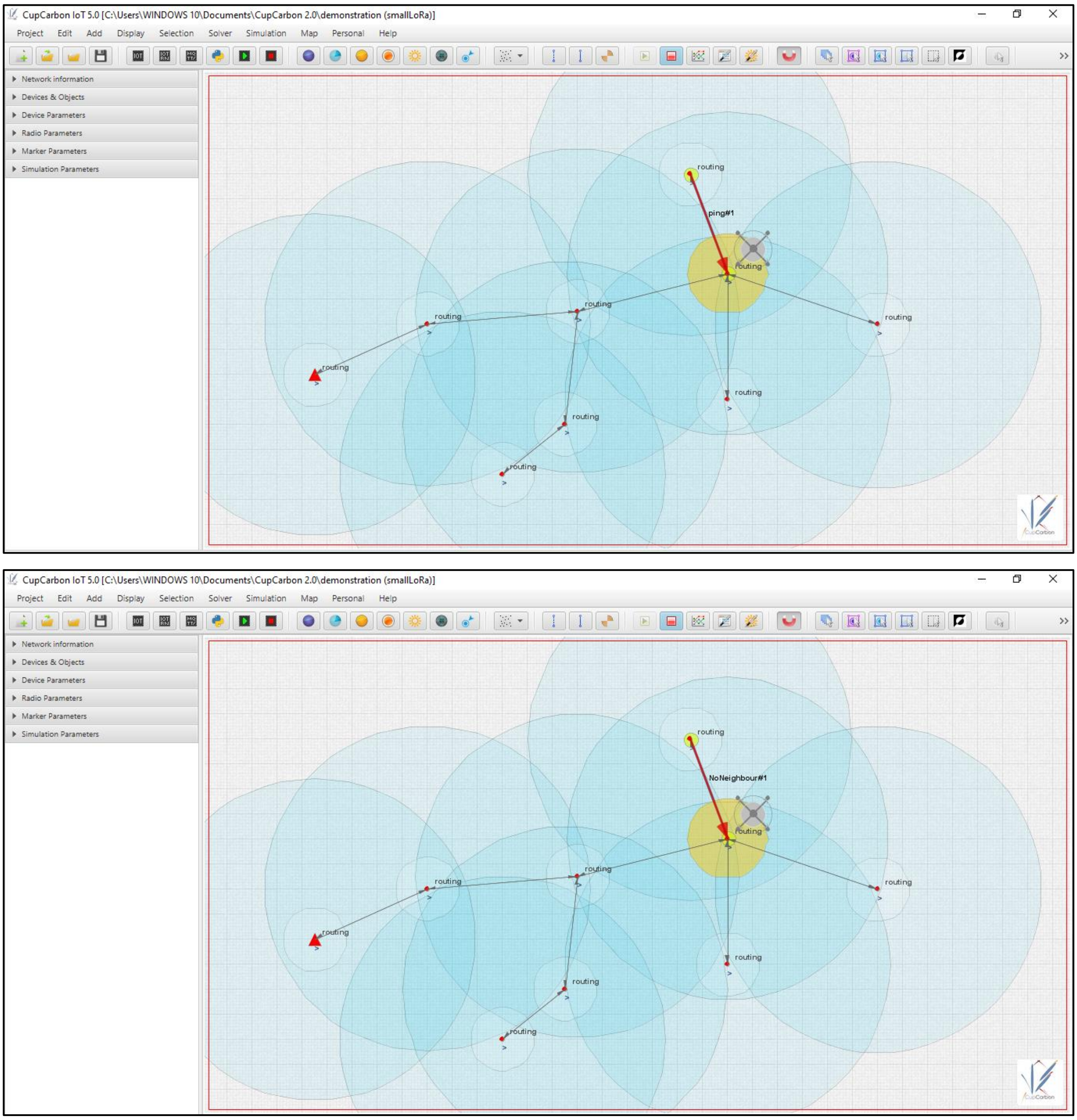


Figure 4.7 Routing process step 3.

Figure 4.7: In this process, with index number 1 node is then be elected and marked in a yellowish color. Then, it will again start to generate the "PING" message. However, it then finds out that it has no neighbor node connecting to itself. Besides, its only neighbor node which was its sender node is already been visited. Therefore, it is the moment that "NoNeighbor" message is generated and passed to its sender node. This message is believed to be smart that can mitigate the occurrence of routing loop.

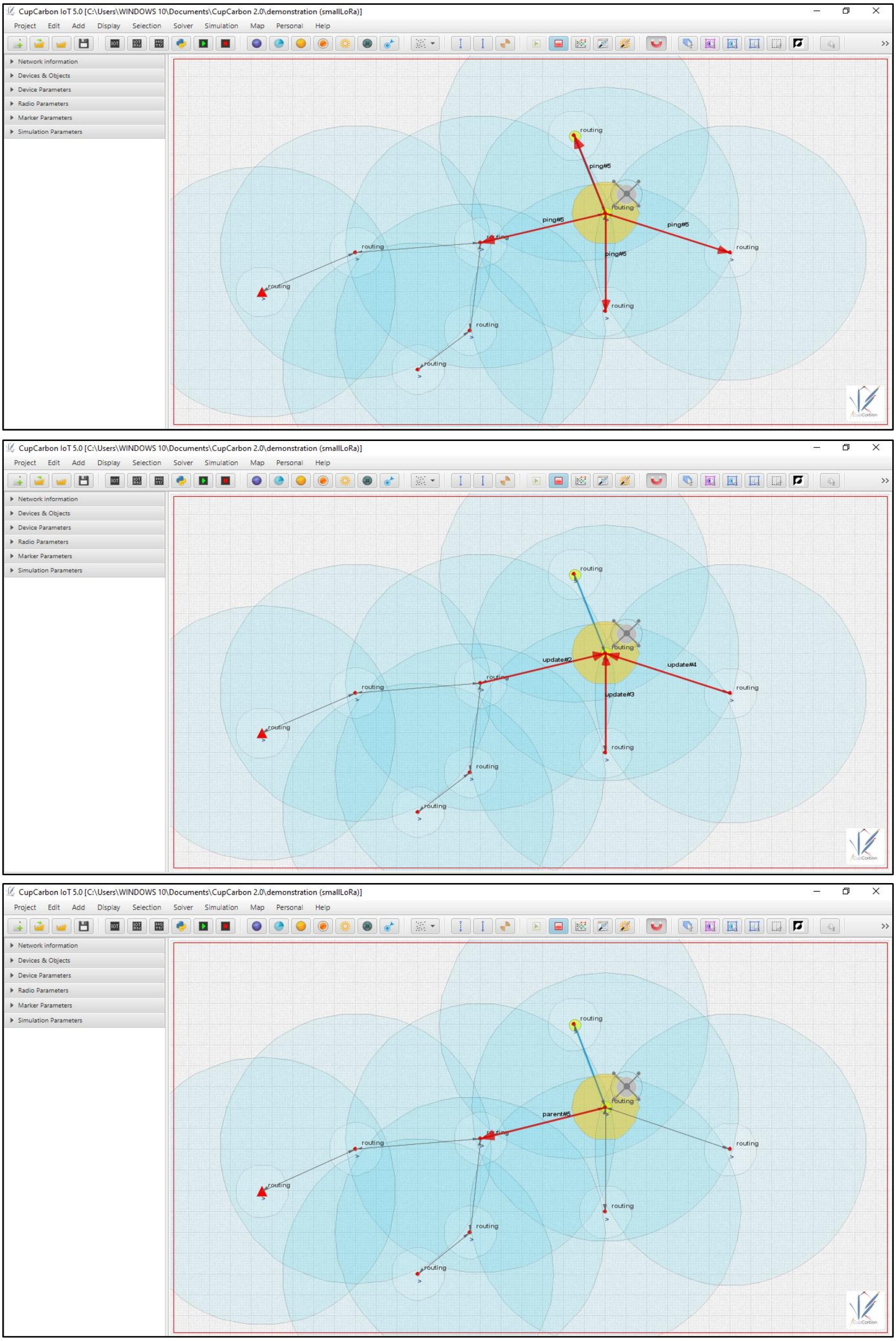


Figure 4.8 Routing process step 4.

Figure 4.8: This process shows the continual of the routing process after “NoNeighbor” message is received. After the sender node received the message, it then generates a “PING” message again and send to its neighbor node. However, the “UPDATE” message is then replied by the rest of the neighbor node. The visited node will not send its “UPDATE” message again. Through this way, it is also considered smart whereby it can prevent the occurrence of routing loop. Why? It is because the sender will not choose again the node with smallest index number as it was previously visited node. The whole routing process will enter a blocked stage or occurrence of routing loop if the visited node is visited again and again. Therefore, this concept is compulsory to be implemented in our algorithm.

