AN ENHANCED ENERGY EFFICIENT ROUTING PROTOCOL IN WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless Sensor Network (WSN), is a network that comprises of hundreds or thousands autonomous wireless sensor nodes that are scattered randomly in a selected area to monitored the desire physical phenomena and relay the information that it acquired wirelessly to the base station. However, these sensor nodes have small amount of energy source due to its small size form factor thus limited energy resource in sensor nodes has become a major problem in WSN. An enhanced energy efficient routing protocol named Distance Selection Cluster Head Protocol (DCHSP) is proposed in this research. This routing protocol improves the energy efficiency in WSN by electing a new cluster head based on the distance of previous cluster heads which will prevents the new appointed cluster head from concentrating in one part of the network area only. In this routing protocol, for a sensor node to be elected as cluster heads, it must have a distance equal or larger than 2 times of cluster range radius (2CRR) to the previous cluster heads. This make the current cluster head to be spread widely across the network area and therefore all the sensor nodes of the cluster will have a fair travel distance to its cluster head which result in reduced of energy usage for data transmission of the sensor nodes to cluster heads. The performance of DCHSP is evaluated by comparing with several existing protocol namely LEACH and SEP using MATLAB simulation tool. All the routing protocols are simulated in this research and evaluated based on several performance parameters namely number of alive nodes, number of dead nodes, average energy of a nodes, number of packets delivered to the base station and the overall energy consumption of the network. The result from the simulation shows that DCHSP has a better performance compared to LEACH and SEP in number of dead nodes, number of alive nodes, average energy of a node, number of packets delivered and overall energy consumption of the network. In the nutshell, DCHSP has a better performance compared to existing protocol based on energy efficiency.

Keywords: Wireless sensor networks, energy efficient, sensor node, MATLAB, cluster head selection

PROTOKOL RANGKAIAN SENSOR TANPA WAYAR CEKAP TENAGA

ABSTRAK

Rangkaian Sensor Tanpa Wayar (WSN), adalah rangkaian yang terdiri daripada ratusan atau seribu nod sensor tanpa wayar autonomi yang tersebar secara rawak di kawasan terpilih untuk memantau keinginan fenomena fizikal dan menyampaikan maklumat yang diperoleh secara tanapa wayar ke stesen pangkalan. Walau bagaimanapun, nod sensor ini mempunyai sumber tenaga yang kecil kerana faktor bentuk saiznya yang kecil. Oleh itu, sumber tenaga yang terhad dalam nod sensor telah menjadi masalah utama dalam WSN. Satu protokol penghalaan yang cekap tenaga yang dinamakan Protokol Pemilihan Kepala Kluster bedasarkan Jarak (DCHSP) dicadangkan dalam penyelidikan ini. Protokol penghalaan ini meningkatkan kecekapan tenaga di WSN dengan memilih kepala kluster baru berdasarkan jarak kepala kluster sebelumnya dan menghalang ketua cluster daripada berkumpul dalam satu bahagian kawasan rangkaian sahaja. Dalam protokol peralihan ini, jarak nod sensor yang dipilih sebagai ketua kluster mestilah sama atau lebih besar dari 2 kali radius jarak kluster (2CRR) daripada kepala kluster sebelumnya. Ini menjadikan kepala kluster untuk tersebar luas dalam kawasan rangkaian dan semua nod sensor kluster akan mempunyai jarak perjalanan yang adil ke kepala klusternya. Untuk menguji prestasi DCHSP, ia dinilai dengan membandingkan dengan beberapa protokol sedia ada iaitu LEACH dan SEP menggunakan alat simulasi MATLAB. Semua protokol disimulasikan dan dinilai berdasarkan beberapa parameter prestasi iaitu bilangan nod hidup, bilangan nod mati, tenaga purata nod, bilangan paket dihantar ke stesen pangkalan dan penggunaan tenaga keseluruhan rangkaian. Hasil daripada simulasi menunjukkan bahawa DCHSP mempunyai prestasi yang lebih baik berbanding dengan LEACH dan SEP dalam bilangan nod yang mati, bilangan nod alahan, tenaga purata nod dan penggunaan tenaga keseluruhan rangkaian. Secara ringkasnya, DCHSP mempunyai prestasi yang lebih baik berbanding dengan protokol sedia ada.

Kata kunci: Rangkaian tanpa wayar, tenaga cekap, nod sensor, MATLAB, pemilihan kepala kluster

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LIST OF SYMBOL AND ABBREVIATION

Term	Definition
DCHSP	Distance Cluster Head Selection Protocol
WSN	Wireless Sensor Network
QoS	Quality of Service
LEACH	Low Energy Adaptive Clustering Hierarchy
SEP	Stable Election Protocol
SPIN	Sensor Protocol for Information via Navigation
TEEN	Threshold Sensitive Energy Efficient Network
GAF	Geographic Adaptive Fidelity
GEAR	Geographic and Energy Aware Routing
MANET	Mobile Ad-Hoc Network
GPS	Global Positioning System
SAR	Sequential Assignment Routing
ReInForM	Reliable Information Forwarding using Multiple path
M-MPR	Meshed Multipath Routing
PSO	Particle Swarm Optimization
V-LEACH	Vice Low Adaptive Clustering Hierarchy
DAPTEEN	Distance Adaptive Threshold Sensitive Energy Efficient Sensor Network
APTEEN	Adaptive Periodic Threshold-sensitive Energy Efficient Sensor Network
HADMMN	Hybrid Approach for Data Collection using Multiple Mobile Nodes
TDMA	Time Division Multiple Access

CSMA	Carrier Sense Multiple Access
CH	Cluster Head
CRR	Cluster Radius Range
BS	Base Station

CHAPTER 1: INTRODUCTION

1.1 Research Background

Wireless sensor network or also known as WSN, is a network that consist of scattered autonomous wireless sensor nodes that monitor the physical changes in its environment such as temperature, pressure, humidity, motion, sound and many more. The physical changes are then store as data in the sensor nodes. These data will be transmitted cooperatively through the network to a main node or central location called base station. As for today, modern wireless network sensors are bi-directional which not only allowing transmission of information being monitored from nodes to base station but also enabling control activity from the base station.

In comparison to wired network, WSN does not required physical media to enable data transfer and communication within network. This offers WSN the advantages to reduce the infrastructure cost and improved the scalability of the network. The main characteristics of WSN are flexibility, maintainability, scalability and self-monitoring. Moreover, WSN must able to provide a good quality of services and fulfil its task in harsh condition environment.

There are several components needed in order to create a wireless sensor network model. These components needed are sensor field, sensor nodes, sink and task manager. Example of wireless sensor network model is shown in Figure 1.1.

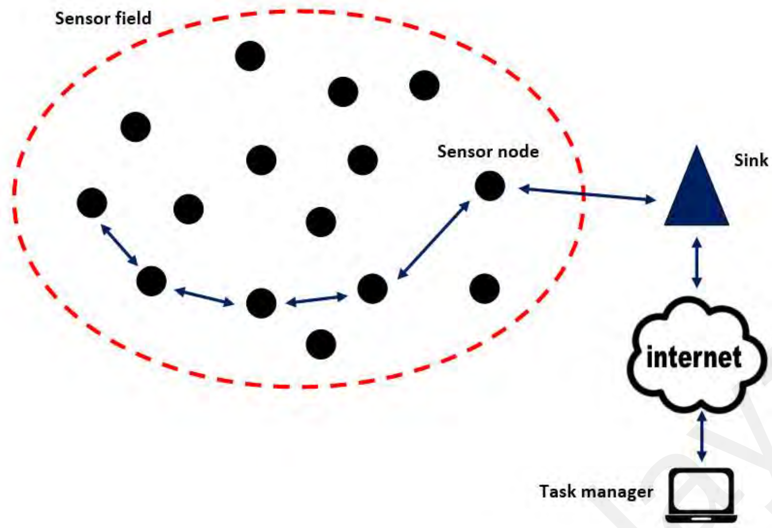


Figure 1.1 : Example of wireless sensor network model

Sensor field is the area where the sensor nodes are being placed. Sensor nodes are in charge of collecting data from its environment and routed the information to the sink. These sensor nodes can be either arranged or scattered randomly in the sensor field. Sink can also be called as aggregation point where it has specific task of processing, receiving and storing the data from the sensor nodes. Sink is also used to reduce the total number of messages the needed to be sent, therefore reducing the energy requirement of the network. Task manager is the centralize point of control in the network. Sink communicate with task manager by internet or satellite. Task manager also acts as a gateway to other network, data storage centre and also an access point for human interface. Some examples of task manager are laptop and workstation.

Sensor nodes play a central role in sensing changes and acquiring data of its network area of WSN. A typical sensor node in WSN is small sized hardware unit that not only acquires data from its environment but forwards the data wirelessly to its base station. The architecture of typical sensor node in WSN is shown in Figure 1.2. A typical sensor node consists of few components namely microcontroller, radio transceiver, sensor unit, analog-to-digital converter (ADC), memory and power source (Misra, 2016). Microcontroller is responsible to control the activity of other components in the sensor nodes. The radio transceiver is the combination of transceiver and receiver and used during data transmission and receiving data from others sensor nodes. Sensor unit is used to sense any environment changes while analog-to-digital converter is used for converting the analogue value from the sensor unit to a digital value so that it can be understand by the microcontroller. The memory on the other hand is used to store the data that is sensed by the sensor unit. The most important thing in sensor nodes is the power source as its store the energy in sensor nodes. Sensor nodes are usually designed in small size form.

The cost in developing sensor node is depending on the complexity of the individual sensor node. Apart from that, sensor nodes generally deployed in unintended or harsh condition area therefore they must also be robust to make sure it survives in harsh condition area.

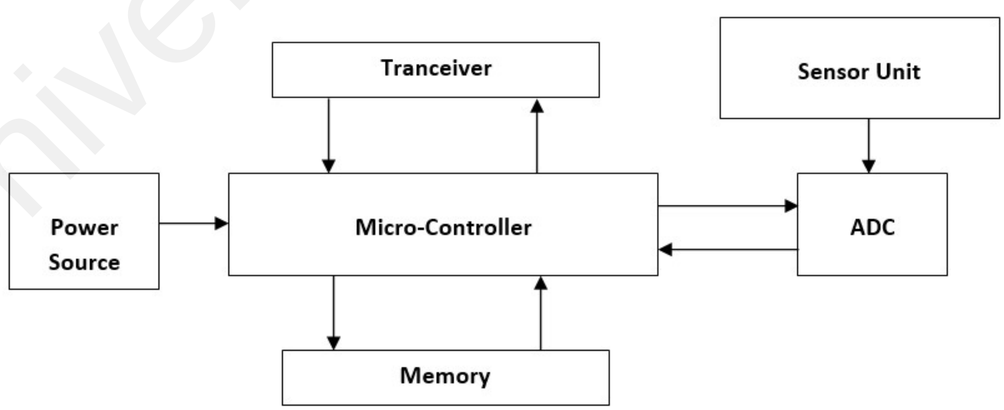


Figure 1.2 : An example of sensor node model

WSN can be implemented in wide variety of application due to its characteristics. The concept of WSN was initially motivated by military application (Singh, H. & Singh, D., 2016). It is first used during the Cold War where Sound Surveillance System (SOSUS) (Whitman, 2005) was deployed to detect any Soviet submarines. Nowadays, WSN can be used widely in many areas of application. WSN can be used to monitor environmental condition such as habitat monitoring and density of the forest (Manshahia, 2016). Moreover, WSN also can be implement for natural disaster sensing. Sensor nodes can be deployed to detect seismic activities such as earthquakes, volcanic eruption or even tsunami (Kaushik, 2014). WSN also can be implement in home network where sensor nodes are embedded in home appliances such as vacuum cleaner, air conditioner and television where the user can remotely control these appliances via internet or satellite easily (Sharma & Mittal, 2013). Apart from that, WSN can be use in health field where it can be used to monitor patients and various human system. One of the promising new direction of WSN usage in health field is telemonitoring of patients where elderly can be care and monitor from their home (Boukerche et. al, 2008).

Despite the vast opportunity provides by the wireless sensors network, it also come with several challenges. These challenges are mostly due to the characteristics of the sensor nodes in WSN. Sensor nodes are usually come in small form factor for easier deployment on the network. Since the sensor nodes are design in a small form factor, the energy source in these sensor nodes become limited. Energy is important for sensor nodes since it use a lot of energy to do its tasks such as sending and receiving data, data aggregation and in-network processing. The energy limitation of the sensor nodes can cause some complication to the network. When a sensor node loses all its energy, it is considered as dead sensor node. A dead sensor node will disrupt the flow of the network and reduce the network lifetime.

In order to conserve energy in WSN, an efficient energy routing protocol can implement to the network. The most well-known energy efficiency routing protocol is Low Energy Adaptive Clustering Hierarchy (LEACH) (Heinzelman et al., 2000). In LEACH, cluster heads act as the router for the sensor nodes and base station. Cluster heads then aggregate the data send by the sensor nodes and deliver it as a packet to the base station. The energy of the sensor nodes can be conserved since it does not need to communicate directly to the base station. Therefore, sensor nodes use less energy and can improve its lifetime.

1.2 Problem Statement

LEACH is highly known to have the ability to improve the energy efficiency of a network due to its hierarchal routing structure where the cluster head will do the data aggregation and deliver the data to the base station. This will reduce the stress load from the sensor nodes and therefore improve the lifetime of the sensor nodes.

However, due to its random selection of cluster heads it makes the energy saving on the network to inefficient. Since cluster head use more energy for data aggregation and delivery, sensor nodes that selected to be the cluster head need to have the adequate amount of energy for it to perform as the cluster head or else the cluster head will die early and disrupt the network data delivery flow.

The random selection of cluster heads in LEACH can also caused the cluster heads to be concentrated only in one part of the network area. These cause some of the sensor nodes have longer distance travel for data transmission to its cluster head. This will make the sensor nodes to consume more energy during data transmission to the cluster heads and therefore reduce the sensor nodes lifetime.

Since the development of LEACH, there are many researchers that had done research to improve the performance of LEACH. Some of these examples are EEE-LEACH (Bharti et al, 2015) where Cluster heads, master head and co-operative master head is select based on highest residual energy and shortest distance from base station. Another Improvement of LEACH is M-LEACH (Krishnakumar & Anuratha, 2017) where the cluster head is selected based from the residual energy of the sensor nodes and its distance from the sensor nodes while LEACH-GA (Sivakumar et. al, 2018) elect a cluster head based on the optimal number of cluster heads needed by the network. However, the improvement of LEACH before does not consider the distance between cluster heads as another way to achived the energy efficiency of the network. If the distance between cluster heads are not adjusted to a proper distance it causes some of the cluster heads to be concentrated in one part of the network area only. This will cause some of the sensor nodes to be very far from its cluster head and therefore have higher energy consumption which will reduce the lifetime of the sensor nodes

1.3 Motivation

One of the ways to evaluate a WSN is by its network lifetime. The network lifetime of a WSN can be define as the period of time during the network continually satisfies the application requirement (Soua et al, 2011). Energy limitation of the sensor network has become one of the biggest concerns in WSN. Limited amount of energy can cause the network lifetime of WSN to be short. One of the ways to reduce the energy consumption of the sensor network is by implementing an energy efficient routing protocol into wireless sensor network. In a wireless sensor networks, hierarchical clustering protocol is the mostly used protocol to reduce the energy consumption and extend the lifetime of the network. Hierarchical clustering protocols aim at clustering the nodes so that cluster heads can do some aggregation and reduction of data in order to save energy (Kirola et al, 2017). In hierarchical clustering protocol, sensor nodes are divided into several group called cluster. Each cluster consists of several sensor nodes and a cluster head. Sensor nodes responsible for sending the data to the cluster head. The cluster head then aggregates the data that it received from the sensor nodes into a data packet. The data packet is then transmitted to the base station. The hierarchical based protocol architecture can be seen on Figure 1.3.