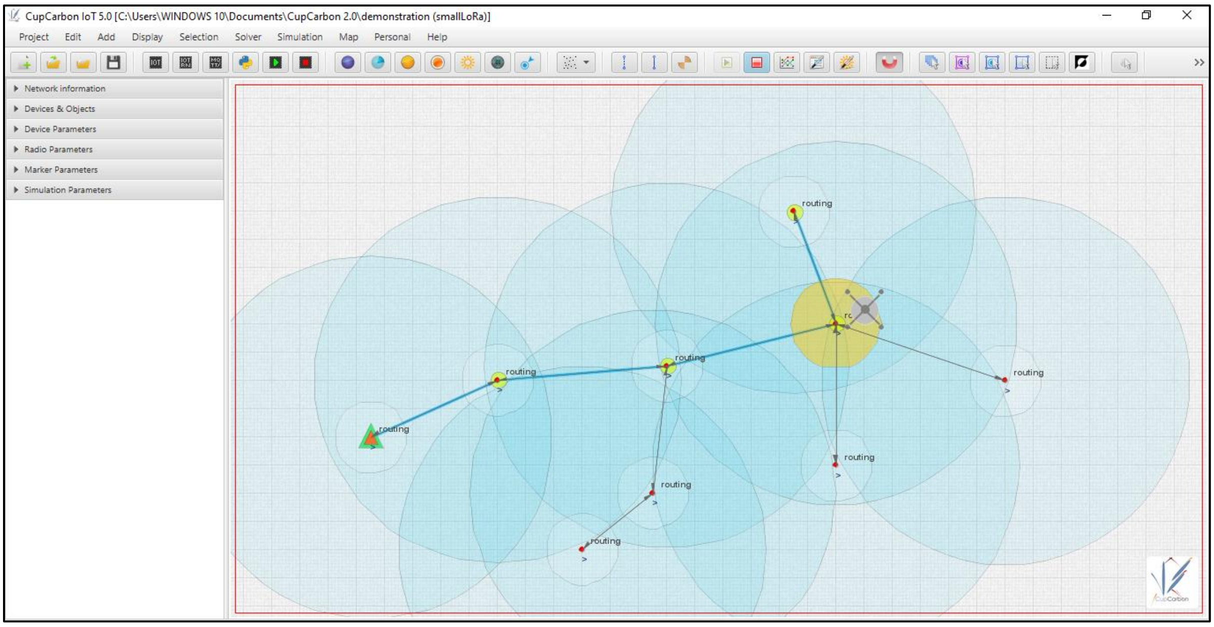


Figure 4.9 Routing process step 5.

Figure 4.9: The above-mentioned steps are repeated and terminated once the sink node is reached. The route is also formed which can allow user to understand the flow of reaching the targeted sink node from the beginning node.

In this chapter, the result such as packet delivery ratio and energy consumption are generated and used to do comparison. Number of sensors will be increased and compared. In figure 5.0, it shows the design of network in 100 number of sensor nodes placed in the network. In figure 5.1, it shows the design of network in 150 number of sensor nodes placed in the network. In figure 5.2, it shows the design of network in 200 number of sensor nodes placed in the network. In figure 5.3, it shows the design of network in 250 number of sensor nodes placed in the network. Their simulation parameter is “Simulation time = 86400.0s”, “Simulation speed = 1000ms” and “Arrow speed= 500ms”.

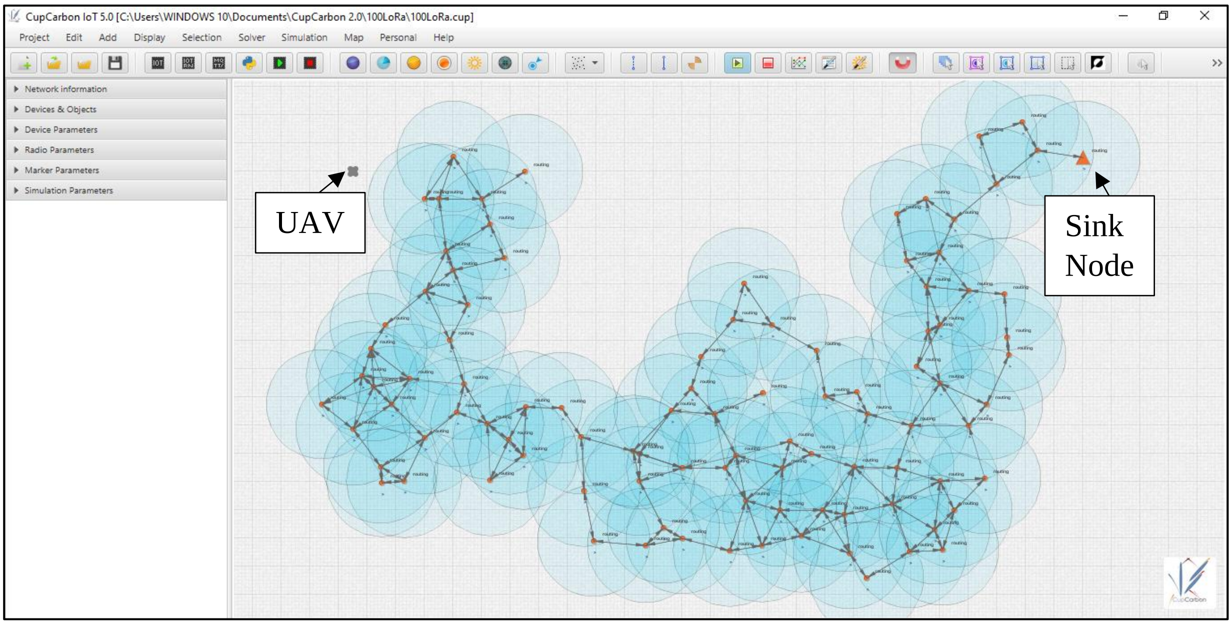


Figure 5.0 100 sensor node in the network.

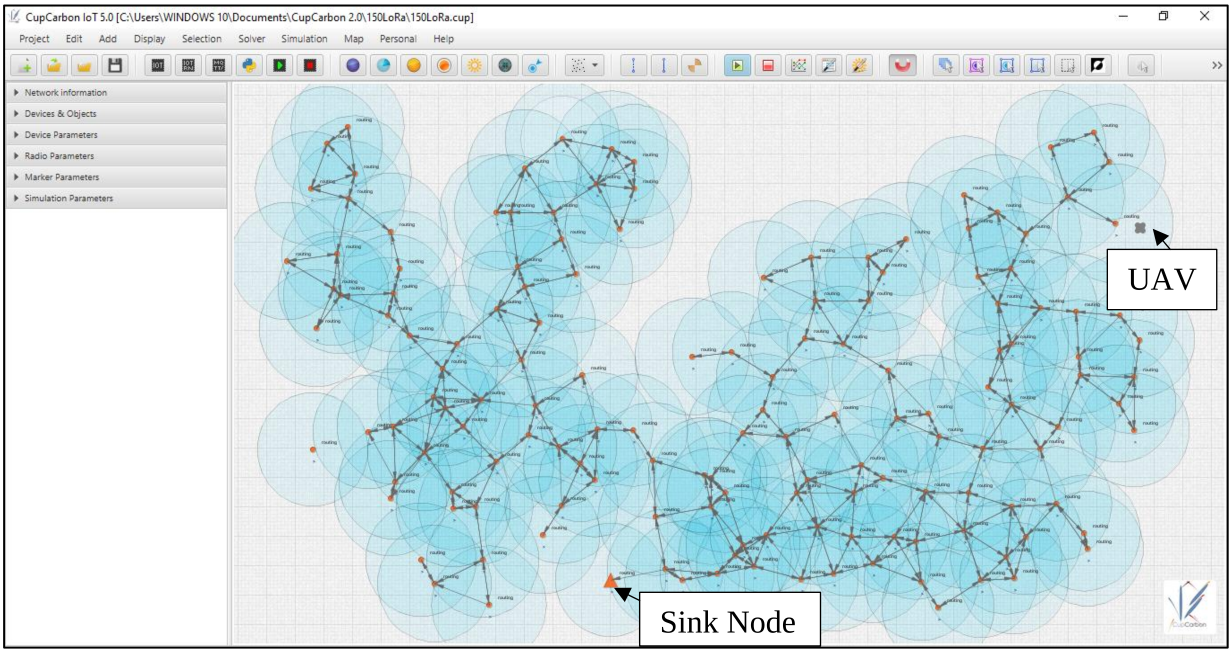


Figure 5.1 150 sensor node in the network.

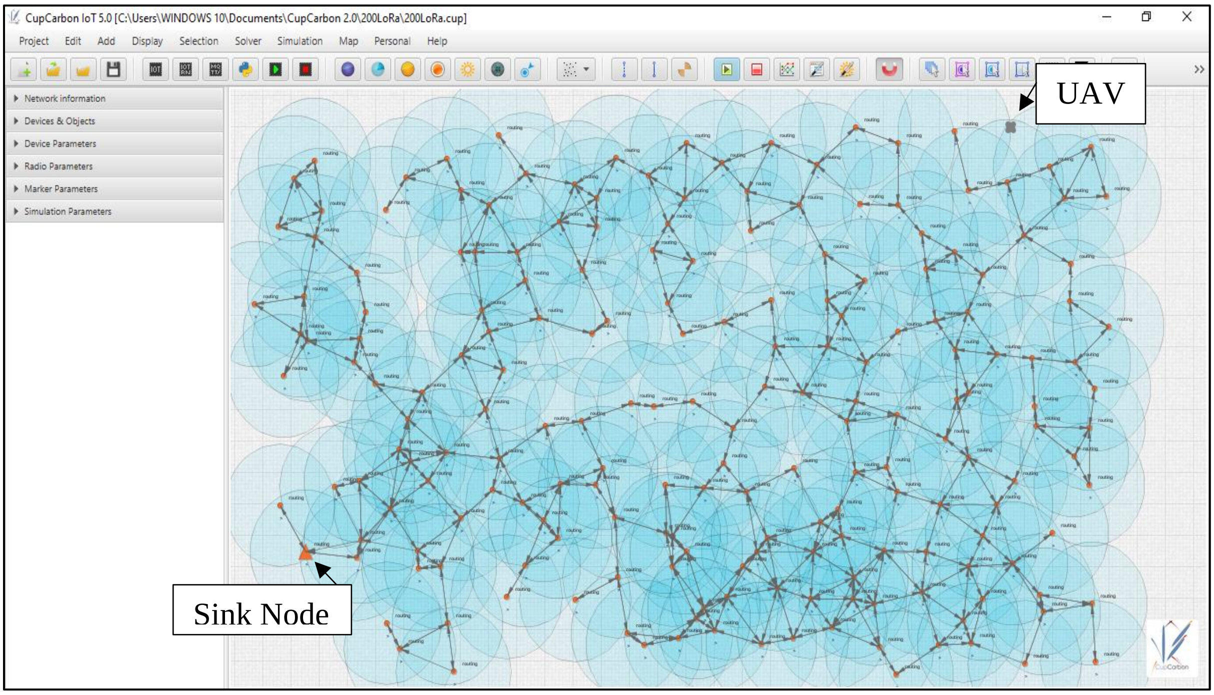


Figure 5.2 200 sensor node in the network.