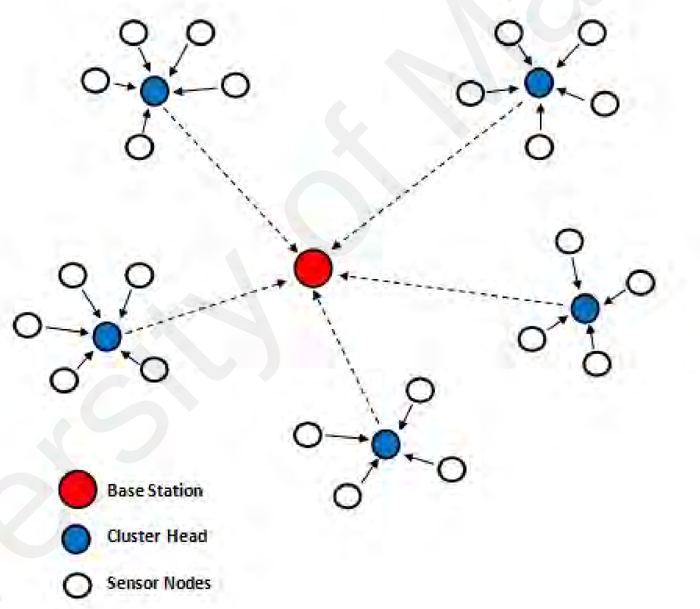


Figure 1.3 Hierarchical Clustering Routing Protocols Model

LEACH is an example of hierarchal routing protocol model. In LEACH, sensor nodes are divided into several clusters where each cluster will select a cluster head that will collect data from the sensor nodes within the cluster and aggregate the data to form a packet. This packet is then delivered to base station for further action. However, the major drawback of LEACH is the random selection of cluster heads of the protocol. This can cause some of the cluster heads to be concentrated in one part of the network area only. This will cause some of the sensor nodes to be very far from its cluster head and therefore have higher energy consumption which will reduce the lifetime of the sensor nodes.

In this research, we propose a protocol called Distance Cluster Head Selection Protocol (DCHSP). DCHSP is a protocol that use distance of the previous cluster heads to select the next cluster head. In this protocol, for each round of the network, the first cluster head is selected randomly from the network. However, the second cluster head will only be select if the distance between it and the first cluster head is equal or bigger than two times of the value of cluster range radius (2CRR). For the third cluster head and so on, cluster head will only be selected if the distance between it and the previous two cluster heads is equal or bigger than 2CRR. By implementing distance selection on the cluster heads, it prevents the cluster heads to be concentrated only in one part of the network area and create a fair distance travel for sensor nodes to its cluster head. This propose protocol not only reduce the energy consumption for each sensor node but also increases its network lifetime.

1.4 Research Aim and Objectives

The aim of this research project is to develop an enhancement protocol that improved energy efficiency of network from existing routing protocols. To achieve the aim, these objectives are defined:

- To study and review on existing routing protocols that focuses on energy efficiency
- To develop enhance routing protocol that can improve its energy efficiency of WSN
- To simulate the enhanced routing protocol using MATLAB and do benchmarking with existing protocols based on metric parameters such as number of alive nodes,

number of dead nodes, average energy value, number of packet nodes delivered and energy consumption of the network

1.5 Research organization

This research consists of five chapters. The first chapter introduce us to wireless sensor network and it implementations. Apart from that, problem statement, motivation and research objectives are also discussed in chapter one. Chapter two presents the taxonomy of wireless sensor network routing protocol and literature review on existing wireless sensor network routing protocol. Chapter three provides the methodology on how the research was conducted. Moreover, the proposed protocol and how it works to improve the energy efficiency is also presented in chapter three. Chapter four discussed about the simulation setup and result. The experiment is carried out using MATLAB which is a programming platform that can be used to analyse data and develop algorithms using C++ programming language. In chapter five, the research conclusion is presented. In addition, the achievements of this research are described and future works are outlined in this chapter.

CHAPTER 2: LITERATURE REVIEW

This chapter reviews the research papers and findings from other researchers that are related to energy efficiency based wireless sensor network routing protocol. The first section provides a brief introduction and classification of routing protocol. Second section explains about the design requirement in creating wireless sensor network. In the third section, other routing protocol proposed by other researchers is discussed and compared with each other. Last but not least is section four where summarization of chapter two is done.

2.1 Classification of Routing Protocol

In wireless sensor network, sensor nodes are scattered around the area and each node will independently senses and computes in the network. These sensor nodes communicate and forward the sense data to base station. However, most of the data from the source nodes cannot reach to its destination because of the transmission range between the source nodes and its destination. Therefore, routing protocol is used to send the data from the source to its destination.

Routing Protocols specifies how nodes communicate with each other. It helps the node to send packet to its destination by providing a route from the source to the destination in an efficient way according to the network needs. These protocols usually focused on energy consumption. The designs of the routing protocol are usually created based on the application scenario and backbone of the networks. The wireless sensor network routing protocols can be classified based on mode of functions, participation style of the sensor nodes and network structure (Navreetindeer Kaur, 2016).The mode of functions can be proactive, reactive or hybrid. In participation style of sensor nodes, it can be categorized as direct, flat or cluster-based protocol. The network structure can be divided into several categories namely data centric, hierarchical, location-based, quality of services (QoS) and multiple paths routing protocol.

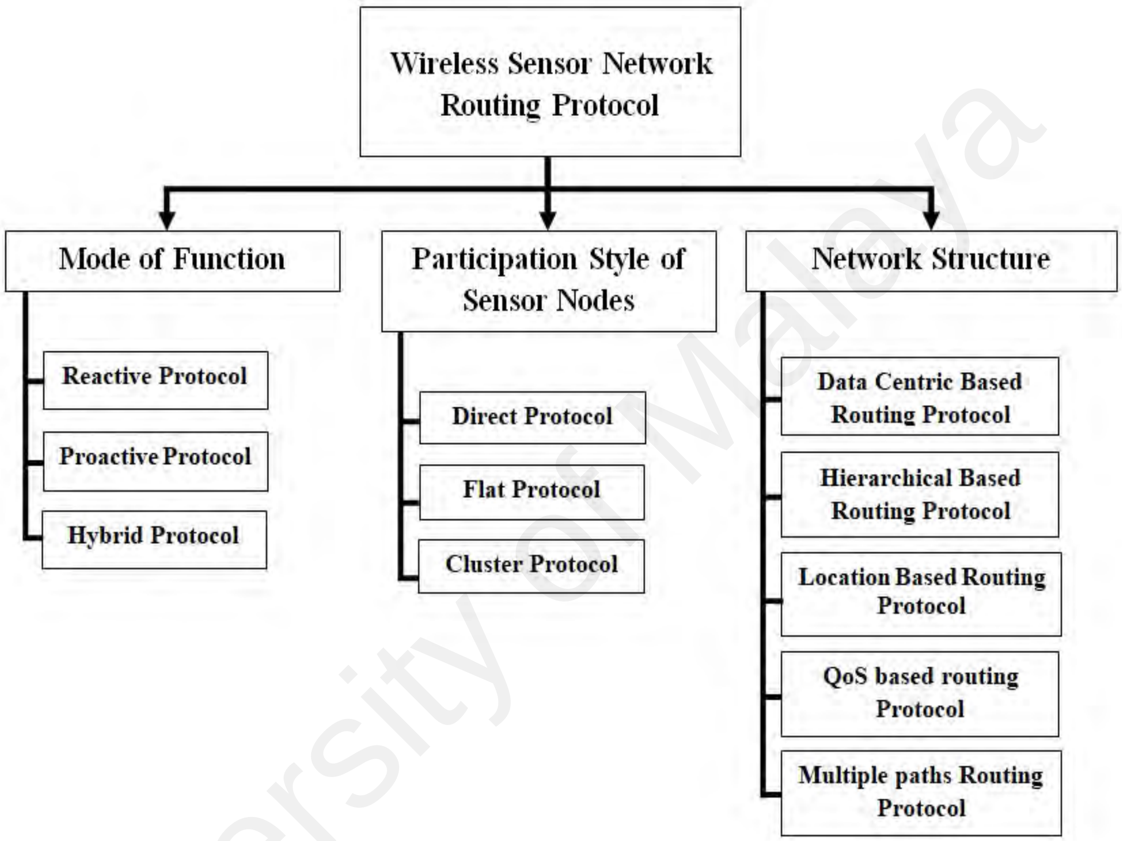


Figure 2.1: Classification of WSN routing protocols.

2.1.1 Mode of Functions

The first classification of wireless sensor network routing protocols is based on mode of functions. Primarily mode of functions can be categorized into three types which is reactive routing protocol, proactive routing protocol and hybrid routing protocol. Each of this protocol has their own advantages and disadvantages.

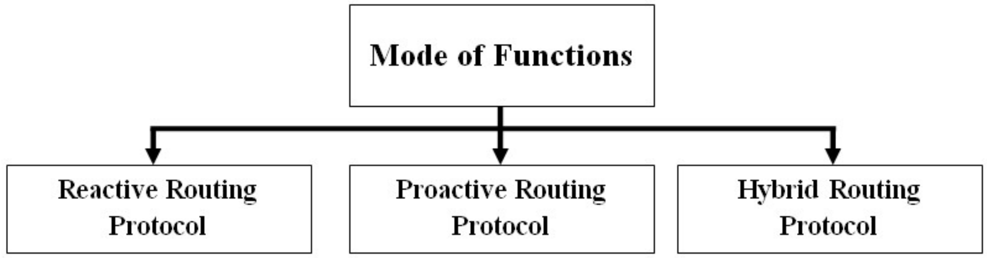


Figure 2.2: Types of mode of functions

Reactive protocol is also known as on demand routing protocol (Bendele et. al, 2018). In reactive routing protocols, routing table is not generated and route discovery is generated whenever it is required. In other words, the routes between the nodes are attained on demand. There are two major components in reactive protocol which are route discovery and route maintenance. In route discovery, source node will consult its route caches for available route from source to destination. If no routes found for the transmission of the data packet from source node to its destination, the source node will initiate a route discovery request through the entire network and wait for reply from the destination node. After the route has been established, it is maintained by the route maintenance until the destination is inaccessible by any path from the source or the route is not desired anymore (Rout & Ambulgekar, 2013). The advantages of using reactive protocol is that the protocol does not require each node to store routes for the entire network since node just need to find the routes for the data packet to reach its destination. In a nutshell, reactive routing protocol reduce the burden of the network because it maintains the route only when it is needed (Kaushik, 2014). However, reactive protocol also has its drawback. Sometimes the process of route discovery may take time and cause a delay in network which increases the latency rate of data transmission (Anwar et. al, 2015).

In proactive protocols, the routing table is generated at every node and the update of routing information of complete network is done periodically (Anwar et. al, 2015). In proactive protocol, it is said that every sensor node in the network will have one or more routes to its destination in its routing table at any given time (Patil, 2012). In proactive protocol, routing information is generally flooded in the whole network whenever the nodes require a path to the destination (Frank & Seun, 2013). All the route information of the path will be collected and put into a table for the nodes. By using this approach, data packet can be sent out to its destination immediately without the delay that is cause by route discovery that can be found in reactive protocols. Latency will be low since the path is already known by the nodes during the sending process of information from the source to its destination (Pandey & Swaroop, 2011). Proactive protocols are better for static node because a lot of energy can be saved compare using reactive protocols which depend on route discovery of the best path for data transmission. However, the management of its routing table management and the needs to keep it update periodically may cause an increase of the overhead of the protocol. Therefore, it is not suitable to use in a large network.

Hybrid routing protocol is the combination of both proactive and reactive protocol. Hybrid combines the advantages from both reactive and proactive protocols (Raheja & Maakar, 2014). It uses the discovery mechanism of reactive protocols and the table maintenance mechanism of proactive protocol. Hybrid protocols have the potential to provide higher scalability than pure reactive and proactive protocols by attempting to minimise the number of rebroadcasting nodes and allow nodes to work together to organised how the routing is to be performed.

2.1.2 Participation Style Protocol

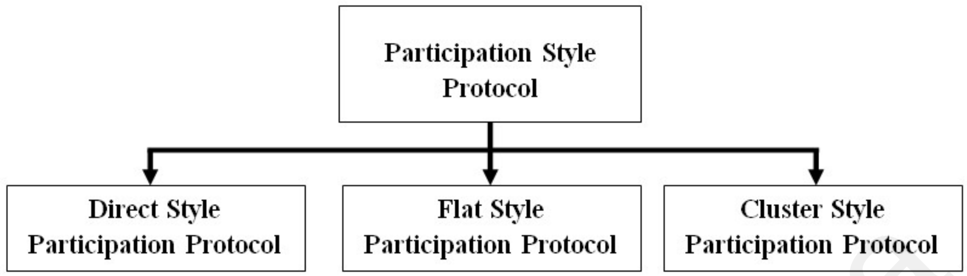


Figure 2.3: Classification of participation style protocols

There are three types of participation style of sensor nodes. These types are known as direct, flat and clustering. Direct participation, any node can send directly to the bases station (Pal et. al, 2010). The advantage of using direct participation style is base station will receive data faster compare to flat and clustering style since no intermediate nodes involved during data transmission. However, the energy of sensor nodes may drain quickly if it is applied in a very large network therefore scalability in this protocol is small very small (Navreetinder Kaur et. al, 2016).

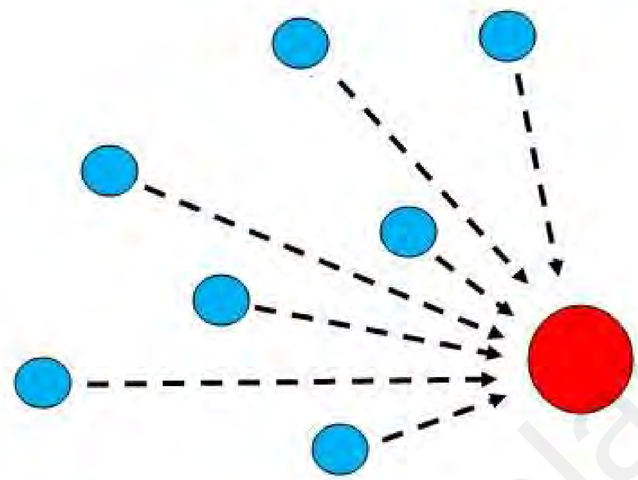


Figure 2.4: Direct style nodes participation protocol

In flat style, a valid route which is shortest path to the base station is first searched and then data is transmitted (Navreetinder Kaur et. al, 2016). Each sensor nodes in flat style participation plays the same role and sensor nodes collaborate to perform the sensing task. (Al-Karaki & Kamal, 2004). In flat participation, sensor nodes will first search a valid route to base station and then forward its data to intermediate nodes through routing. This type of mode reduces the energy consumption of the sensor nodes but time taken for data to reach from the sensor nodes to the base station will be longer especially sensor nodes that is far from base station since more intermediate nodes needed for the data to be transmitted. Sensor nodes that closer to the base station also die faster because of higher workload performed by it compare to sensor nodes that are far from base station. The scalability of flat style participation is medium.