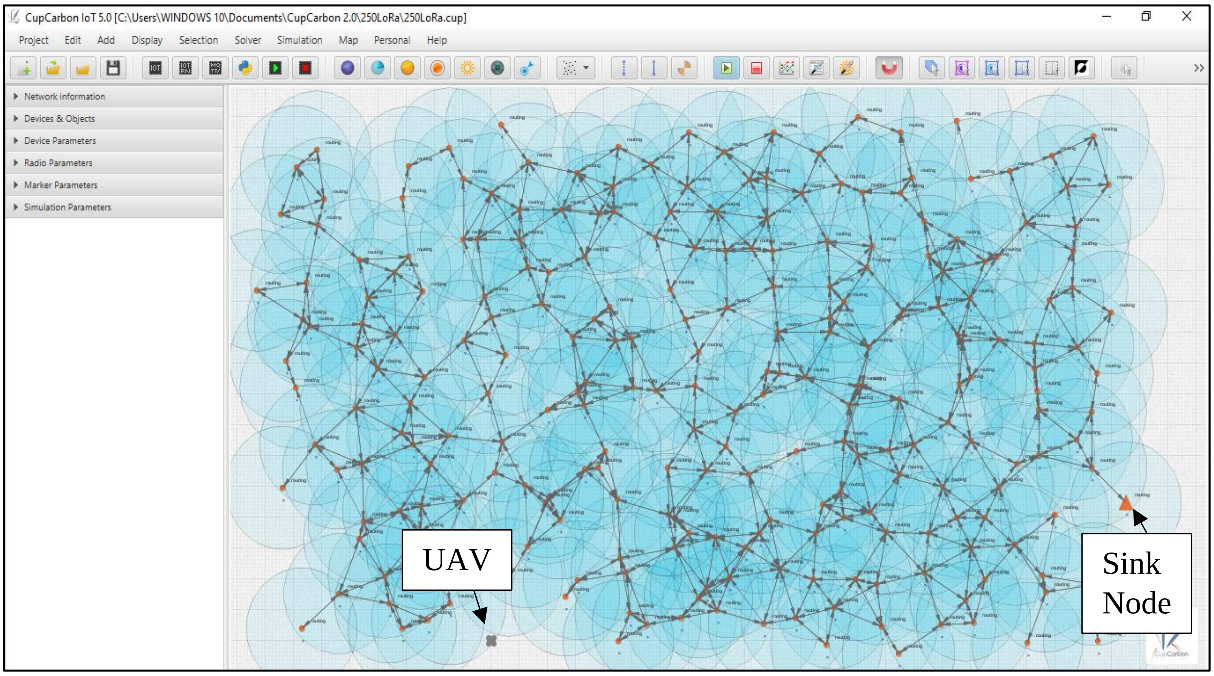


Figure 5.3 250 sensor node in the network.

In the following section, it will present the route from UAV to the bae station (sink node). It will follow the steps that have first mentioned in the beginning of subtopic 5.2 All the node that has been elected as the node to pass the message, will be marked in yellowish color. The route will also be formed in a light blue color for better viewing. However, node without marked and linked are the node that did not elected as part of the routing process.

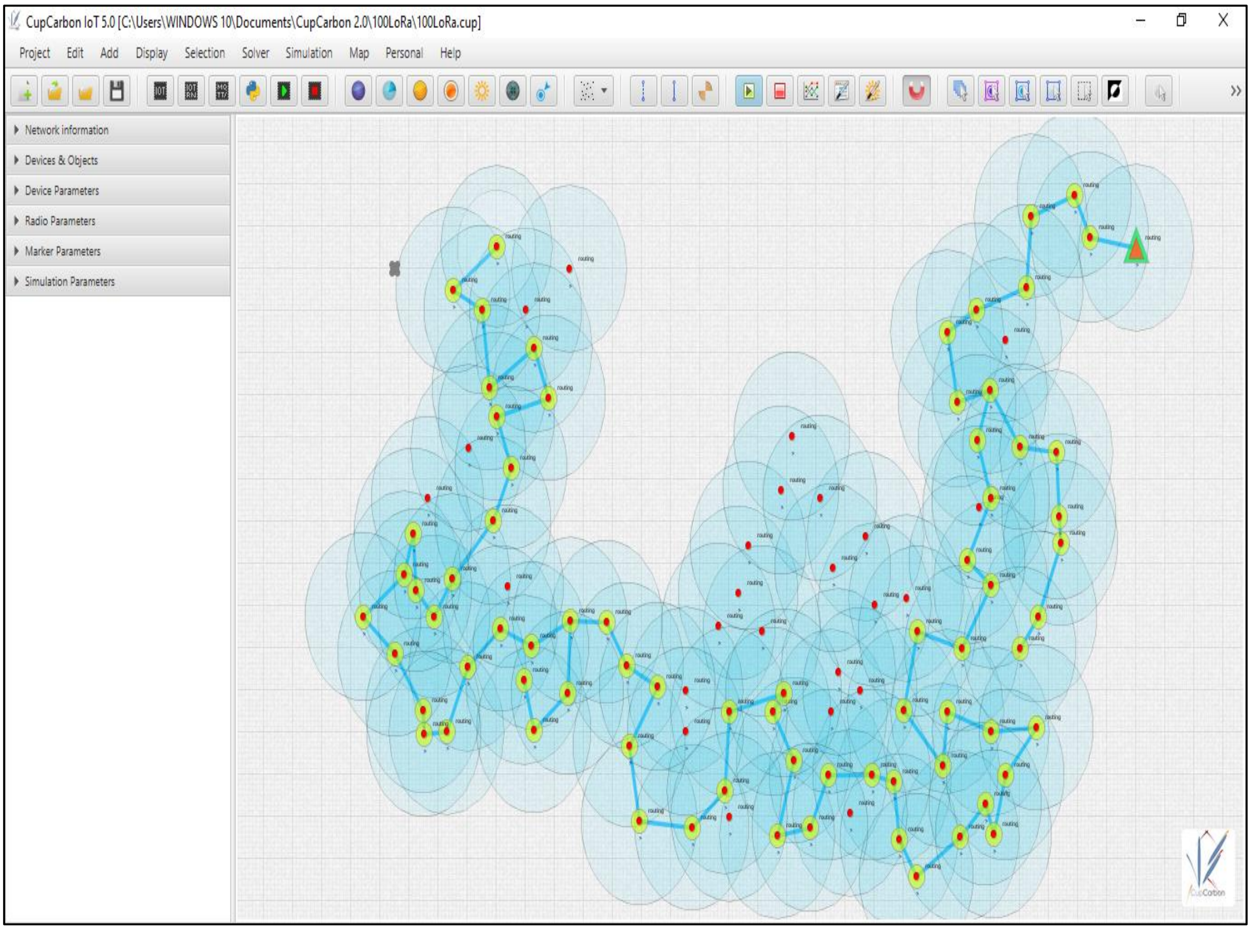


Figure 5.4 Route generated in 100 sensor nodes.

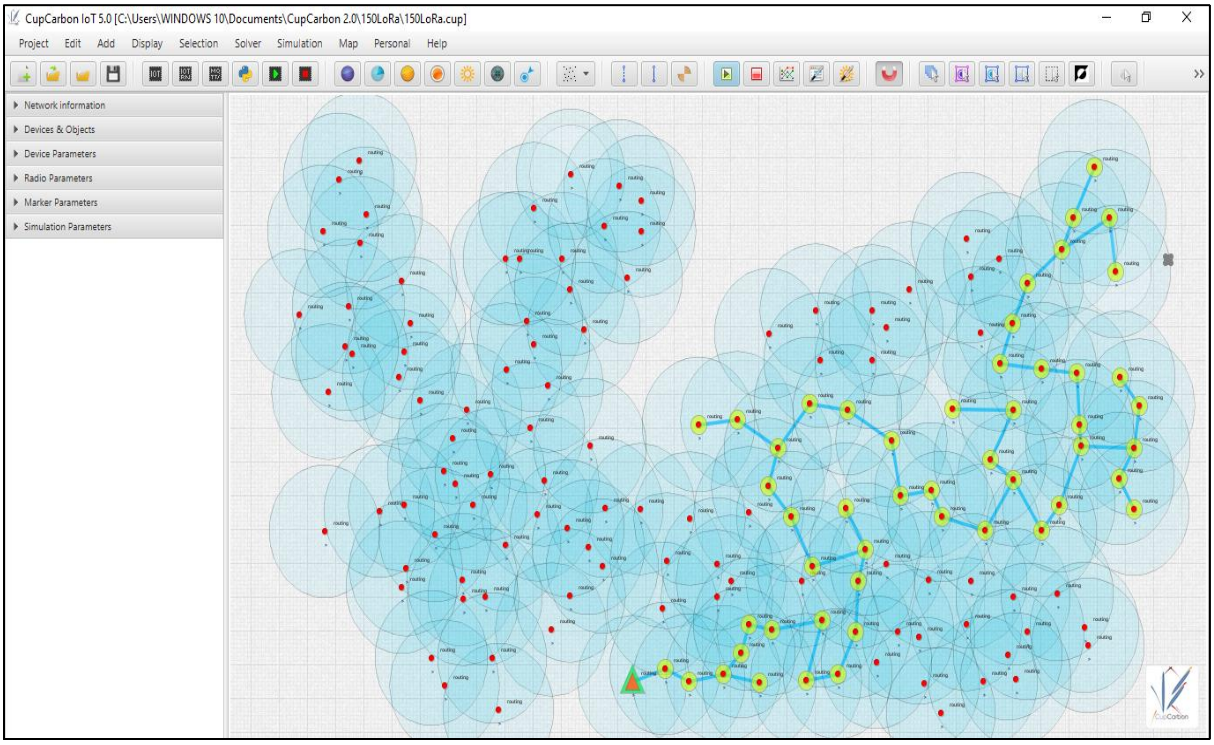


Figure 5.5 Route generated in 150 sensor nodes.

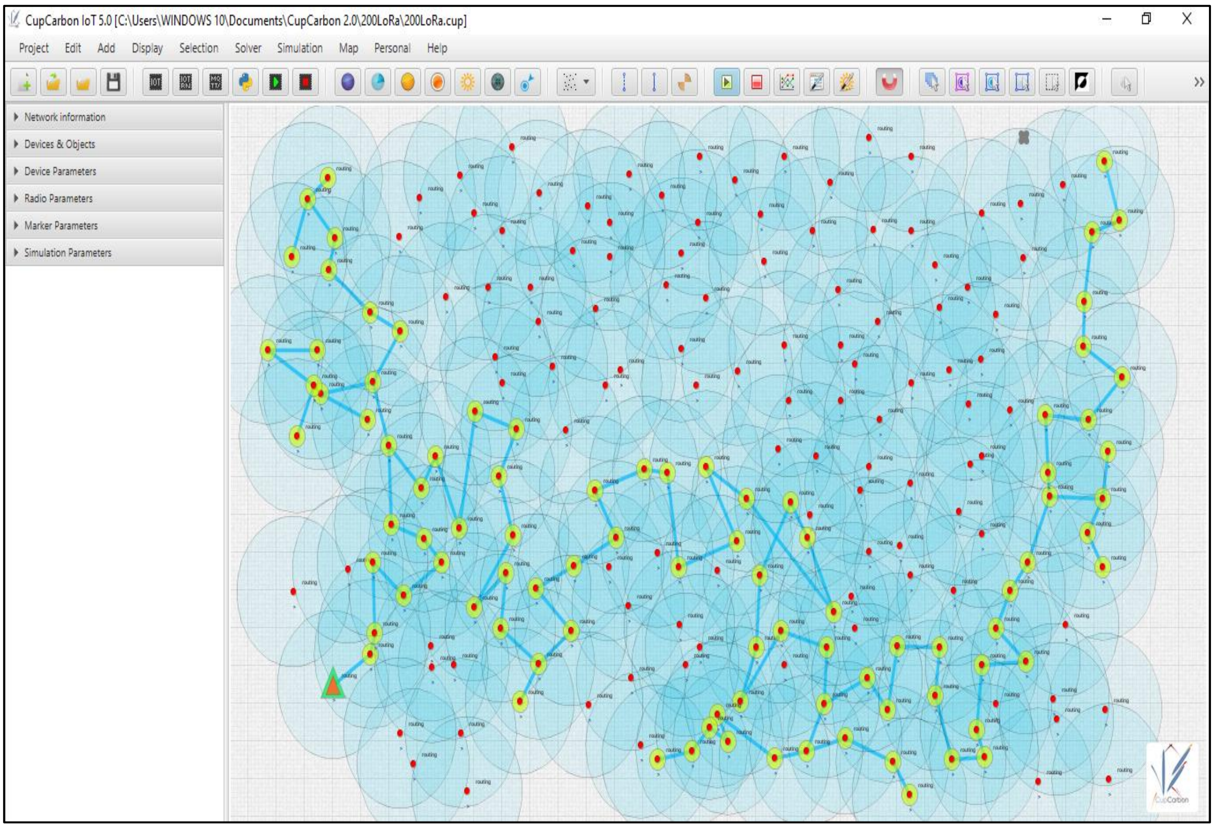


Figure 5.6 Route generated in 200 sensor nodes.

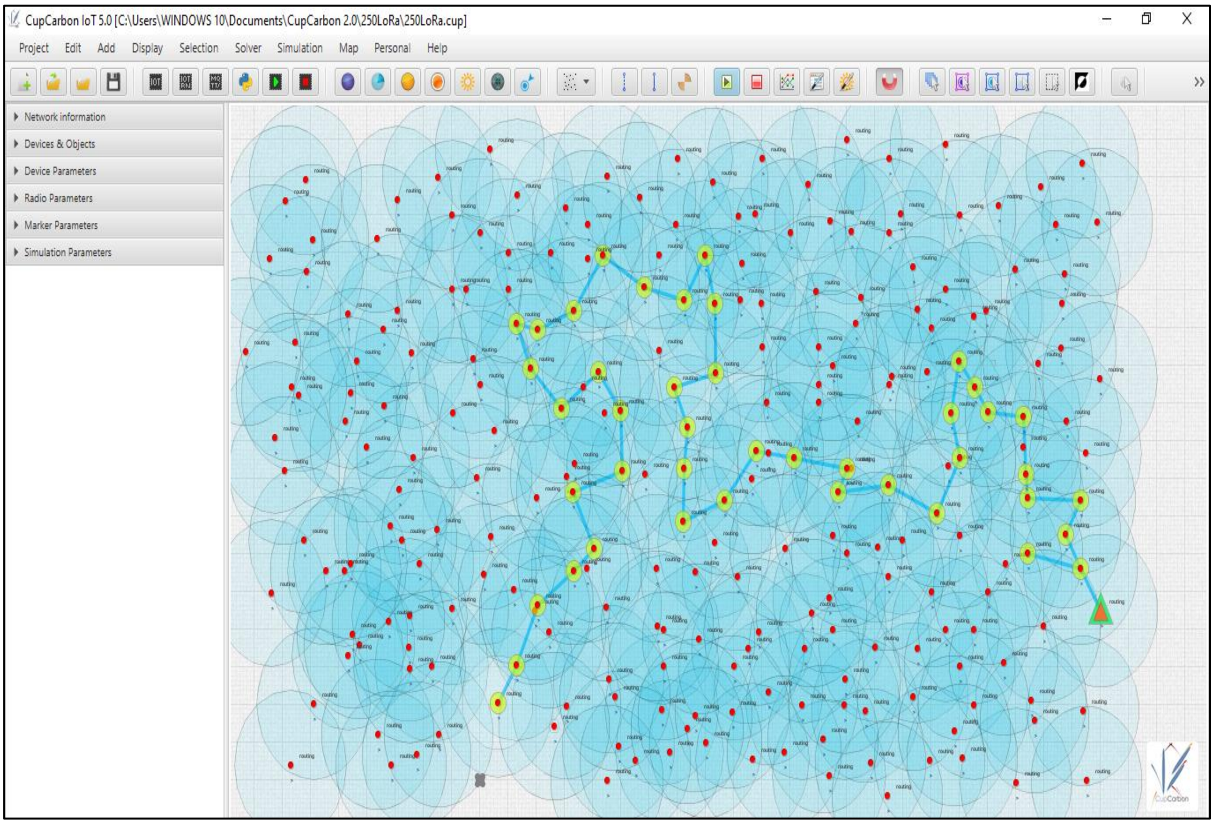


Figure 5.7 Route generated in 250 sensor nodes.

5.3 Packet Delivery Ratio

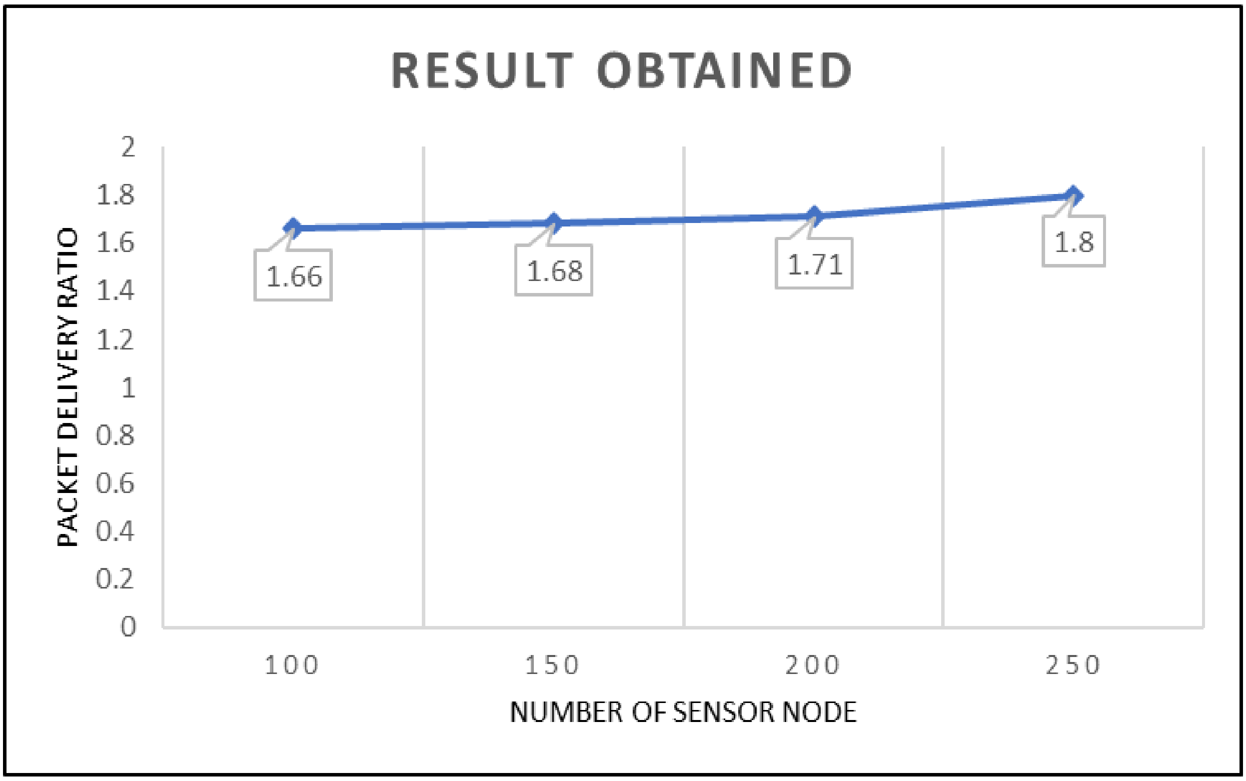


Figure 5.8 Packet Delivery Ratio.