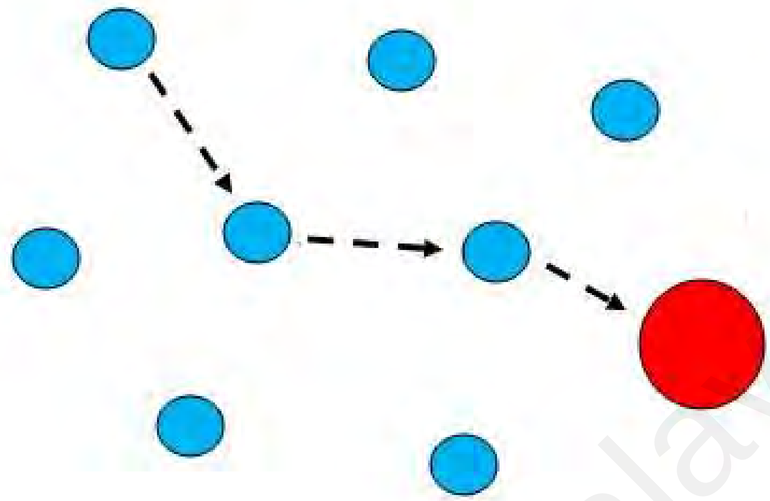


Figure 2.5: Flat style node participation protocol

In clustering type, the nodes are divided into several groups called cluster and each cluster will have a leader that is known as cluster head. Nodes that are not the cluster head will be known as cluster member. Cluster member will send the packets to the cluster head. The cluster head will form data aggregation and send the aggregated data to base station. Other than that, cluster heads from different cluster can communicate which each other to reach the destination node faster which will reduce the number of hops for communication. (Kushal & Citra, 2016). After certain of time, the cluster head will be re-selected by turns, then the networks with change of cluster heads needs to be re-clustered (Ruyan et. al, 2010). In this mode, energy consumption can be reduced as well the time taken for the data to reach the base station since less intermediate nodes involved.

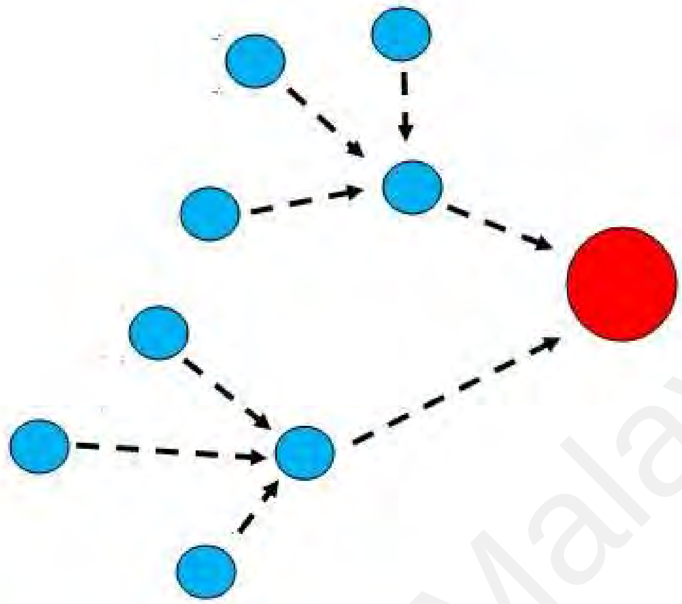


Figure 2.6: Cluster style node participation protocol

2.1.3 Network Structure

The structure of wireless sensor network is different compare to conventional fixed network in many ways. In wireless sensor network structure, there several things need to consider such as energy consumption of the sensor nodes, changes in network topology and network scalability. Wireless sensor network structure can be categorised into few major types depending on its architectural framework. According to Pal et al. (2010), depending on the network structure, routing protocols can be classified as data centric, hierarchal, location based, QoS based and multipath protocol.

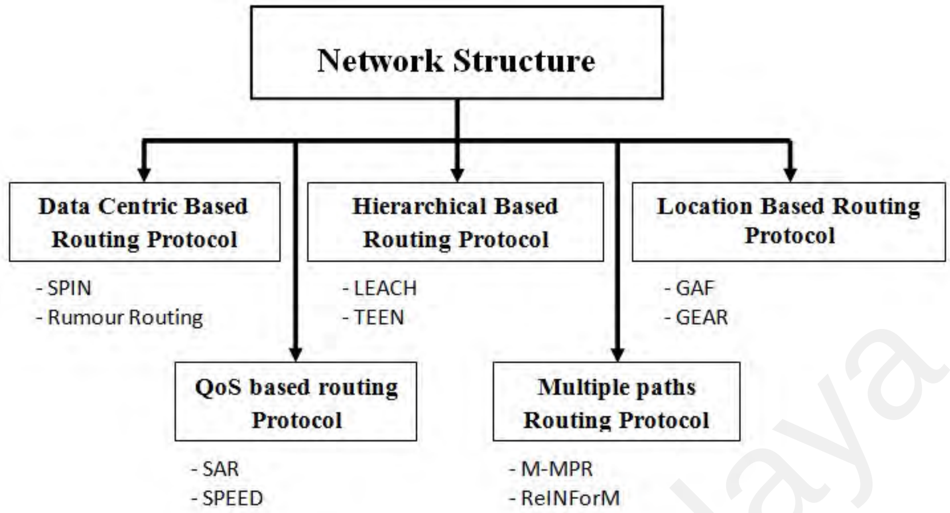


Figure 2.7: Classification of network structure protocols and its examples.

2.1.3.1 Data Centric Based Routing Protocol

Data centric protocols is a protocol that use multiple-hop for data transmission where intermediate sensor nodes are used to deliver the data from source to the destination. In data centric based protocols, when the source sensors send data to the base station, intermediate sensor performed data aggregation from original data that comes from multiple sensor nodes before sending it to the base station (S. K. Singh et al, 2010). In the data centric, base station will send queries to certain region and wait for data from the sensor nodes located in the selected region (Reshma & Kavitha, 2013). The data that has been aggregated is then sent to base station. This process requires less transmission to send data from source nodes to the base station and therefore energy can be saved. Examples of data centric based protocol are Sensor Protocol for Information via Navigation (SPIN) (J. Kulik et. al, 2002) and Rumour Routing.

SPIN improve classic flooding protocols and overcome the problem they may cause such as implosion and overlap. The sensors running with SPIN protocols able to compute the energy consumption required to send and receive data over the network. SPIN enables sensors to negotiate with each other before any data dissemination can occur in order to avoid putting non-useful and redundant information in the network.

In rumour routing, an agent which is a long-lived packet that transverses a network will inform each sensor that it encounters about the event that it has learned during its network transverse. Rumour routing creates the paths leading to each event when the event happens and then later route the queries along the paths (Branginsky & Ersting, 2002). The agent will travel the network for a certain number of hops before it dies. The agent will create an event list during the travel. When the agent encounters a sensor on its path, it will synchronize its event list with the encounter sensors.

2.1.3.2 Hierarchical Based Routing Protocol

The objective of routing protocol in WSN is not only to transfer the sensed data from source node to the destination node but also to provide a way to optimize energy consumption to extend the lifetime of the network (Priyadarshini, 2017). The hierarchal routing is based on clustering is the solution to not only route the sensed data from the source to its destination but also provide optimization of the network to reduces the amount of energy usage and therefore increase the lifetime of the network.

In last few years, many research projects on sensor network have been explored using hierarchical based routing protocol. The aim of hierarchal routing is to manage the consumption of energy in WSN be establishing multi-hop communication in cluster by performing data aggregation and fusion to reduce the number of transmitted packets (Brijbhushan & Anand, 2015). This routing type creates a virtual hierarchy among the nodes of the sensor network.

In general, hierarchal protocol support data collection, network scalability and also decrease data delay to improve the network lifetime (S. Dhivya & N. Jayanthi, 2017). Hierarchical routing protocol acts in two steps. The first step tends to build the hierarchy while the second steps define the rules and strategy for transferring data between nodes (Beydoun & Felea, 2012). In hierarchical based routing protocols, there are two types of nodes present namely high-level nodes and low-level nodes. The high-level nodes take part in processing and data transmission while the low-level nodes are basically used to sense data in interested area. Low Energy Adaptive Clustering Hierarchy (LEACH) and Threshold Sensitive Energy Efficient Network (TEEN) (Manjeshwar & Agrawal, 2001) are some of examples for hierarchical based routing protocols.

LEACH is based on a simple clustering mechanism by which energy can be conserved since cluster heads are selected for data transmission instead of other nodes in network. The local cluster head is selected to serve as the router to the base station. LEACH performs a randomized rotation of the cluster head to enable all nodes in the cluster group to become a cluster head in order not to drain the battery of a single node. The disadvantage of LEACH protocol is that the cluster head selection is unreasonable as all sensor nodes have equal chances to become the cluster head irrespective of their residual energy. If a low residual energy is sensor nodes is selected as the cluster heads, the cluster head will have shorter lifetime and therefore can cause failure to the network. Apart from that, the distribution of cluster heads on LEACH does not consider the distance between sensor nodes which can result in more energy consumption and node failure. To avoid this problem from happening, several routing protocols on improvement of LEACH had been created. These routing protocol will be discussed on section 2.3.

In TEEN, the cluster head broadcast two types of threshold value to all the nodes which are hard threshold and soft threshold. The hard threshold is the minimum possible value of an attribute on which the sensor nodes will be transmitting data to the base station. If the sensed value of the attribute greater than the hard threshold, the data sent to the cluster head. Next, the nodes check if the difference in the current and earlier values is greater than the soft threshold. If it is greater, the new data will be transmitted.

2.1.3.3 Location Based Routing Protocol

In location-based protocols, the location information for nodes are needed before any packets can be forwarded to its destination nodes. This location information needed so that the routing protocols can calculate the distance between two particular sensor nodes. Moreover, calculation between two particular sensor nodes also needed to estimate the energy consumption of the sensor nodes (Lakshmi & Srikanth, 2015). To reduce the energy consumption, sensor nodes then send the packet to its nearest neighbour. Examples of location-based routing protocol are Geographic Adaptive Fidelity (GAF) (Xu et all, 2001) and Geographic and Energy Aware Routing (GEAR).

GAF is an energy-aware routing protocol that primarily being used in MANET. However, it can also be used in wireless sensor network due to its energy saving characteristic. In GAF, sensor nodes are divided into several grid squares and each sensor nodes use its location information which provided by Global Positioning System (GPS) or other location information system. It has three mode of transition which is discovery, active and sleeping. In discovery mode, the sensor nodes exchange discovery message to learn other sensor nodes in the same grid. In active mode, sensor nodes broadcast its discovery messages to inform other sensor nodes about its state. In sleeping mode, sensor nodes turn off its radio for energy conservation. These modes can be tuned depending on the network needs.

GEAR is an energy-efficient routing protocol that proposed a routing query based on its location in the sensor field. GEAR technique uses energy aware and geographically informed neighbour selection heuristics to route a packet towards the target region (Yu et. all, 2001). Similar to GAF, sensor nodes will know its current position by using localization equipment such as GPS. Transmission of data from a sensor node is done according to location and residual energy of its neighbours. Sensor nodes will select the nearest and the highest residual energy of its neighbours to send the packet.

2.1.3.4 QoS Based Routing Protocol

QoS based routing protocol is used not only consider energy consumption but also other metric such as end-to-end delay, reliability and fault tolerance in order to help a better efficiency routing in wireless sensor network. Some examples QoS based routing protocol that find the balance between energy consumption and QoS requirements are Sequential Assignment Routing (SAR) and SPEED (T. He et. all, 2003).

SAR is a table-driven multipath approach that strives for energy efficiency and fault tolerance. Its routing decision depends on three factors which are energy resources, QoS on each path and the priority level of each packet. It creates a tree rooted network at one hop neighbours of the base station to sensors nodes. By creating the trees, multipath from sensor to sink can be formed and one of these paths will be selected for data transmission depending on the energy resources and the QoS on the path.

In SPEED protocol, it requires each node to maintain information about its neighbour and uses geographic forwarding to find paths. It also ensures certain speed of each packet in the network so that application can estimate the end-to-end delay for the packets in by dividing the distance of the sink by the speed of the packet before making the admission decision.

2.1.3.5 Multi-Path Based Routing Protocol

Multipath routing protocol creates multiple paths from the source node to its destination node to create an effective route around failed nodes or invalid links. In a single-path routing protocol, if a links fails, additional control packets have to generate and broadcast to find new route. This extra process not only makes the node consume more energy but also increase the latency for packet delivery. By using multipath routing techniques, these problems can be avoided because there is always a secondary route ready if route failure happen. Examples of multiple path routing protocol are Meshed Multipath Routing (M-MPR) (De et. all, 2003) and Reliable Information Forwarding using Multiple path (ReInForM).

In M-MPR, each packet is sent along to different disjoint routes and the decision of path selection is made by the source on packet-by-packet basis and multiple copies of data are transmitted simultaneously along the multiple disjoint routes from source to destination. M-MPR is set up into three steps which is acquiring neighbour's information, route discovery and route reply. In acquiring neighbours' information, each active node will broadcast its ID, location and residual energy to local neighbours and each node will save their neighbours information in its database. In route discovery, sensor nodes will attempt to create a meshed multipath based on the neighbourhood database and the data sink. Sensor nodes will send the packet according to the paths that being created. The neighbour will do the same step until the packet successfully sent to the data sink. In route reply, after getting the packet from the source node, the data sink will send a route reply message in reverse direction to the source nodes. This message contains the source node ID, source location and Intermediate ID.

In ReInForM, the source nodes use the local knowledge of the network such as hop count to base station and send multiple copies of packet through multiple paths. The network condition is recorded in the packet header as it is forwarded to the next node. The intermediate node then sends the packet based on the stored information. This routing protocol adapts to channel errors and topological changes while maintaining reasonable overhead.

2.2 The Routing Challenges and Design Issues in WSN Protocols

Despite the innumerable application of WSN, designing a routing protocol for WSN is challenging due to several network constraints. It suffers from limitation of several network resources such as energy, bandwidth, central processing unit and storage due to its small size form. The design of routing protocols in WSN is influenced by many challenging factors (Al-Karaki, 2004). These factors must be overcome before efficient communication can be achieved in WSN.

2.2.1 Energy Consumption

Many of the challenges of WSN revolve around the limited energy resources. The size of the sensor nodes limits the size of its battery (Boukerche, 2008). Sensor nodes are mostly design in a small form factor which make them to have very limited energy capacity. The process of computation and transmission of data in sensor will consume a lot of energy (Kumar et. al, 2013). Moreover, sensor usually deployed in hazardous condition which makes it difficult for battery replacement therefore it is required to develop a protocol that can efficiently use the energy from the battery (G. Singh & Arora, 2013). Therefore, routing protocol that is designed for the wireless sensor network should be energy efficient and can prolong the network lifetime while making sure the overall performance of the network is not being compromised.

2.2.2 Node Deployment

Node deployment in WSN can be implemented in two ways either manual deployment or randomized deployment (Singh, H. & Singh, D., 2016). In manual deployment, sensor nodes are manually place in specific area and data is routed through a predetermined path. On the other hand, in random deployment, sensor nodes are scattered randomly in the monitored area. For random deployment, the sensor nodes should be able to self-configured without intervention from human (Gupta & Sikka, 2015). If the distribution of sensor nodes is not uniform, an optimal cluster is needed to allow connectivity and enable energy efficient network operation. Apart from that, sensor nodes in WSN must be able to detect its neighbour sensor nodes and make sure every sensor node has the ability to communicate with its neighbour and has a pathway for it to send data to the base station.

2.2.3 Data Aggregation

Data aggregation can be described as a routing technique that combine data from many sensor nodes into meaningful information and eliminate any replication (Deepa et. al, 2015). Since sensor nodes are deployed randomly in the network, a scenario where multiple sensor nodes are deployed in a same area may occur. Therefore, the sensor nodes may generate a similar and redundant data. One way to minimize this challenge is by developing a routing protocol that can aggregate data from multiple sensor nodes so that number of transmissions can be reduce and improve the energy efficiency.

2.2.4 Scalability

Another design issue that need to consider in developing a routing protocol is the scalability. A system is considered to be scalable if the performance of the system improves when hardware is added to the system, proportionally to the capacity added (Indu & Dixit, 2014). In other words, if new sensor nodes are added to the network, routing protocol should be able to create network path for the new sensor nodes with the existing network. A WSN consist of hundreds to thousands of sensor nodes therefore the routing protocol must be able to handle all the functionalities of the sensor nodes so that the lifetime of the network can be stable (Bhattacharyya et. al, 2010).

2.2.5 Quality of Services

In some scenario, data from the sensor nodes should be delivered within a certain time of period or it will become useless (K. Kaur et al, 2014). Therefore, latency for data delivery also should be considered in designing a routing protocol. Apart from that, the design of routing protocols should satisfy certain QoS parameters such as data latency, energy, packet loss, bandwidth and error rate (Deepa et. al, 2015). However, a protocol the focuses on energy conservation, energy efficiency which is directly related to network lifetime is considered to be more important than the quality of services of the routing protocols. As the energy of the sensor nodes decreases, the network may need to reduce the quality of services and focus more into energy conservation to lengthen the network lifetime.

2.3 Review on Existing Energy Efficiency Routing Protocols

The utilization of wireless sensor network gives a lot of benefits in several growing application. However, the use of wireless sensor network is very limited due to energy constraint from the sensor nodes. The energy usage from the sensor nodes occurs during environment sensing, wireless communication and data processing. Therefore, most routing protocols that are being designed are mainly aim to for energy efficiency of the sensor nodes. Several research studies have been done where energy efficiency is the main purposed in designing the routing protocols.

2.3.1 Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH is a dynamic, self-organizing protocol that chooses cluster heads in rotation manner randomly (Heinzelman et al, 2000). In LEACH protocol, each sensor node has equal chances to become a cluster head. There are two level involve in LEACH protocol. In the first level, sensor nodes are grouped together to form cluster while in second level the information detected by the sensors is forwarded to destination by cluster head (Mishra, 2017). If the cluster head dies, all the sensor nodes in that cluster will loss communication in the network.

There are two phases in LEACH protocol namely set-up phase and steady state phase. In set-up phase, each sensor nodes volunteers itself to become a cluster head by choosing a value between 0 and 1 randomly. Sensor node is picked as cluster head if the random value is lower than the value of the threshold, T(n). The threshold value can be obtained by:

$$T(n) = \begin{cases} \dfrac{P}{1 - P\,(r \bmod 1/p)} & \text{if} \quad n \in G \\ 0 & \text{if} \quad n \notin G \end{cases}$$

Equation 1

Where ***P*** is the estimated probability of optimal cluster head for the network for a particular round. ***G*** is defined as the number of nodes that not yet elected as cluster heads while ***r*** determines the ongoing round. After the cluster head selection is done, each cluster head advertises their message to all non-cluster head nodes. These nodes then decide which cluster head will they join to and thus cluster are formed. In steady-state phase, data transmission is taken place. In this phase, each sensor node sends their data to their respective cluster head according to the time schedule given to them using TDMA scheme. The cluster head aggregate the data obtained from its member nodes and forward it to remote base station.

Hierarchical based routing in LEACH increase the energy efficiency of wireless sensor network by creating several numbers of clusters. Each cluster selects a cluster head that will acts as a medium for data transmission from sensor nodes to base station. These cluster heads will aggregate the data from the sensor nodes which reduce the traffic in the entire network therefore reducing the energy consumption of the network (Tandel, 2016). The Cluster Heads aggregates the whole data which lead to reduce the traffic in the entire network. However, due to randomization of cluster head selection, cluster heads that are selected may have insufficient amount of energy which can cause it to die before the end of its round. When the cluster head die, cluster become useless and sensor nodes cannot deliver the data to base station.

2.3.2 Stable Election Protocol (SEP)

Stable Election Protocol has been proposed by Georgios Smaragdakis, Ibrahim Matta and Azer Bestavros in 2004. It works with heterogeneous network where heterogeneous network is more similar to real life network compare to homogenous network that is used in other routing protocol such LEACH. A heterogeneous network can be defined as a network that comprised of sensor nodes with different initial energy value while homogenous network consists of sensor nodes with initial energy value.

SEP is a protocol for two-level heterogeneous network. The aim of SEP is to maintain the constraint of well- balance energy consumption by assuming that each node in the network has different value of energy (Siddiq Iqbal et al, 2014). Therefore, the network has two types of sensor nodes namely advanced nodes and normal nodes. Advanced nodes have an amount of more energy compare to the normal nodes. In order to increase network lifetime, SEP attempts to maintain the constraint of well balance energy consumption. Therefore, advanced nodes have to become the cluster head more often than the normal nodes. To make advanced nodes to be the selected as the cluster head, a new epoch is created. The new epoch must be equal to:

$$\textit{Epoch for advanced nodes} = 1/P_{opt} * (1 + \alpha * m)$$

Equation 2

Where P_{opt} is the percentage of optimal cluster head, α is the energy factor between advanced nodes and normal nodes and m is the percentage of advanced nodes.

SEP improves cluster heads selection in LEACH by assigning weight probability in each sensor node. It decreases the epoch interval for advanced nodes therefore increases the probability for advanced nodes to be selected as cluster heads. However, the cluster heads selection between normal nodes and advanced nodes are not dynamic and can cause the cluster heads located close to each other. This creates a problem where some sensor nodes will be located far away from its cluster head and need to use more energy to deliver its data to its cluster head.

2.3.3 Enhanced Energy Efficient LEACH (EEE - LEACH)

EEE-LEACH (Bharti et al, 2015) is a protocol where the sensor nodes transmit their data to the cluster heads by using shortest distance algorithm to improve the network lifetime. There are five stages in EEE-LEACH namely cluster head selection, shortest path algorithm, master head selection, co-operative master head selection and data transmission.

During the cluster head selection, the residual energy of each sensor nodes is being considered. In order for the sensor node to selected as the cluster head, it must have the highest residual energy in its cluster and has the minimum distance from the base station. After the cluster heads is selected, an algorithm is run to find the shortest route for data transmission. In this algorithm, the sensor node that has the largest distance from the cluster heads to be the first sensor node of the path. The second sensor node of the path is then selected based on the minimum distance to the first sensor node. This process will repeat until it reaches the cluster head nodes which is the last node in the path.

Next, the master head and co-operative master head is selected in the protocol. The master head and co-operative master head is selected based form the distance of the cluster heads and the amount of the residual energy of the cluster heads. Cluster head with shortest distance from the base station and has the residual energy is selected as the master head while the second shortest distance from the base station and second highest energy value will become the co-operative master heads.

The last stage is the data transmission where the data from the sensor nodes is transmitted to the cluster heads based on the shortest path algorithm. The cluster head then aggregates the data and transmit the data to master head. The master head transmits the data to the co-operative master heads and both of them send the aggregated data to the base station.

In this protocol, the energy value and the minimum distance of the cluster heads, master head and co-operative master is being considered during selection. This ensure the cluster heads, master head and co-operative master head has the sufficient amount of energy to perform their task. However, since the shortest path algorithm involved intermediate nodes for the data to be transmitted, the intermediate sensor nodes will also lose energy during the transmission process.

2.3.4 Distance Adaptive Threshold Sensitive Energy Efficient Sensor Network (DAPTEEN)

Distance Adaptive Threshold Sensitive Energy Efficient Sensor Network (DAPTEEN) was proposed by Anjali, A. Garg and Suhaili in 2016. This protocol based from Threshold-sensitive Energy Efficient Sensor Network (TEEN) and Adaptive Periodic Threshold-sensitive Energy Efficient Sensor Network (APTEEN). In TEEN, protocol uses two types of threshold value which are called hard threshold and soft threshold. In TEEN the sensor nodes sense the environment continuously. If the data value of the sensed environment is greater than the hard threshold, the data value is check by the soft threshold if value is similar to the previous data value. If the current data value is greater in soft threshold, the data is then sent to the base station. In other words, hard threshold reduces the number of transmissions by allowing the sensor nodes to transmit only when the sensed attribute is in the range of interest while soft threshold reduces further the number of transmissions by eliminating transmission that already occurred.

APTEEN is a hybrid network where once the cluster heads are selected, the cluster head will broadcast a set of parameters which the user interested about. It also broadcast the parameter consist hard threshold and soft threshold where these thresholds are similar to the threshold in TEEN. It can also able to broadcast the count time (T_c) which is the maximum time period between two successive reports sent by node. Moreover, APTEEN has the ability to control the energy consumption by the count time and the threshold values.

DAPTEEN has the similar characteristics of TEEN and APTEEN with the additional ability of reducing data redundancy by using adaptiveness measure based on the distance between nodes in a cluster. Since sensor nodes that are close together usually sensed the same data, only one of those sensor nodes will be selected to transmit its data. This can be done by evaluating the distance between two sensor nodes before the sensor nodes are able to send their data. If the distance is close between the sensor nodes, only one sensor node will send the data. By this way, number of network transmission can be reduced which also increases the energy efficiency of the network. DAPTEEN also has the same drawbacks in TEEN and APTEEN where complexity in cluster construction affects the network latency of the protocol.

2.3.5 Energy efficient routing using Particle Swarm Optimization (PSO) and Vice Low Energy Adaptive Cluster Head (V-LEACH) Protocol

Energy efficient routing using Particle Swarm Optimization (PSO) and Vice Low Energy Adaptive Cluster Head (V-LEACH) Protocol (A. Singh et al, 2016) combines the PSO technique with V-LEACH routing protocol. In this approach, cluster head will be selected based on the energy value of each sensor node inside the cluster. Since cluster head use a lot of energy compare to normal sensor nodes, cluster head may die faster than the normal sensor nodes. Once the cluster head is dead, the cluster will become useless. In order to avoid the cluster from becoming useless, a vice cluster head is introduced where it will replace the cluster head and perform the task of cluster head if the cluster die during its round.

The criteria to become the vice cluster head is it must have lower energy value from the actual cluster head but higher energy value from other sensor nodes within the cluster. The disadvantages of using this is it need to know the energy level of each sensor nodes in each round before cluster heads selection can be performed therefore increase the network latency. Besides that, there is no solution after the vice cluster head die during its round and therefore the cluster will die if the vice cluster head is dead.

2.3.6 Modified-LEACH (M-LEACH)

Modified LEACH or also known as M-LEACH follows same as the LEACH in forming the cluster and cluster heads. However, the cluster heads are elected based on two specified parameters. The specified parameter are Residual Energy of the sensor node and the distance between the sensor node and the base station.

The residual energy is the first parameter being consider in selecting the cluster heads. This is because the performance of the network is mainly retained in the energy of the sensor node. The sensor node consume energy in sensing the data and forward it to the cluster head. Cluster heads then forward the data to its base station. Cluster heads must have high energy since it need to aggregate the data before forward the data to the base station where as the sensor nodes only need to forward the sensed data to the cluster heads only.

The second parameter that is being consider in selecting the cluster heads is the distance between the sensor nodes and the base station. This parameter also put into consideration because it will affect the energy consumption of the sensor nodes. Shorter distance from the base station means that the sensor nodes will require less energy to forward the data to its base station. Therefore, less distance between the cluster head and base station will improve the performance the network. The disadvantage of this protocol is it does not consider the distance between the cluster heads. This can cause the cluster head to form in a very short distance from each other and cause some sensor nodes to use more energy to transmit the sensed data to its cluster heads.

2.3.7 LEACH-Genetic Algorithm (LEACH-GA)

LEACH-Genetic Algorithm is genetic algorithm-based variant of LEACH the determine the optimal value number of cluster heads for various base station placements. This GA-based optimization procedure will be performed only once which is before the set-up of the first round.

During the beginning of the preparation phase, each sensor nodes will be determined whether or not it should be a candidate cluster head by using a cluster head selection procedure. Each sensor node will select random number either 0 or 1. Each sensor nodes will send its ID, location information and whether or not it is a CCH to base station. After base station had receives message sent by all sensor nodes, it will perform GA operation to determined the optimal probability of cluster heads to minimize the total of amount energy consumption in each round.

The optimal probability of cluster heads is determined by the GA using the searching solution space through evolutionary optimization process that incorporate the probabilistic transition and non-deterministic rules. Once the optimal probability of cluster heads is found, the base station broadcast the value to all sensor nodes. After that, only the set up- and steady-phases begin. The disadvantage of this routing protocol is that the procedures of set-up and steady-state phase are the same as in LEACH. This means that sensor nodes with low energy can still be selected as the cluster heads in the network and distance between the cluster heads are not consider.

2.3.8 Energy Efficient Based Hybrid Clustering (EBBHC)

Energy Efficient Based Hybrid clustering (EEBHC) Algorithm (Perumal et. al, 2018) is a protocol that distributed in hierarchical clustering communication from sensor nodes to the base station. It used the hierarchical clustering structure in order to achieve energy efficiency by implementing clustering communication.

The hybrid architecture divided into equal and unequal cluster. The hybrid clustering method is done by two ways exchanging method. The first exchanging method is done when the sensor node density is higher where it can cause data collision during data transmission. This situation can cause packet loses and energy wastage. Therefore, a cluster member with high energy is chosen as the cluster head. If there are no cluster member with high energy value, sensor nodes from neighbouring cluster is chosen as the cluster and send the data to the base station.

The second exchanging method is done when the sensor node density is detected to be low, the cluster heads transmits the data directly to the base station. This method avoids any unnecessary packet losses. However, this protocol needs to evaluate the density of sensor nodes on every turn and this can cause more time needed for data transmission from the source to its destination.