Based on figure 5.8, the packet delivery ratio is obtained and compare in a graph format. The result is obvious that the higher the number of sensor node placed in the network, the greater the packet delivery ratio. Also, based on connection between the sensor node, it can be concluded that their connection is complex. As the increase in number of sensor nodes, the network complexity also increased. There are some of the nodes have many neighbor nodes connecting to it which makes the network become more complex. Though the complexity, the routing algorithm still manage to get a greater packet delivery ratio as number of sensor nodes increase. It can be concluded that the SEA routing algorithm is suitable for large and complex network if without comparing their energy consumption level. Besides, the occurrence of routing loop in different number of sensor nodes placed in the network is equal to zero. It also proved that the SEA routing algorithm can eliminate the occurrence of routing loop which has high occurrence in many other existing routing algorithms. With disqualify node detection, it can also increase the overall quality of service as it filters out all the disqualify node in the network.

5.4 Result for Energy Consumption Level

In this section, the energy consumption level is obtained after the simulation process is executed.

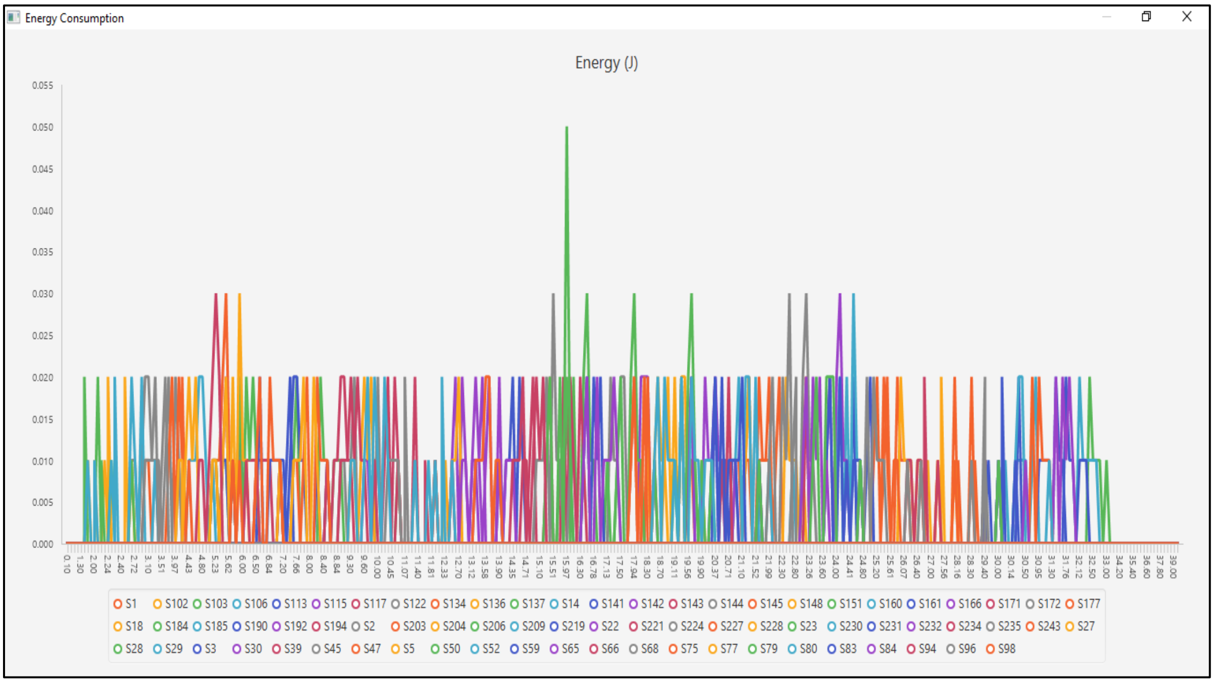


Figure 5.9 Energy Consumption level in 100 sensor nodes.

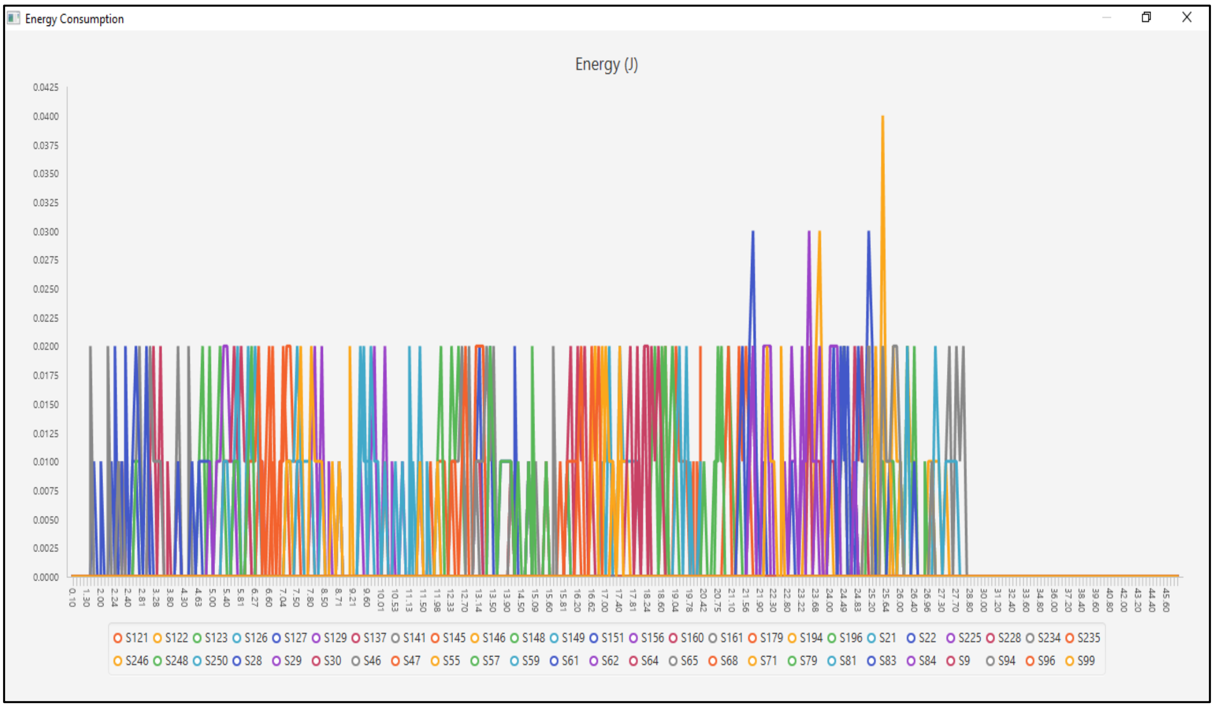


Figure 6.0 Energy Consumption level in 150 sensor nodes.

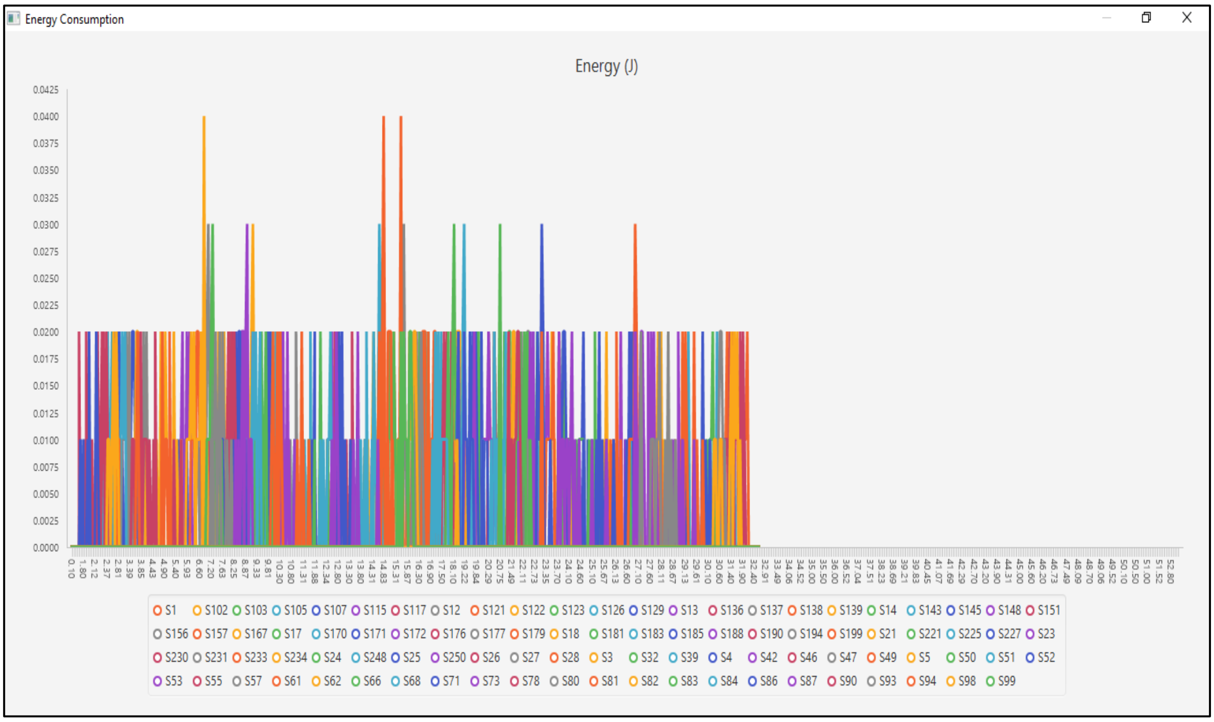


Figure 6.1 Energy Consumption level in 200 sensor nodes.