Table 2.1: Comparison table on Energy Efficiency Routing Protocol

Protocol	Mode of Function	Participation Style	Network Structure	Advantage	Limitation
LEACH (Heinzelman et al, 2000)	Proactive protocol	Cluster	Hierarchical based protocol	Formation of cluster heads to reduce direct transmission that used more energy	Cluster heads are selected randomly
SEP (Smaragdakis et al, 2004)	Proactive protocol	Cluster	Hierarchical based protocol	Advanced nodes more likely to be selected as cluster heads	Cluster heads selection between two types sensor nodes are not dynamic
EEE-LEACH (Bharti et al, 2015)	Proactive protocol	Cluster	Hierarchical based protocol	Cluster heads, master head and co-operative master head is select based on highest residual energy and shortest distance from base station	The intermediate sensor nodes will lose more energy during data transmission to cluster heads.
DAPTEEN (Anjali et. al, 2016)	Hybrid Protocol	Cluster	Hierarchical based protocol	If sensor nodes are near to each other, only one node will be selected	Complex clustering construction

				for data transmission	and threshold function
Particle Swarm Optimization (PSO) and Vice - LEACH Protocol (A. Singh et al, 2016)	Proactive protocol	Cluster	Hierarchical based protocol	Cluster heads selection is based on residual energy of sensor nodes Vice cluster heads back up the cluster if actual cluster head dies during its round.	Need global knowledge of energy level of each round to performed cluster heads selection No solution if the vice cluster die
M-LEACH (Krishnakumar, 2017)	Proactive Protocol	Cluster	Hierarchical based protocol	Cluster heads are selected based on its residual energy and the distances between the sensor nodes and the base station	Distance between cluster heads is not consider when selecting the cluster heads
LEACH-GA (Sivakumar, 2018)	Proactive Protocol	Cluster	Hierarchical based protocol	Cluster heads are selected based on the optimal number of the cluster head	Distance between cluster heads is not consider when selecting the cluster heads
EEBHC (Perumal et. al, 2018)	Hybrid Protocol	Cluster	Hierarchical based protocol	Two ways method of data transmission based on the density of the sensor nodes	Needs to evaluate the density of sensor nodes on every turn which cause more time needed for data transmission

2.4 Summary

This chapter has presented the taxonomy of wireless sensor network routing protocol. Routing protocol can be classified based on mode of functions, participation style of the sensor nodes and network structure. In mode functions, the protocol can be either proactive reactive or hybrid protocol. In participation style of sensor nodes, the way for sensor nodes to participated in network can be categorize into three types namely flat style, cluster style and direct style. Network structure described the structural architecture of the network such as direct path, hierarchical based, location based, QoS based and multi-path-based protocol. This chapter also discussed the design requirements of wireless sensor network. Energy capacity, node deployment, data aggregation and scalability are few types of requirements needed to be addressed in creating a wireless sensor network routing protocol. Study on existing routing protocol that focussed on energy efficiency is also been outlined. Each protocol as its own approach on how to increase the energy efficiency in wireless sensor network protocol. The characteristics, advantages and limitation are then compared in table 2.1.

CHAPTER 3: RESEARCH METHODOLOGY

In this chapter, research methodology applied in this research was discussed. This research methodology comprised of three phases. In phase one, the taxonomy and challenges of wireless sensor network routing protocol is review and discussed as well as study of existing routing protocols that focuses on energy efficiency are reviewed and analysed. Comparison between the existing routing protocols is discussed. Phase two involves in design and development of the proposed protocol which is Distance Cluster Head Selection Protocol (DCHSP) which is an improvement of LEACH protocol. Lastly, phase three presents the verification and validation of the proposed protocol where its performance is evaluated against existing routing protocol.

3.1 Problem Analysis and Literature Review

In phase one, the features and challenges of wireless sensor network routing protocol is studied. Wireless sensor network is comprised of hundreds or thousands of sensor nodes that randomly deployed in a monitored area. Wireless sensor network can be implemented in various field such environmental monitoring, military, health and home network system. The ability of it to be used in various type of fields is due to the sensor nodes small size formed and its ability to be deployed in various type of area. One of the challenges faces by wireless sensor network is the energy constraint of the sensor nodes due to its small size formed. Since some sensor nodes are scattered randomly in an unintended area or inaccessible hostile region such as beneath the ocean or in volcanic mountain area, battery replacement cannot be conducted.

Next, the taxonomy of wireless sensor network routing protocol is reviewed. The taxonomy of the routing protocol can be divided into three namely mode of function, participation style of sensor nodes and the network structures. In mode of function, the routing protocol can be classified to either reactive, proactive or hybrid. In participation of sensor nodes indicates how the sensor nodes participate in the network either in direct, flat or cluster style participation. Lastly the network structure is studied to differentiate the structure type of the networks either as data centric, hierarchical, location based, QoS based or multi-path-based network structure. Moreover, design requirement of wireless sensor network routing protocol such as its energy capacity, data aggregation, sensor nodes deployment and scalability are also being discussed

Apart from that, several existing wireless sensor network protocols are reviewed and their features and advantages together with their drawbacks are outlined. Theses routing protocols are created to improve the energy efficiency of the network therefore increases the lifetime of the network. Each of the routing protocols have their own way to improve the energy efficiency of the network such as creating an algorithm for cluster head selection, using threshold value for transmission of data and implementation of mobile nodes as a medium for data transmission. These routing protocols also have their drawbacks such as random selection of cluster head, complex clustering construction and threshold function and high latency in data transmission. However, the distances between the cluster heads are not being considered as the solution for energy efficiency in the network. Therefore, a new solution of WSN routing that based on LEACH is created where the distances between cluster heads are being consider before electing a cluster head. The summary of phase one of the research methodology can be seen on figure 3.1.

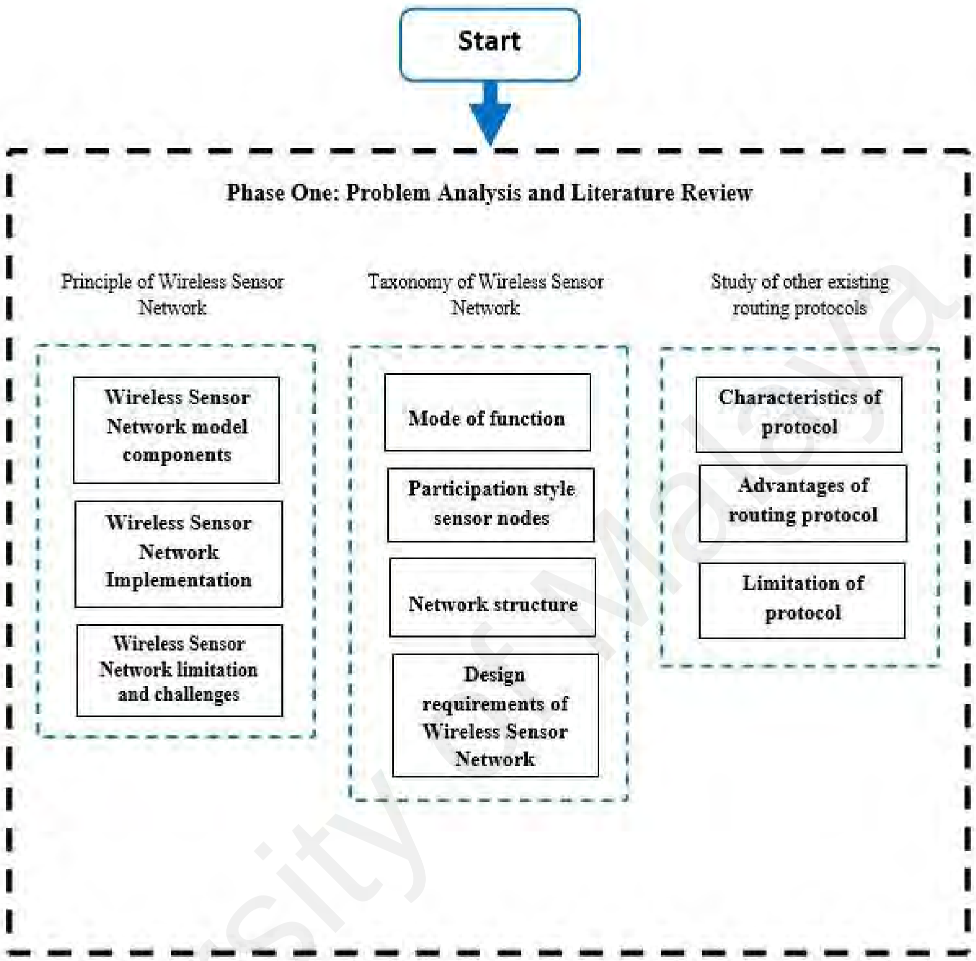


Figure 3.1: Phase one of research methodology

3.2 Design Development

Distance Cluster Head Selection Protocol (DCHSP) are designed and developed in phase two. The design and development are conducted using MATLAB simulation tools. DCHSP is an enhancement of LEACH protocol where it eliminates the randomization of cluster heads in LEACH protocol and replace it with distance-based cluster heads selection. The system model of DCHSP can be divided into network model and energy model. The summary of phase two of the research method can be found in figure 3.5.

3.2.1 Network Model

In developing the protocol, the network model provides operating environment that consists of *N* sensor nodes and a base station. These sensor nodes are deployed randomly in an L x W area with the base station located at centre of the network area. Sensor nodes will sense the environment and send the sensed data to the base station periodically. The base station is responsible for receiving the data from the sensor nodes and presenting the end-user a description of the environment that the sensor nodes are sensing.

In this network, each sensor node has similar capabilities of sensing, processing and communication. Apart from that, these sensors nodes may have different initial energy and have energy constrained. The position of the sensor nodes and base station are fixed which means the sensor nodes and base station are immobile. Despite the energy constrain, all the sensor nodes have enough energy to communicate directly with any other nodes including the base station. The sensor nodes also have enough energy to support different protocols and signal processing tasks. Last but not least, the sensor nodes are left unattended after deployment which means battery recharge is not possible.

3.2.2 Energy Model

For energy calculation, first order radio module is employed as the radio energy module to measure the energy dissipation (F. A. Aderohunmu et al, 2011). There are three main modules in radio module (Liaqat et. al, 2016). These main modules are called as the transmitter, power amplifier and receiver. The transmitter dissipates energy in order for the transmitter circuitry to run while the power amplifier dissipate energy for data transmission and the receiver dissipates energy in order to run receiver circuitry for receiving data.

There are two propagation models which are free space propagation model and two –ray ground propagation model. In free space propagation model, there is a direct path between the transmitter and the receiver. On the other hand, the two-ray propagation model means that the propagation between the transmitter and receiver is not a direct path and electromagnetic wave will bounce off the ground and arrive at the receiver from different paths and different time. In the free space propagation model, the loss of transmitting power can be modelled as inversely proportional to d^2, where d is the distance between transmitter and the receiver. In the two-ray ground propagation l model, the loss of transmitting power can be modelled as inversely proportional to d^4. The energy dissipation for transmitting an l bit message from transmitter to the receiver at distance d is defined as:

$$E_{Tx}(l,d) = \begin{cases} lE_{elec} + l\,\epsilon_{fs} d^2, & d < do; \\ lE_{elec} + l\,\epsilon_{tg} d^4, & d >= do; \end{cases}$$

Equation 3

Where E_{Tx} denoted as the energy dissipated in the transmitter of the source node while E_{elec} is the per bit energy dissipation for running the transceiver circuitry. The amplifier for free space propagation is ϵ_{fs} while the amplifier parameter for two-ray ground propagation model is ϵ_{tg}. The cross-over distance, ***do*** can be obtained from:

$$do = \sqrt{\frac{\in fs}{\in tg}}$$

Equation 4

Based on equation 3, if the distance between transmitter and the receiver is smaller than the crossover distance, the free space propagation model is employed. Otherwise, the two-ray propagation model is employed to measure energy dissipation. For energy required to receive an l bits of message, it can be obtained from:

$$E_{rx}(l) = lE_{elec}$$

Equation 5

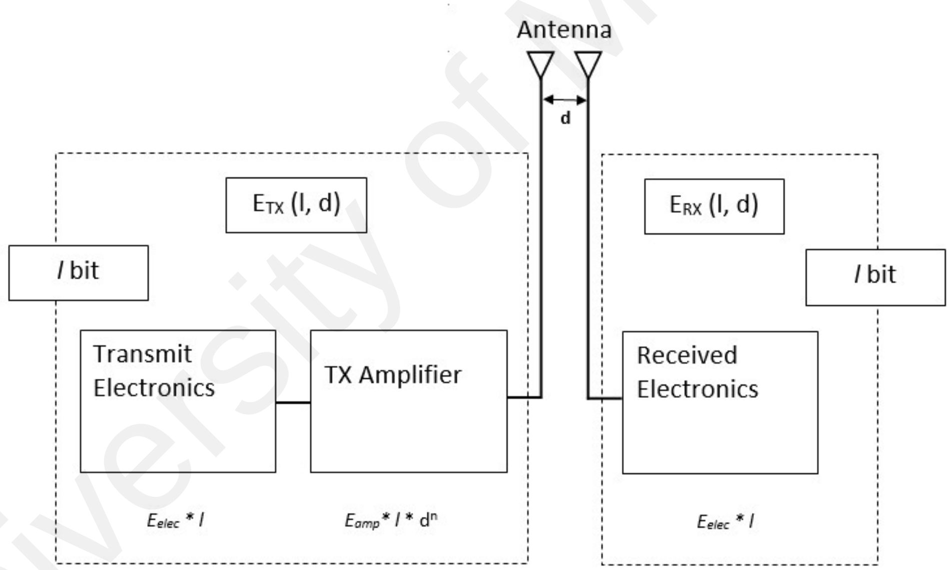


Figure 3.2: Radio Energy Module

3.2.3 Propose Routing Protocol

In this research, an enhancement of routing protocol based from LEACH know as Distance Cluster Head Selection Protocol (DCHSP) is proposed. One of the problems that occur in LEACH is the randomization of cluster heads selection where cluster heads can die early if it does not have sufficient amount of energy. Another problem caused by randomization of cluster heads is the formation of multiples cluster heads that focused only in one area of network. There are latest few works based on LEACH such as LEACH-GA and EBBHC had been done but they do not consider the distance between the cluster heads as a solution for energy efficient routing. This type of scenario caused some sensor nodes to have longer travel distance to the selected cluster head. Therefore, more energy is consumed for that sensor node to transmit data to its cluster head. DCHSP is a protocol that use the distance of several cluster heads to determine the next cluster head on network. This type of cluster head selection will make sure that the cluster heads formation that focus only in one area of network can be minimized. It operates for several rounds and each round consists of two phases. These two phases are setup phase and steady state phase. In setup phase, cluster head selection is performed while data transmission between nodes is performed in steady state phase.