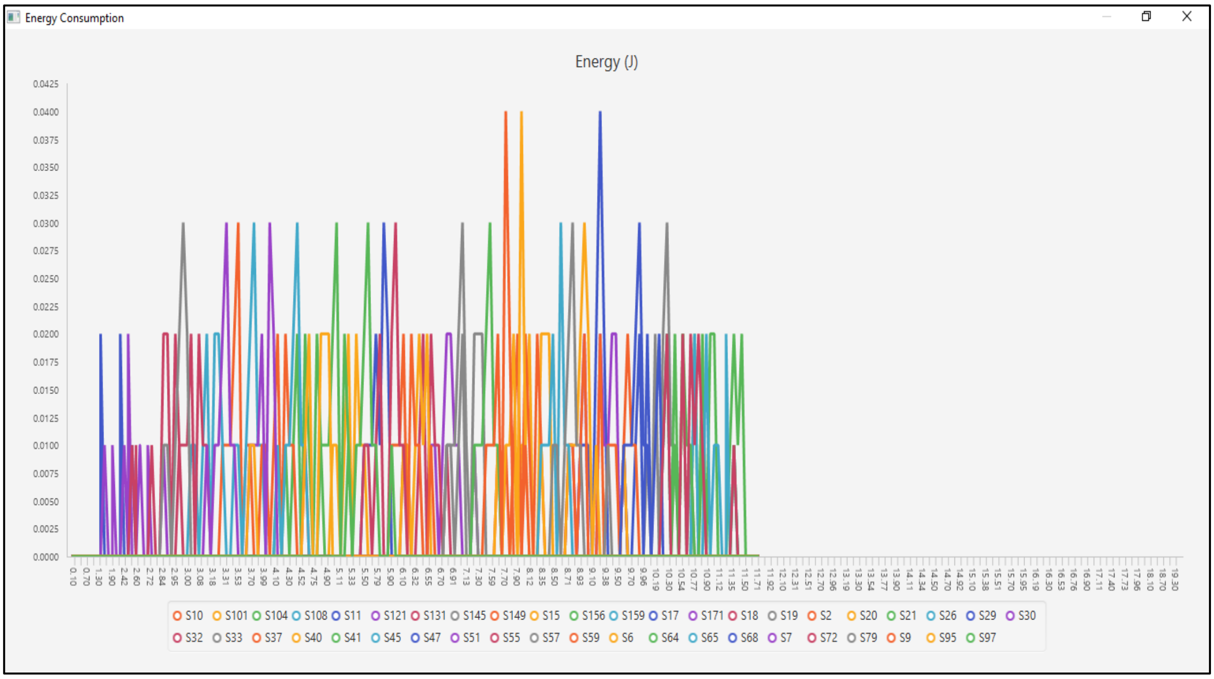


Figure 6.2 Energy Consumption level in 250 sensor nodes.

Based on the respective energy consumption level, maximum of 250 sensor nodes, its highest energy consumption level is 0.0400 joules for particular sensor nodes. Else, the second highest of energy consumption is 0.0300 joules followed by 0.0200 joules and 0.0100 joules of energy for most of the sensor nodes. This obtained results are the same for 150 and 200 sensor nodes in the network. However, the differences between them is that there are 3 sensor nodes consumed 0.0400 joules of energy for both 200 and 250 sensor nodes, 1 sensor node consumed 0.0400 joules of energy for 150 sensor nodes. There is an exemption whereby the 100 sensor nodes consumed 0.0500 joules of the energy.

To sum up everything that has been stated so far, the SEA routing algorithm is smart and energy efficient whereby it can detect dead route, disqualify node, and generate different types of messages based on the situation. Another finding from this project is that, it is very important to add delay instruction into the network. Based on several experiments, it has very high occurrence to result in routing loop when delay instruction is not added into the algorithm. Experiment is completed in a network with 250 number of sensors. Based on figure X.X, it shows that routing loop occur on which node with its respective node ID and the simulation process is terminated halfway. In this case, the node with ID 179 routing occur and simulation process terminated.

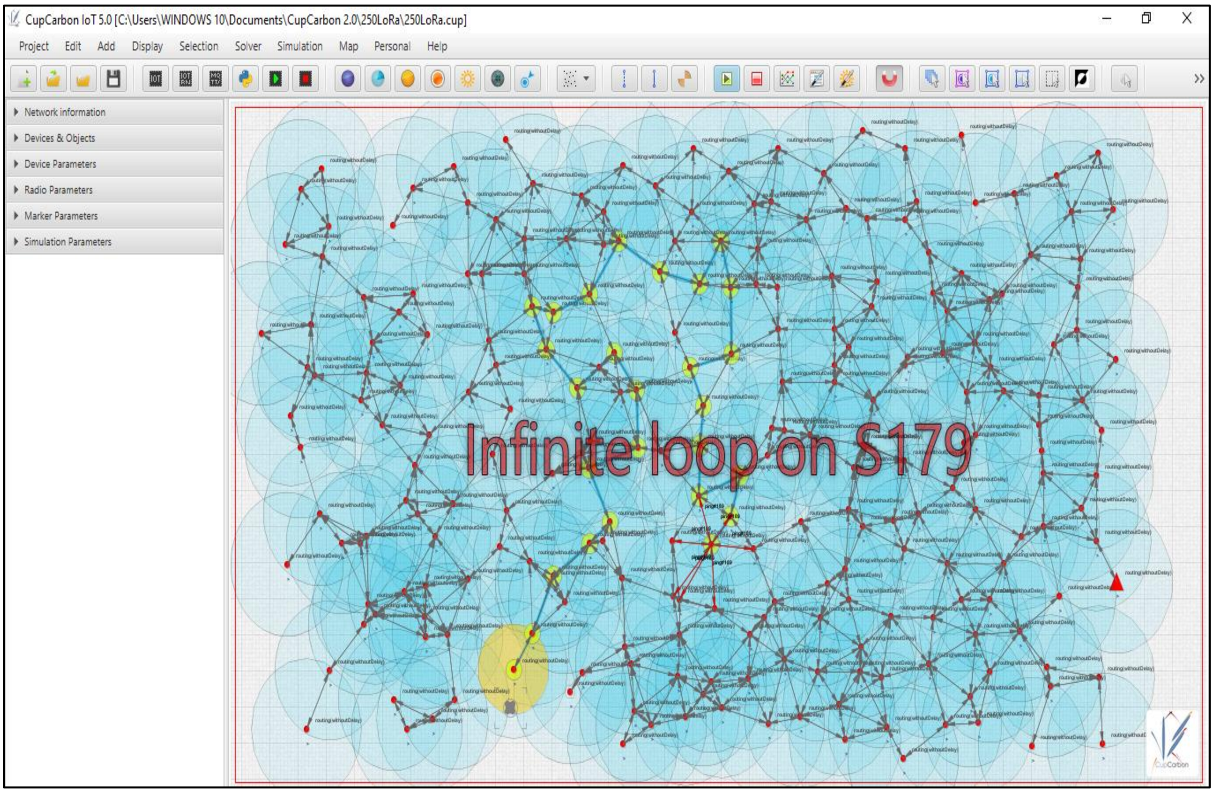


Figure 6.3 Infinite loop in 250 sensor nodes.

Not only that, we then examine the energy consumption level consumed by the marked node which are the node that have been marked in yellowish color and are involved in routing process. The figure 6.4 shows the energy consumption level obtained.