In setup phase, the first cluster heads round is selected randomly in each round. For every sensor node in the network, *r* generates a random value between 1 and 0 for each node. If the value is that being generated by *r* is less than the threshold value, *T(n)* , the node will be selected as the cluster head node. Threshold value, *T(n),* considers the probability of each node to be a cluster head for the current round. Threshold value can be obtained from:

$$T(n) = \begin{cases} p/(1 - p\,(r \bmod 1/p)) & n \in G \\ 0 & n \in G \end{cases}$$

Equation 6

Where $\boldsymbol{p}$ is the denoted as the probability of cluster head and $\boldsymbol{G}$ is the set of nodes the never chosen as cluster head nodes before ***1/p*** round. After the first cluster head has been selected a proposed cluster head is selected randomly from the network. In order for the propose cluster head to become the second cluster head in the network, it need to determined its distance from the first cluster head. The distance is then compared with 2CRR where CRR is defined as the cluster radius range. CRR can be obtained from:

$$\boldsymbol{CRR = \sqrt{(L * \ W)/((N * p) * \pi)}}$$

Equation 7

Where $\boldsymbol{L}$ and $\boldsymbol{W}$ are the length and width of the network area respectively while $\boldsymbol{N}$ is number of nodes in the network. $\boldsymbol{p}$ is the probability of cluster heads. If the distance between the first cluster head and the propose cluster head is larger than **2CRR**, the propose cluster head will become the next cluster head. However, if the distance between the first cluster head and propose cluster head is smaller than **2CRR**, the propose cluster head will become normal nodes and next proposed cluster head is selected randomly from the network.

For the selection of third cluster head and so on, a propose cluster head is randomly selected from the network. In order for the propose cluster head to become a cluster head, the distance between the propose cluster head and the two previous cluster heads need to be considered. In other words, there are two distances need to be measured which are distance between propose cluster head and cluster head(*i*) and distance between propose cluster head and cluster head(*i-1*). The proposed cluster head will only become a cluster head if the both the distance is larger than 2CRR. If both distances are smaller or only one is larger than 2CRR, the propose cluster head will become normal node again and another node will be selected as propose cluster head. This step can be found in figure 3.5 where the yellow shaded area is the improvement of the cluster heads selection based from LEACH.

The cluster head selection in DCHSP enable for the cluster heads to be widely spread across the network area. This will make sure that the data from the sensor nodes do not need to travel far to reach its cluster head. This will reduce the energy needed for transmission of data to cluster head and therefore increase the longevity of the network.

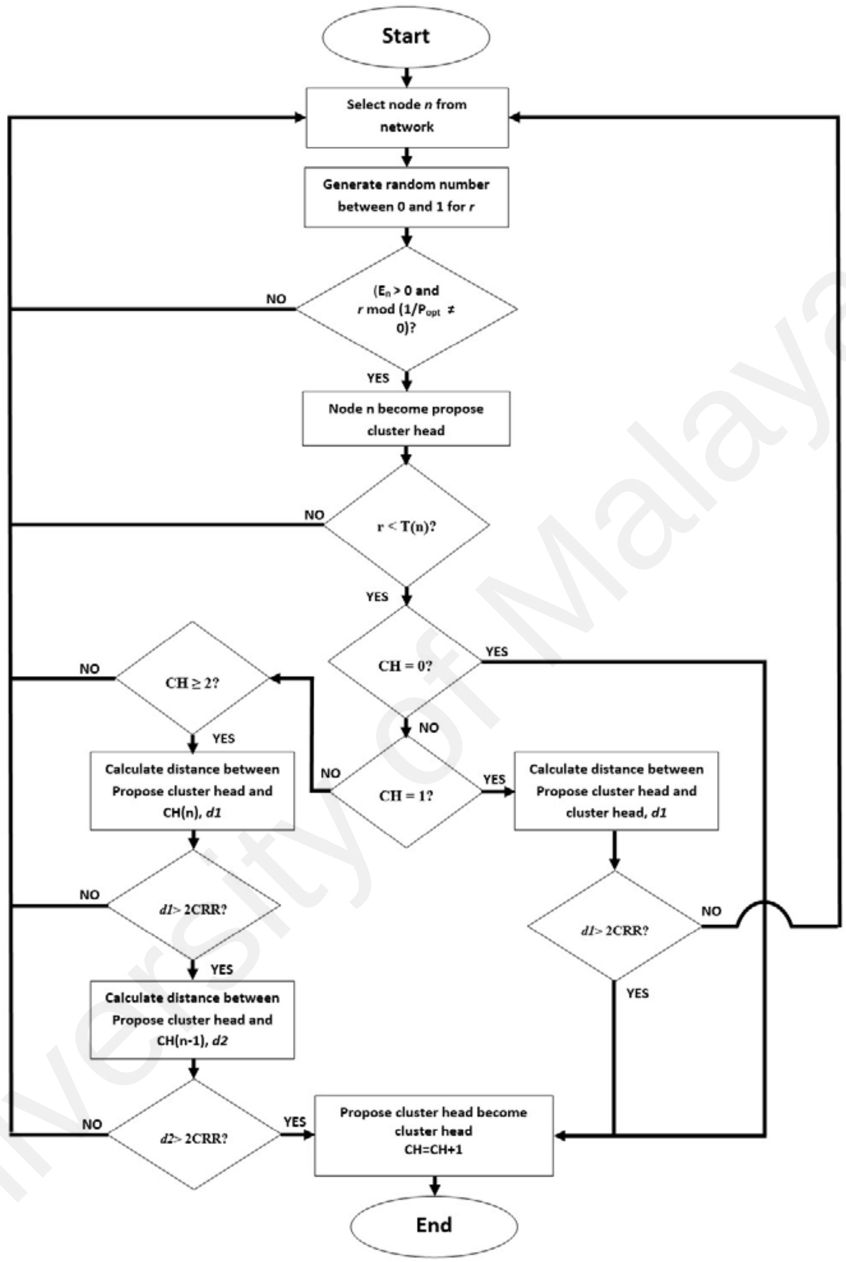


Figure 3.3: Flowchart for CHs selection in DCHSP

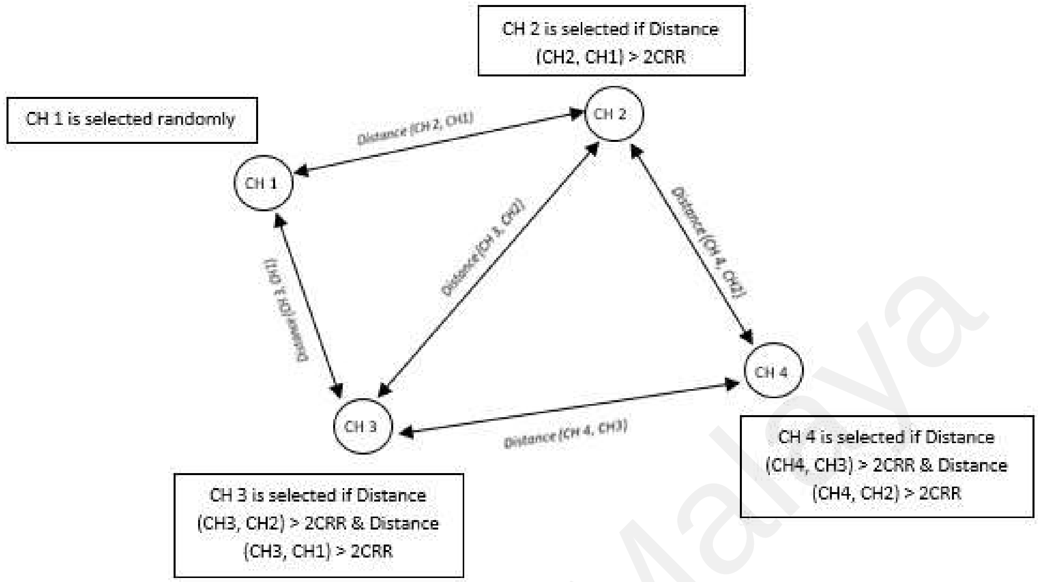


Figure 3.4 : CHs architecture in DCHSP

In steady state phase, cluster head broadcast an advertisement message, with the node 's ID and a header using a non-persistent carrier-sense multiple access (CSMA) MAC protocol to make the elimination of collision to the entire sensor field. The message will be broadcast to reach all of the sensor nodes in the network area. Non-cluster head sensor nodes then will decide to join cluster head that has the strongest received signal. Join-request containing their ID will be send to the closest cluster head using CSMA.

The cluster head will create a time-division multiple access (TDMA) schedule based on all the join-request messages received within the cluster. The TDMA contain a unique spreading code which will be transmitted to the cluster members at the beginning of steady state phase. All sensor nodes in the cluster then will transmit their data packet to their cluster head in the pre-specified TDMA time slot.

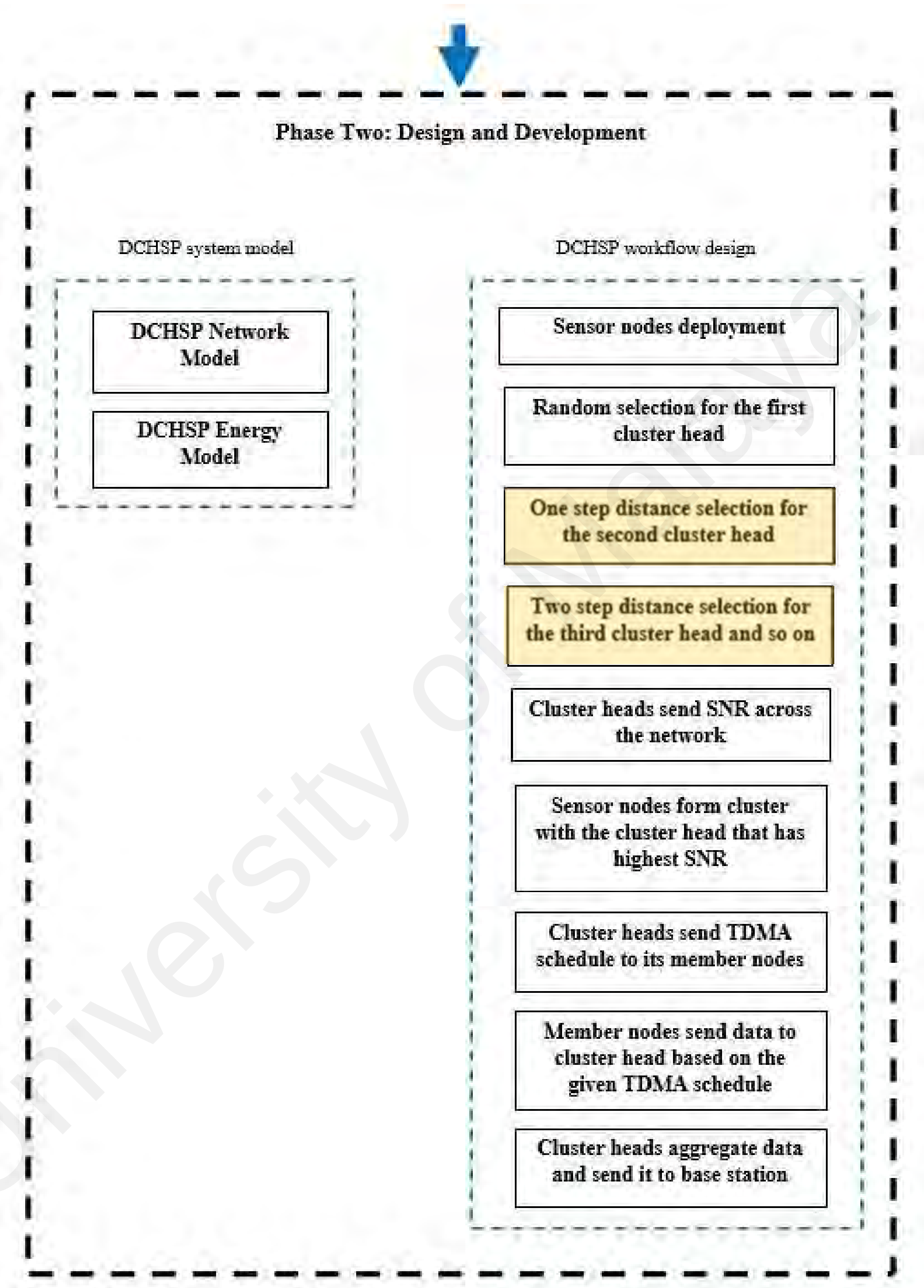


Figure 3.5: Phase two of research methodology

3.3 Verification and Validation

The research is analysed and the performance of DCHSP is evaluated in phase three, the simulation tool used in this research is MATLAB simulation tool version R2017a which run on an Intel i5 CPU with 8GB ram on Windows 10 platform. LEACH and SEP are used as a benchmark for the proposed protocol. Since DCHSP is an enhancement from LEACH, it is important for it to be benchmark against LEACH to evaluate the improvement of DCHSP based on its metric parameters. SEP is selected as the benchmark for this research in order to evaluate the ability for DCHSP to work in a heterogeneous network. The following are the assumptions when setting up the simulator:

1. Base station located at the centre of the network.
2. Sensor nodes are deployed randomly across the network.
3. Both base station and sensor nodes are static nodes.
4. Some sensor nodes have higher initial energy than the others.
5. Sensor node is considered dead if energy value is 0.
6. No data transmission will occur from the sensor node if the sensor node has died.