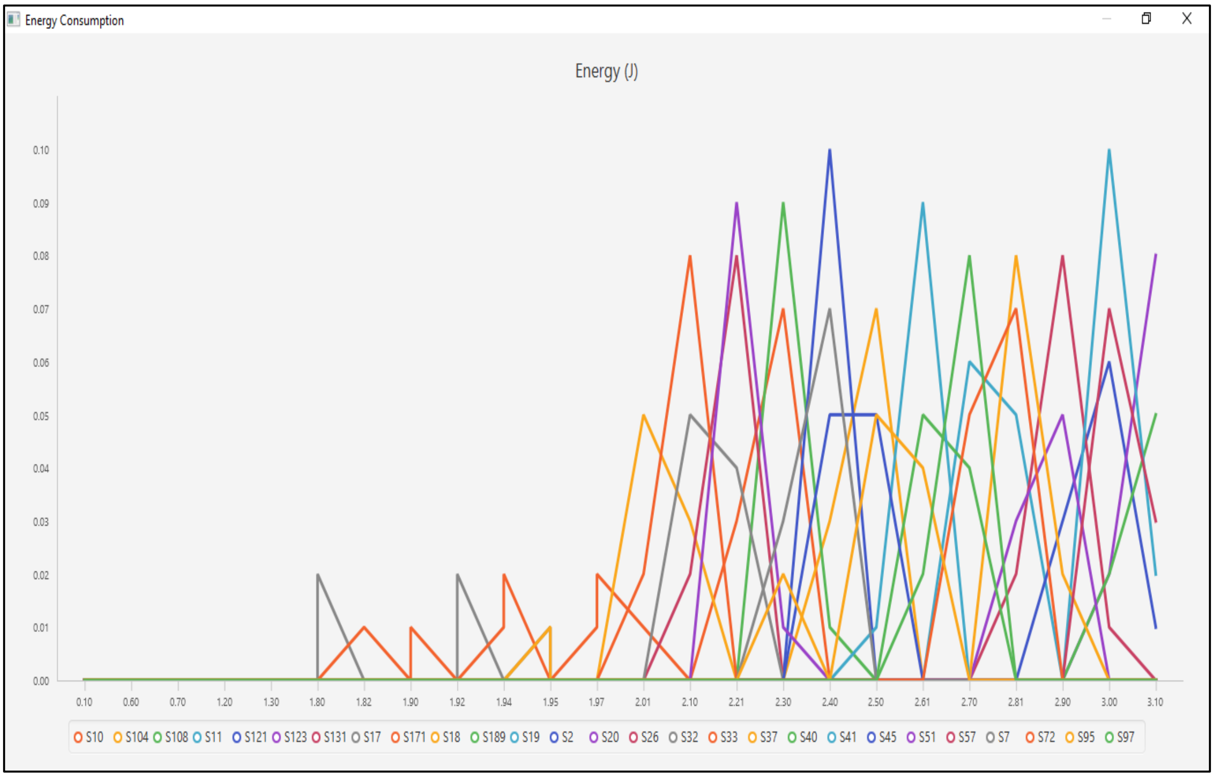


Figure 6.4 Energy Consumption level in 250 sensor nodes (without delay instruction.)

Based on figure 6.4, it is obvious that it consumed maximum of 0.10 joules of the energy. Besides, the routing process is not executed successfully and is terminated halfway. Compare to the result made earlier, the maximum is only 0.05 joules to 0.04 joules of energy. Thus, 0.10 joule is considered high in this project. Routing process is not executed successfully but already consumed maximum 0.10 joules of energy. If the routing process continue and the routing loop is ignored, the level of energy consumed is unimaginable. Therefore, delay instruction plays a very important role to ensure energy efficiency and a little help in avoiding routing loop.

CHAPTER 6: CONCLUSION

To sum up everything that has been stated so far, this project is about doing a research on the several existing routing algorithm and protocol. It is then followed by developing a new routing algorithm and protocol that could eliminate the routing loops problem which result in poor quality of service in the network and high energy consumption in the sensor nodes. Motivation of doing this project is to develop a new routing algorithm and protocol which can result in an energy aware and achieve the smart context for the IoMT devices.

In this project, the routing algorithm is developed and improved based on the informative comment given in the project I. The routing algorithm to be developed in this project is called SEA routing algorithm and is dedicated for the routing in IoMT device. The routing process focuses on generating 4 different types of messages according to the scenario faced. The smart part for this routing algorithm is the ability of filtering out the disqualify node, detect dead end route, and determine if the node has been visited earlier. To prevent occurrence of routing loop, delay instruction, detecting dead end route and determine if the node is visited previously are significantly important in this project. Based on countless of testing and simulation process, the routing loop still occur even when the algorithm can detect the dead-end route and know if node has been visited before. Therefore, the delay instruction is added every time when the types of messages are sent to the node. Based on observation, the delay instruction does help to prevent routing loop. So, every subpart of the algorithm that helps to prevent routing loop are essential and indispensable. The algorithm is ruined without any part of these.

To summarize, the SEA routing algorithm is smart and is an energy aware routing suitable for the IoMT device with the results such as packet delivery ratio and energy consumption level generate during the simulation process. The maximum energy consumed is 0.05 joule and the least energy consumed is 0.01 joule. The algorithm can form a complete route to the targeted sink node and no routing loop or any issue occur during the simulation process. Besides, with the results obtained, the SEA routing algorithm is also suitable for large and complex network.

6.1 Future work

During the process of doing this project, I realize how important routing is in ensuring a smooth in end-to-end communication. Also, routing plays a really important part in ensuring day-to-day operation. Thus, hopefully the routing algorithm can be built in a way that can reach to very secluded places. In this pandemic, we all know that how difficult the students living in secluded places to try and connect to an internet or contact their loved ones. Therefore, it is hope that a more advanced and energy aware routing algorithm is developed and put into use in our daily lives. It is also believed that people from any sector could be benefited once a more improved and advanced routing is introduced. In this project, hopefully there will be more advanced graphical user interface network simulation tool introduced into the market. As a result, more and more potential researcher can handle the tool easily and do their research to benefit the whole world. With the increasing number of IoT usage, it is also believed the routing topic can be taught in any level of education. Almost everyone in the world require wireless communication to keep in touch with their loved ones, so hopefully in the future Malaysia IT specialist gets to involve in the development of advanced routing.

REFERENCES

Amamou. A, Piccolo. VD, Haddadou. K and Pujolle.G (2020). A Survey of Network Isolation solutions for multi-tenant data centers. Articles in IEEE Communications Surveys & Tutorials. pp.2-10.

Beghdad. R and Lamraoui.A. (2016). Boundary and holes recognition in wireless sensor networks. *Journal of Innovation in Digital Ecosystem*. pp.1-14.

Chan.HF, Rudolph.H. (2015). *New Energy Efficient Routing Algorithm for Wireless Sensor Network.* Available at https://www.researchgate.net/publication/283507649_New_Energy_Efficient_Routing_Algorithm_for_Wireless_Sensor_Network (Accessed 4rd February 2021)

Christensson, P. (2006). SMART Definition. Available at https://techterms.com/definition/smart (Accessed 30th June 2020)

Destino. G and G.T. Freitas de Abreu, Network boundary recognition via graph-theory, in: Proceedings of the 5th Workshop on Positioning, Navigation and Communication, 2008, pp. 271–275.

S. Funke. (2018). Topological hole detection in wireless sensor networks and its applications, in: Proc of the Joint Workshop on Foundations of Mobile Computing, pp. 44–53.

Gavalas. D, Venetis.Ioannis, Pantziou, G, Charalampos. K. (2014). Benchmarking Mobile Agent Itinerary Planning Algorithms for Data Aggregation on WSNs. *Conference: 6th International Conference on Ubiquitous and Future Networks (ICUFN 2014).* pp.1-7.

Guoyou He (n.d.). Destination-Sequenced Distance Vector (DSDV) Protocol. *Networking Laboratory*. pp.1-8.

Hsieh K.Y., Sheu J.P, (2017). Hole detection and boundary recognition in wireless sensor networks, in: Personal, Indoor and Mobile Radio Communications, IEEE, pp. 27–76.

Kamal.Z and Salahuddin.M. (2015). Introduction to Wireless Sensor Networks, in Wireless Sensor and Mobile Ad-Hoc Networks: Vehicular and Space Applications (BenHaddou.D and Al-Fuqaha.A,2015). pp.4-5.

Lazarescu.M. (2017). Wireless Sensor Networks for the Internet of Things: Barriers and Synergies. pp.1-27.

REFERENCES

Liang.R, Wang.P and Zhao.L (2020). Performance Evaluations of LoRa Wireless Communication in Building Environments. *Journal of Sensors.* Volume:*20, 3828, pp.2-6.*

Low.TJ, Zaman.N and Yasin.MM. (2016). Enhancing Energy Efficiency of Wireless Sensor Network through the Design of Energy Efficient Routing Protocol. *Journal of Sensors.* Volume: 2019, pp.2-4.

Mancilla. M.C, Mellado. E.L and Siller. M (2016). Wireless Sensor Networks Formation: Approaches and Techniques. *Journal of Sensors.*Volume: 2016, pp.1-5.

Moore.F.(2017). *Routers (Network Routing)*. Available at https://www.researchgate.net/publication/ 317057644_Routers_Network_Routing. (Accessed 1st July 2020)

Sahoo P.K., Sheu J.P., Hsieh K.Y., Target tracking and boundary node selection algorithms of wireless sensor networks for internet services, Inform. Sci. 230 (1) (2013) 21–38.

Shaikh.R and Sayed.A (2015). Sensor Node Failure Detection in Wireless Sensor Network: A Survey, 14(2). pp.72-74.

Singh. H, Kaur.H and Sharma. A. (2016). Geographic Routing Protocol: A Review. *International Journal of Grid and Distributed Computing.* 9(2). pp.245-254. Available from: http://dx.doi.org/10.14257/ijgdc.2016.9.2.21.(Accessed 20 July 2020).

Singh.M and Kumar.S (2017). A Survey: Ad-hoc on-Demand Distance Vector (AODV) Protocol. *International Journal of Computer Applications.* 161(1). pp.1-7.

Yang.X (2014). The Application of RPL Routing Protocol in Low Power Wireless Sensor and Lossy Networks. *Sensors & Transducers.* 170(5), pp.107-109.