When the simulation ends, MATLAB would generate four result in the form of graphs. These graphs are known as number of dead nodes, number of alive, average energy of nodes (J), number of packet delivery to base station and network energy consumption. The evaluation is done based on four performance metrics, namely number of alive nodes, network lifetime, average energy consumption and network throughput. Figure shows 3.6 shows how graph for number of alive nodes against time is computed in MATLAB. Summary of phase three of the research methodology can be found in figure 3.7.

```
figure('Name','Number of Alive Nodes vs Round','NumberTitle','off');
r=0:rmax;
plot(r,STATISTICS.ALLIVE3(r+1),'-g',r,STATISTICS.ALLIVE(r+1),'-b',r,STATISTICS.ALLIVE2(r+1),'-r')
legend('DCHSP','LEACH','SEP');
xlabel('Rounds');
ylabel('Allive Nodes');
```

Figure 3.6 : Graph for Number of allive nodes against round compute in MATLAB

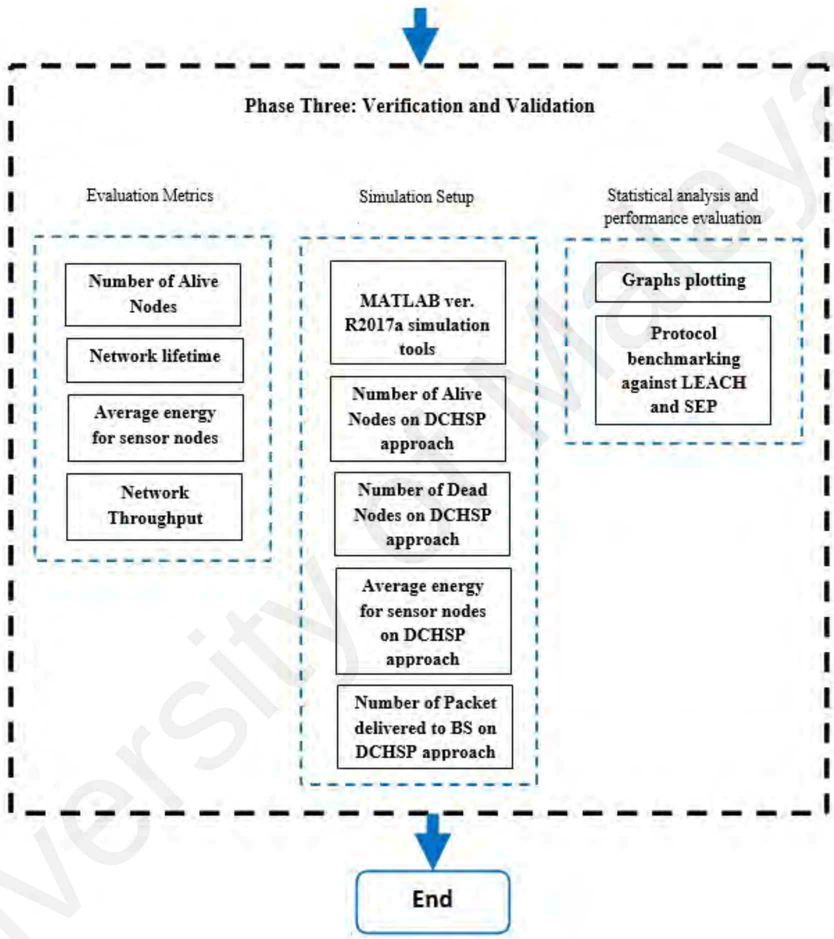


Figure 3.7: Reseach Methodology in phase three

3.4 Summary

This chapter has presented the research methodology used in this research which consists of three phases. Phase one, the background, features and challenges of wireless sensor network are studied. Energy constraint are one the challenges faced by wireless sensor network due to the small form of its sensor nodes. Since some of the sensor nodes are deployed in an inaccessible hostile region, battery replacement cannot be done. One way to improve energy efficiency in wireless sensor network is by providing it with a routing protocol that focuses on energy efficiency. Thus, the taxonomy wireless sensor network routing protocol is studied and literature review on existing routing protocols are assessed thoroughly. Next, the characteristics, advantages and drawbacks of existing routing protocol are evaluated.

In phase two, the design and development of DCHSP are outlined and developed using MATLAB simulation tools. DSCHSP is an enhancement from LEACH protocol where it eliminates the random cluster head selection in LEACH and change it for cluster head distance in order to choose the cluster heads in the network. It works by selecting the new cluster head according to the distance between the previous cluster head. In order for new cluster head to be selected, the distance between it and previous cluster head must be larger than 2CRR where CRR is defined as the cluster radius range. Distances selection step can be done either one or two times according to the number of cluster heads.

Lastly, the verification and validation of the research experiments are conducted in phase three. Experiments are carried by comparing the performance of DCHSP to the benchmark protocol namely LEACH and SEP. The performance evaluated are number of alive nodes, network lifetime, average sensor nodes energy and number of packet delivery delivered to base station.

CHAPTER 4: DATA ANALYSIS AND RESULTS DISCUSSION

In this chapter, performance of DCHSP is discussed and evaluated. First section describes the network simulator setup, scenario and configuration parameters that used in this research. In the second section, performance metrics such as number of alive nodes, network lifetime, average energy of sensor nodes and number of packet delivered to base station of DCHSP are evaluated and compared against the existing protocol, namely LEACH and SEP.

4.1 Simulation Environment Setup

MATLAB is used to evaluate the performance of the proposed protocol. The performance of the proposed protocol is then compared with existing protocol such as LEACH and SEP. For this simulation, a parameter is created where 100 static sensor nodes are randomly distributed in a 100m x 100m network area with a base station located at the center of the network.

In order to create a heterogeneous network, sensor nodes are divided in two types, namely normal sensor nodes and advanced sensor node. Advanced sensor nodes have higher energy value compare to the normal sensor nodes. The initial energy value of an advanced node can be obtained by:

$$E_{adv} = E_o(1+\alpha)$$

Equation 8

Where ***Eadv*** is the initial energy of advanced sensor nodes, ***Eo*** define as the initial energy value of normal nodes and α is the additional energy factor between advanced nodes and normal nodes. For the research purpose, we let 10% of the nodes to become advanced nodes with $\alpha = 2$. In this research, the performance metrics of both LEACH and SEP are used as a benchmark for DCHSP. The performance metrics that being used in for this research are number alive nodes, number of dead nodes, average energy of sensor nodes, number of packet delivered to base station. The research is simulated for 3000 rounds in order to test the stability and usability of the protocols in a long period of time.

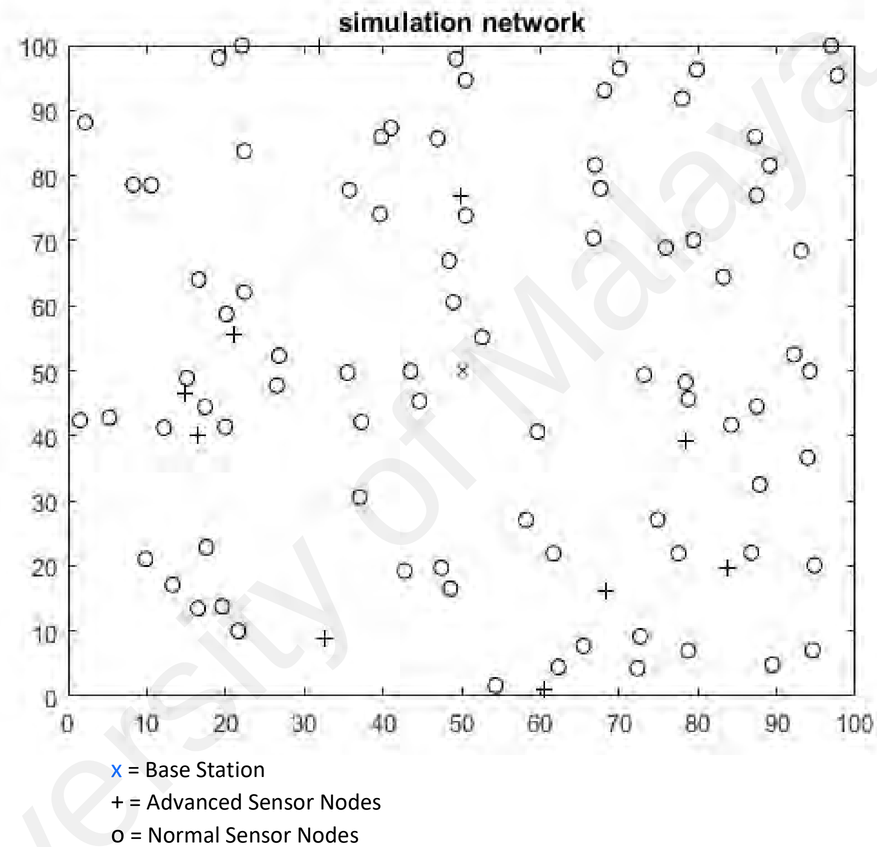


Figure 4.1: Topology simulation of the network with random sensor nodes distribution

4.2 Network Parameters

Table 4.1 depicts the network parameters that are used to study the performance of DCHSP, LEACH and SEP. For consistency, the parameters for the simulation are the same for all protocols that being simulate.

Table 3.1: Simulation Parameters

Parameters	**Value**
Network Size	100M x 100M
BS coordinate	(50, 50)
Sensor Nodes	100
Transmission Range	100M
Routing Protocols	DCHSP, LEACH and SEP
E_o	0.2 J
E_{elec}	50nJ/bit
E_{TX}	50nJ/bit
E_{RX}	50nJ/bit
E_{fs}	10pJ/bit/m^2
E_{mp}	0.0013pJ/bit/m^4
E_{DA}	5nJ/bit
Probability for optimal CH	0.1
Probability for Advance node	0.1

4.3 Result Analysis and Discussion

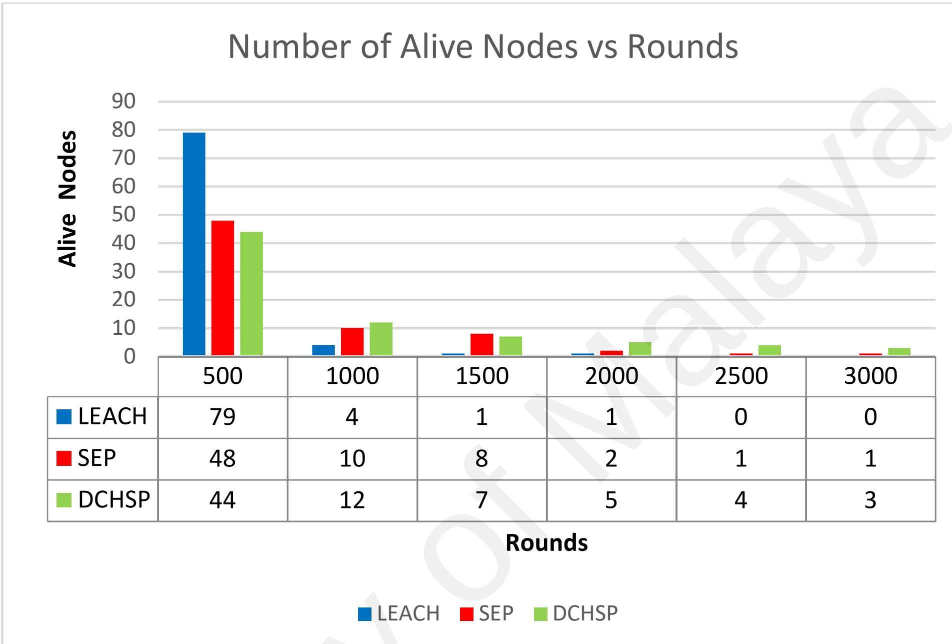
In this section, result of number of alive nodes, number of dead nodes, average energy in a sensor node and amount packet delivered to base station from DCHSP are evaluated. to create a benchmark for DCHSP, LEACH and SEP are also run with same network configuration in DCHSP. The result of the parameter metrics value from LEACH and SEP is then use as a benchmark for DCHSP in order to determine if DCHSP really improve energy efficiency from the existing protocol.

4.3.1 Number of Alive Nodes

Based on result of number of alive sensor nodes against the number rounds in Figure 4.2, DCHSP has the highest number of alive sensor nodes compare to SEP and LEACH after being simulated with the same network after 3000 rounds. The number of alive sensor nodes in the network can indicates the energy efficiency of the protocols. Based from the result, DCHSP has the highest energy efficiency followed by SEP and lastly LEACH.

SEP has better network lifetime compare to LEACH since probability of advance nodes to be selected as cluster heads is higher compare to normal nodes. However, the selection cluster heads for advanced clusters head and normal cluster heads are not dynamic. This can cause multiple cluster heads formed in short distance to each other. This can cause some sensor nodes to use more energy to transmit its data to its cluster heads. This can cause the node to die faster and shorten the network lifetime.

In DCHSP, the distance between cluster heads must be larger than 2CRR, this ensure the cluster heads to be widely spread across the network. By this way, sensor nodes distance to its cluster head become shorter. Therefore, sensor nodes do not need to use a lot of energy to send data to its cluster heads. Thus, energy of the sensor nodes can be conserved for future. This also lengthens the lifetime of the sensor nodes and at the same time lengthens the network lifetime.



	500	1000	1500	2000	2500	3000
LEACH	79	4	1	1	0	0
SEP	48	10	8	2	1	1
DCHSP	44	12	7	5	4	3

Figure 4.2: Bar chart for number of alive nodes against rounds

4.3.2 Number of Dead Nodes

The network lifetime can be determined based on the number of dead sensor nodes. Based on the result shown in Figure 4.3, DCHSP has the least number of numbers of dead sensor nodes follow by SEP and LEACH. Insufficient energy cluster heads due to random cluster heads selection in LEACH can cause the node to die early, therefore the network lifetime become shorter.

SEP has better network lifetime compare to LEACH since probability of advance nodes to be selected as cluster heads is higher compare to normal nodes. However, the selection cluster heads for advanced clusters head and normal cluster heads are not dynamic. This can cause multiple cluster heads formed in short distance to each other. This can cause some sensor nodes to use more energy to transmit its data to its cluster heads which cause the node to die faster and shorten the network lifetime.

In DCHSP, the distance between cluster heads must be equal or larger than 2CRR, this ensure the cluster heads to be widely spread across the network. By this way, sensor nodes distance to its cluster head become shorter. Therefore, sensor nodes do not need to use a lot of energy to send data to its cluster heads. Thus, energy of the sensor nodes can be conserved for future. Because of DCHSP ability to determine the distance between the cluster heads compare to SEP and LEACH, it will make sure every cluster heads are not close together in the network which will lengthen the lifetime of the sensor nodes and at the same time lengthen the network lifetime.

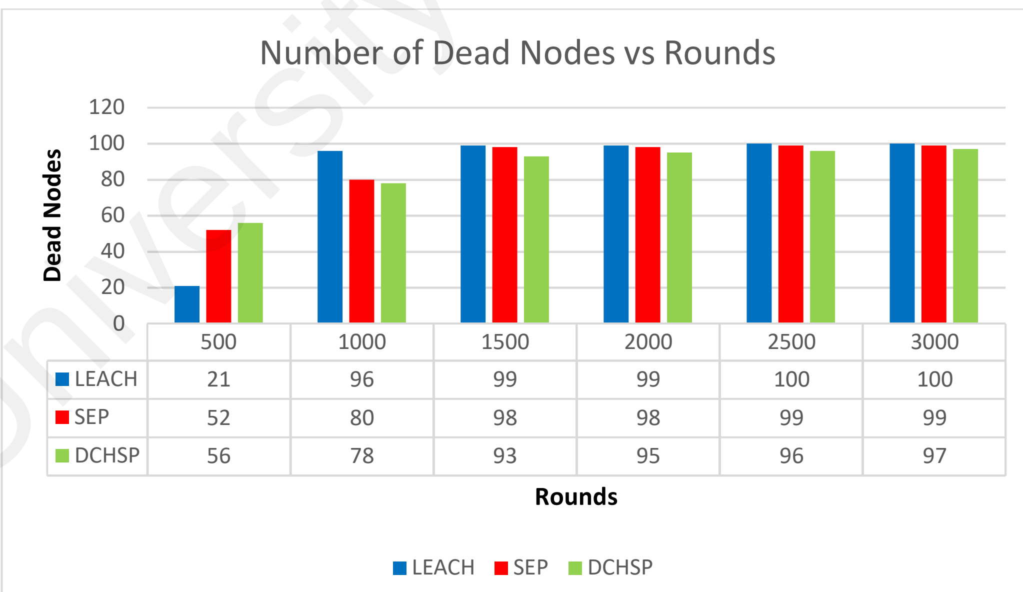


Figure 4.3: Bar chart for number of dead nodes against rounds

4.3.3 Average Energy for a sensor network

Based from the results gathered in average energy of sensor nodes, we can determine how well is the energy efficiency of the protocols. A protocol that has good energy efficiency will have better average node energy as the time goes. In Figure 4.4, DCHSP has the highest value of average energy for a sensor node follow by SEP and lastly LEACH.