Zanjireh.M and Larijani.H (2015). A Survey on Centralised and Distributed Clustering Routing Algorithms for WSN. IEEE 81st Vehicular Technology Conference. pp.1-2. Available from: doi:10.1109/VTCSpring.2015.7145650 (IEEE) (Accessed 9 July 2020).

Zhao.M, Kumar.A, Han.P and Lu.R (2016). A comprehensive study of RPL and P2P-RPL routing protocols: Implementation, challenges and opportunities. *Article in Peer-to-Peer Networking and Applications.* Available from: doi:10.1007/s12083-016-0475-y.(Accessed 20 July 2020).

Smart and Energy aware Routing for the Internet of Mobile Things

Introduction

Wireless routing algorithm is essential in nowadays IoT technology. However, routing loop and efficient of energy consumption happen frequently. In this project, it focuses on developing a smart & energy aware routing algorithm for the IoMT devices called SEA routing.

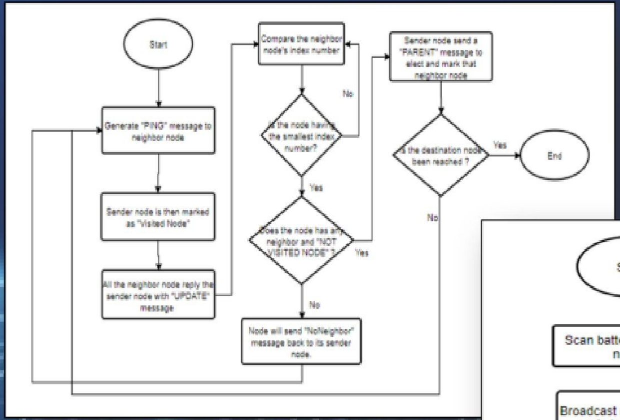
Conclusion

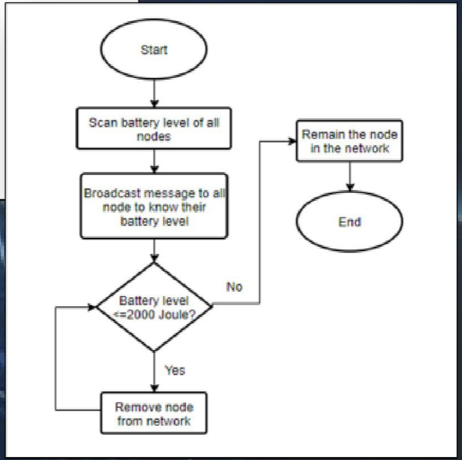
- ✓ Work in small & large network.
- ✓ Smart to perform routing.
- ✓ Energy efficient

Discussion

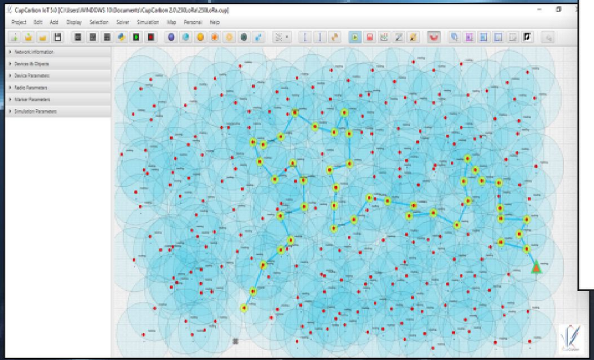
The SEA routing is able to perform routing in large and small network. The energy consumption level is reduced greatly with delay instruction. At the end, it manages to solve the problem of as high occurrence in routing loop and unsuccessful packet routing under high mobility environment

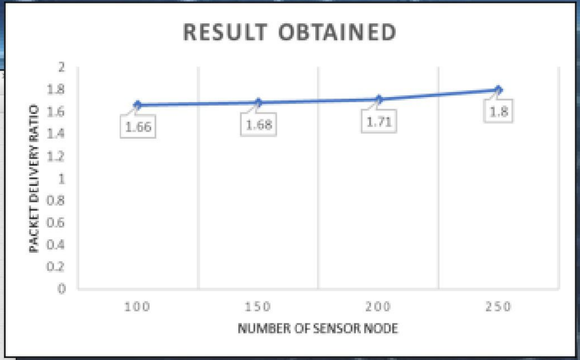
Method





Results





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CHAPTER 1: INTRODUCTION

1.1 Problem Statement and Motivation

In this project, the packet routing process among the Internet of Mobile Things (IoMT) devices play a pivotal role. Many sensor nodes are embedded inside an IoMT devices which therefore form a wireless sensor network (WSN) to communicate with each other. However, the WSN is well known as a resource constrained and energy limitation network as well as surviving solely on the lifespan of the sensor nodes' battery. According to the findings done by Shaikh.R and Sayed.A (2015), one of the major reasons that lead to the degradation quality of services in the network is the lack of implementing dead node detection method. Not only that, the existing routing protocol could not support the nature of WSN which is high mobility then result in packet drop or loss of traceability. In line with the present demand, the formation of network devices has become larger and complex. From this, the problem statement can be concluded as the high occurrence in routing loop and unsuccessful packet routing under high mobility environment for Internet of Mobile Things which can also be found from many

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Trimester, Year: Trimester 3, Year 3	**Study week no.: 2**
Student Name & ID: BEH ZI XUAN, 17ACB01923	
Supervisor: VASAKI A/P PONNUSAMY	
Project Title: SMART AND ENERGY AWARE ROUTING FOR THE INTERNET OF MOBILE THINGS	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Study on different routing related articles.
- Make preparation on what content could be added into the project.

2. WORK TO BE DONE

- Write the introduction part for the project.
- Draft a list on what to achieve in this project.

3. PROBLEMS ENCOUNTERED

- None

4. SELF EVALUATION OF THE PROGRESS

- Manage to handle everything at the moment.

Supervisor's signature

beh

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project I / Project II)

Trimester, Year: Trimester 3, Year 3	**Study week no.: 4**
Student Name & ID: BEH ZI XUAN, 17ACB01923	
Supervisor: VASAKI A/P PONNUSAMY	
Project Title: SMART AND ENERGY AWARE ROUTING FOR THE INTERNET OF MOBILE THINGS	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Able to build the dead node detection feature.
- Completed the collection of information for literature review.

2. WORK TO BE DONE

- Continue to develop the routing algorithm.
- Design the network architecture.

3. PROBLEMS ENCOUNTERED

- The routing algorithm faces several bugs and could not be programmed successfully.

4. SELF EVALUATION OF THE PROGRESS

- Learn a lot of new things especially building code using SenScript. Discovered a lot of software tools to assist me in this project.

Beh

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FINAL YEAR PROJECT WEEKLY REPORT

(Project I / Project II)

Trimester, Year: Trimester 3, Year 3	Study week no.: 6
Student Name & ID: BEH ZI XUAN, 17ACB01923	
Supervisor: VASAKI A/P PONNUSAMY	
Project Title: SMART AND ENERGY AWARE ROUTING FOR THE INTERNET OF MOBILE THINGS	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Manage to perform a demonstration of some features.
- Planned the way to construct the network diagram.

2. WORK TO BE DONE

- Continue to develop the routing algorithm.
- Observe and compare the result generated from simulation process.

3. PROBLEMS ENCOUNTERED

- The routing algorithm faces several bugs and could not be programmed successfully.

4. SELF EVALUATION OF THE PROGRESS

- Learn a lot of new things from different research papers.

Supervisor's signature

beh

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FINAL YEAR PROJECT WEEKLY REPORT

(Project I / Project II)

Trimester, Year: Trimester 3, Year 3	**Study week no.: 8**
Student Name & ID: BEH ZI XUAN, 17ACB01923	
Supervisor: VASAKI A/P PONNUSAMY	
Project Title: SMART AND ENERGY AWARE ROUTING FOR THE INTERNET OF MOBILE THINGS	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Completed the documentation for introduction and literature review.

2. WORK TO BE DONE

- Do the documentation of this project.
- Arrange information collected for documentation purpose.

3. PROBLEMS ENCOUNTERED

- The routing algorithm faces several bugs and could not be programmed successfully.

4. SELF EVALUATION OF THE PROGRESS

- This project gives an opportunity to learn new programming script -SenScript.

beh

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FINAL YEAR PROJECT WEEKLY REPORT

(Project I / Project II)

Trimester, Year: Trimester 3, Year 3	Study week no.: 10
Student Name & ID: BEH ZI XUAN, 17ACB01923	
Supervisor: VASAKI A/P PONNUSAMY	
Project Title: SMART AND ENERGY AWARE ROUTING FOR THE INTERNET OF MOBILE THINGS	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- The routing algorithm is developed successfully.
- Completed the documentation for every chapter.

2. WORK TO BE DONE

- Submit for draft check and do necessary correction.
- Design a poster.

3. PROBLEMS ENCOUNTERED

- None.

4. SELF EVALUATION OF THE PROGRESS

- This project gives an opportunity to learn and debug new programming script -SenScript.

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FINAL YEAR PROJECT WEEKLY REPORT

(Project I / Project II)

Trimester, Year: Trimester 3, Year 3	**Study week no.: 11**
Student Name & ID: BEH ZI XUAN, 17ACB01923	
Supervisor: VASAKI A/P PONNUSAMY	
Project Title: SMART AND ENERGY AWARE ROUTING FOR THE INTERNET OF MOBILE THINGS	

1. WORK DONE [Please write the details of the work done in the last fortnight.] • Completed all the documentation and poster.
2. WORK TO BE DONE • Submit for final submission.
3. PROBLEMS ENCOUNTERED • None.
4. SELF EVALUATION OF THE PROGRESS • This project allows me to learn many types of existing routing algorithm. • Realize my own weaknesses

Supervisor's signature

beh

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