The reason for DCHSP to have the highest average energy for a sensor node is because the wide spreading of the cluster heads. Due to its distance selection mechanism in cluster heads formation, cluster heads are spread widely across the network. Therefore, sensor nodes use less energy to transmit data to the cluster head.

The mechanism of SEP that give higher probability for sensor nodes with higher energy value to be the cluster heads also improve the energy of the sensor nodes. However, some cluster heads can be close together from each other and caused the cluster heads to be concentrated to one part of the network area only. This can cause several sensor nodes to use more energy to transmit data to their cluster heads. The random selection of cluster heads in LEACH has taken it tolls because it does not have energy left after being simulated for 3000 rounds.

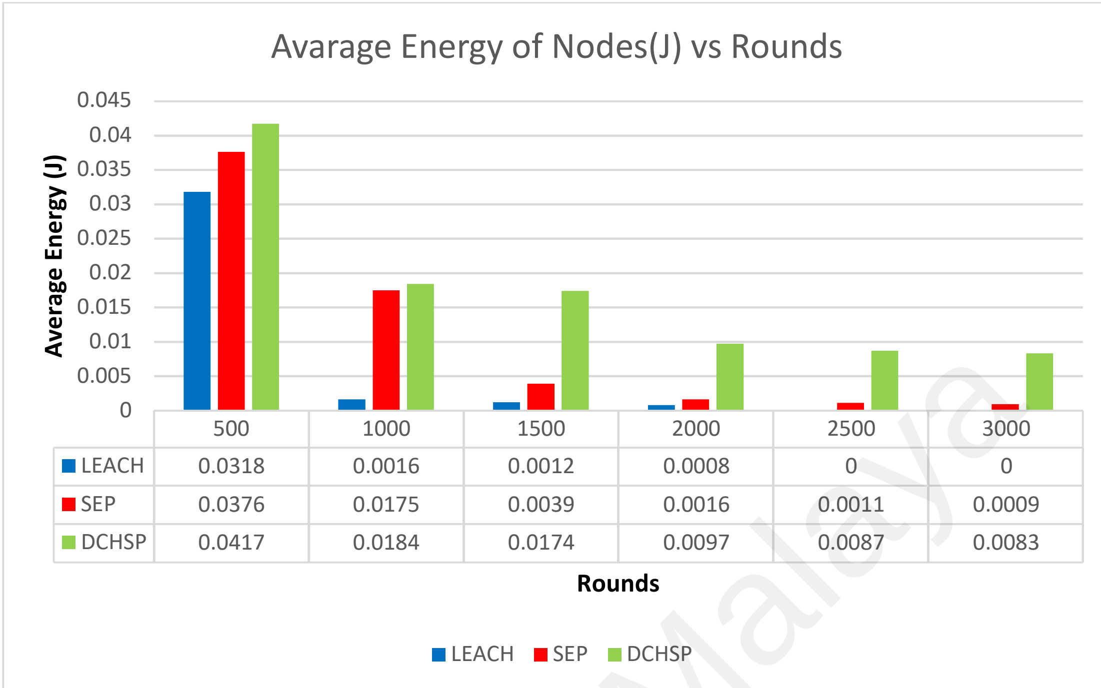


Figure 4.4: Bar chart for average energy for sensor nodes against rounds

4.3.4 Packet Delivered to Base Station

The network throughput of the protocol can be determined by evaluating the amount of packet delivered to the base station. Network throughput is the amount of data successfully transmits from one place to another in a given period of time. Based on the result in Figure 4.5, SEP has the highest network throughput follow by DCHSP and lastly LEACH.

SEP has the highest network throughput because of its ability to give high probability for advanced nodes to be the cluster heads. Since cluster head has more energy compare to the normal sensor nodes, advance nodes that become cluster head can send more data to the base station. DCHSP does not have the ability to give advanced nodes higher chances to be selected as cluster heads therefore packet delivered to the base station in DCHSP is lower than SEP.

Based on the result in Figure 4.8, DCHSP improve LEACH network throughput since it replaces the random cluster head selection into distance cluster head selection. In LEACH, random selection can cause cluster heads that has insufficient amount of energy. Since cluster head need to a lot of energy for data aggregation and transmission, the selected cluster head can die early. Since only cluster heads have the ability to send packet to base station, the amount of packet delivered to the base station will be lesser if the cluster heads die early.

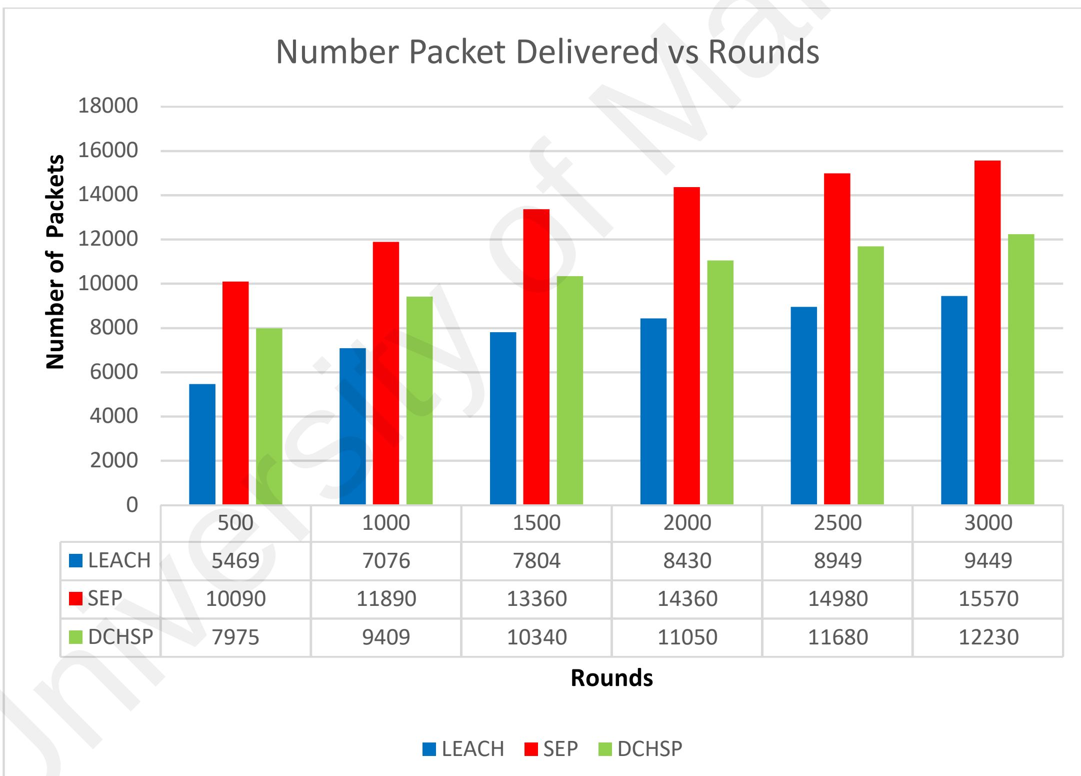


Figure 4.5: Bar chart for number of packets delivered to base station against round

4.3.5 Energy Consumption

Based on Figure 4.6, LEACH has the highest energy consumption followed by SEP and lastly DCHSP. The randomization clustering selection in LEACH has caused it to consumed more energy as it continued its rounds. When cluster heads are selected in LEACH, the cluster heads are not selected dynamically. This means, cluster heads formation that are concentrated only in one part of the network area can occur. Therefore, cluster members have to use more energy for data transmission to cluster head.

In SEP, cluster head selection using probability between two types of sensor nodes have improved the energy consumption of the network. However, the cluster heads that concentrated only in one part of the network area can still occurs since the cluster heads distribution are not done dynamically.

DCHSP has the lowest energy consumption due to its ability to spread the cluster heads widely across the network area. This will make sure the distance between the cluster heads and cluster members to be closer compare to LEACH and SEP. When the distance between the cluster heads and cluster members are closer, less energy needed for data transmission from cluster members to cluster heads. therefore, energy consumption can be reduced.

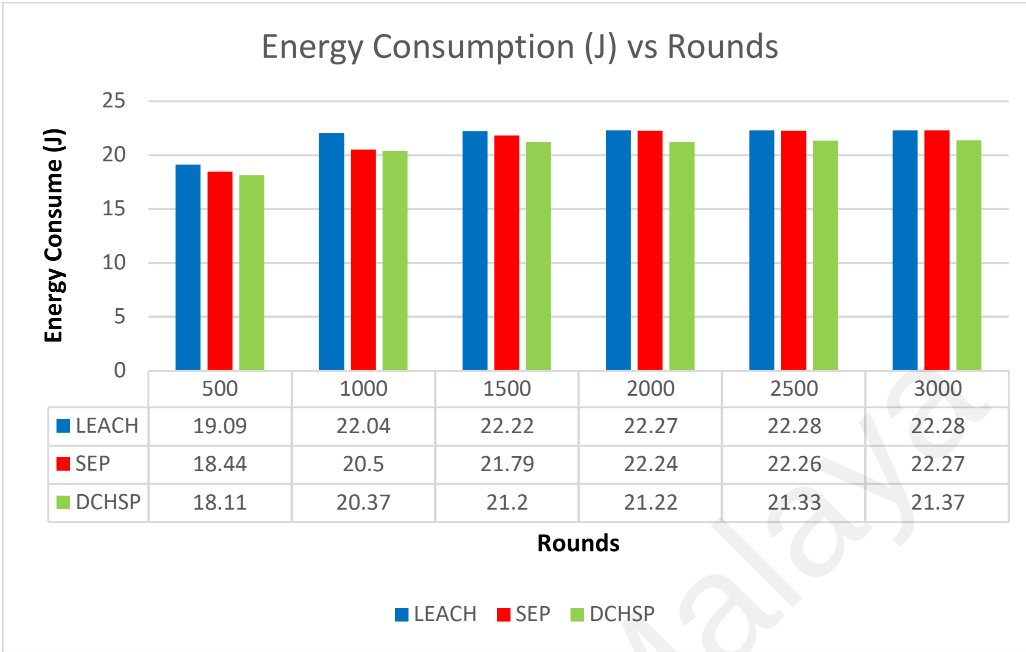


Figure 4.6: Bar chart for network energy consumption against round

4.4 Summary

This chapter discussed the overview of the scenarios and the simulation parameters for the experiments. The results of these performance metrics (number of alive sensor nodes, number dead sensor nodes, average energy of sensor nodes and packet delivered to base station) are compared between DCHSP, LEACH and SEP. The result shows that the DCHSP has a better network lifetime compare to LEACH and SEP. This shown where DCHSP has lesser dead sensor nodes compare to LEACH and SEP. DCHSP also improve the energy efficiency of the network where it has the highest average energy value compare to LEACH and SEP. Based on the result of packet delivered to base station. DCHSP has improve the network throughput from LEACH. However, SEP has the highest network throughput among the protocols.

CHAPTER 5: CONCLUSION

In this chapter, the conclusion of the research, main findings and contributions of the research are presented and is concluded with future works.

5.1 Achievement

An enhanced routing protocol based from LEACH was developed to improve the energy efficiency of wireless sensor network. The proposed protocol is called Distance Cluster Head Selection Protocol (DCHSP). DCHSP is a protocol that use distance between cluster heads for selection of the next cluster heads. This creates cluster heads formation that are widely spread and can cover the whole network area. With the implementation of cluster heads selection in DCHSP, sensor nodes do not need to travel far to send its data to the cluster heads hence less energy use for data transmission.

In chapter two, the taxonomy of wireless sensor network routing protocol such as the mode of function, participation styles of the sensor network and the types of network structures are reviewed in this research. The studies of existing wireless sensor network routing protocols are also conducted and the characteristic of the routing protocol is compared based on taxonomy, advantages and limitation of the routing protocols.

In chapter three, the mechanism of the enhanced routing protocol based on LEACH is proposed. The proposed protocol which is called DCHSP replaces the random cluster head selection in LEACH with a cluster head distance selection to ensure the formation cluster heads is widely spread on the network. With this implementation, sensor nodes do not have travel far to send their data to its cluster head therefore less energy is being use.

In chapter four, DCHSP is simulated using MATLAB simulation tool. The performance metrics of DCHSP such as number of alive nodes, number of dead nodes, average energy of the node and amount of packet delivered to base station was evaluated and compared with the performance metrics of LEACH and SEP which are also simulated in MATLAB simulation tool. based from the comparison, DCHSP improve LEACH based from the result of the performance metrics.

5.2 Contributions

The main contribution of this research is to developed an enhanced energy efficiency routing protocol named DCHSP. The developed routing protocol should improve LEACH protocol based on its energy usage and network lifetime. The research contribution is summarized as follows:

- Develop an enhanced energy efficiency routing protocol for wireless sensor networks using MATLAB simulation tool.
- Writing a source code of the enhanced energy efficiency routing protocol in C++ programming language.
- Evaluate and analyse the number of alive nodes, number of dead nodes, average energy of the sensor node and amount of packet delivered to base station of DCHSP and compare its performance with existing routing protocols such as LEACH and SEP.

5.3 Future Work

In this research, DCHSP is proposed and presented which improves the energy efficiency of LEACH by introducing distance-based cluster head selection in the protocol. The implementation of distance-based cluster heads selection creates a formation of cluster heads that is widely spread across the network. In this way, no cluster heads can be found close together and cluster heads can cover the whole network area. This will benefit the sensor nodes where the sensor nodes do not need to travel far to send the data to its cluster heads therefore reduce the energy usage of the sensor nodes.

The proposed protocol can be improved further by adding residual energy of the sensor as the criteria in selecting cluster heads. By adding residual energy as the criteria for cluster selection, cluster heads will not only spread widely on the network but also has the high residual energy value thus it can improve the network lifetime of the network. Introducing more initial energy value of the sensor nodes can also improve the result of research and create a better network scenario.

5.4 Conclusion

Wireless sensor network technologies continue to grow and has provide opportunities to many fields of work. It comprises of hundreds or thousands small and light sensor nodes that can be deployed randomly in various type of area. It is use to monitored environment of the area for further studies. One of the challenges faces in wireless sensor network is the energy constraint of the sensor nodes. Since sensor nodes are usually in a small size form. It does not have big batteries to contain the energy need to transmit data to the base station for a long period of time. LEACH is an existing routing protocol that can be used to improve the energy efficiency of wireless sensor network. However, the random selection of cluster heads can cause distance between the cluster head and its sensor nodes to be far away from each other. This means sensor need to use more energy to send data to its cluster head.

The proposed protocol in this research which DCHSP, improve LEACH by selecting a cluster head based from the previous cluster heads. This will provide a better formation of the cluster heads on the network where the cluster heads are widely spread across the network. DCHSP is simulated using MATLAB and its performances were analysed and evaluated. Existing protocol such as LEACH and SEP are also simulated in MATLAB and their performances were also analysed and evaluated which will become the benchmark for DCHSP. Four metrics namely number of alive nodes, number of dead nodes, average energy of the node and amount of packet delivered to base station were used to evaluate the performance of the protocol. DCHSP performs the best on number of alive nodes, number of dead nodes and average energy of the node. The simulation show that DCHSP improved the energy efficiency from the existing protocols.

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