An Efficient Energy Aware Clustering Protocol for WSN with Sink Mobility

A Thesis

Submitted to the College of Information Engineering

At Al-Nahrain University in Partial Fulfillment of the

Requirements for the Degree of Master of Science

In

Networks Engineering and Internet Technologies

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May 2016

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ABSTRACT

Recent developments in wireless sensor network fields allow it to be suitable for sensing specified parameter(s) related to a certain environment. Routing the data wirelessly in energy efficient manner is the main task of network layer, thus, clustering routing scheme is one of the most efficient techniques for WSN for achieving this requirement.

This thesis presents two centralized cluster based routing protocols for WSNs with sink mobility: Cluster Head selection based on Fuzzy Logic implemented on Zone Routing Protocol (CHFL-ZRP) & Mobile Cluster Head selection based on Fuzzy Logic implemented on Zone Routing Protocol (MCHFL-ZRP). The proposed protocols work for both static and dynamic sensor nodes; where CHFL-ZRP is applied in an environment that covers fixed nodes only, while MCHFL-ZRP can work with both fixed or/and mobile nodes.

The selection of the cluster head nodes depends on applying fuzzy logic approach by incorporating three extracted node features, the centrality, the concentration and residual energy. A predictable sink mobility pattern for data gathering mechanism is applied by making the sink moves in a hexagonal path pattern and selecting the most appropriate diagonal size for the hexagon with regards to the network life time and the average energy consumption.

Different simulation scenarios are considered in evaluating the performance using NS2.35-Software installed on Ubuntu-14.04 distribution, a Linux operating system which is virtualized on oracle VM-Ware workstation. The overall system is implemented on Windows-8.1 that packs a Core i3 CPU.

Simulation are divided into two parts, the first one is performed on CHFL-ZRP with fixed and mobile sink. Different size of clusters and different diagonal path patterns for the sink movement are examined to exhibit their impact on the appearance of first node to die metric and on the consumed energy. The second part involved the evaluation and performance comparison of the developed CHFL-ZRP & MCHFL-ZRP protocols with the well-known LEACH, LEACH-C, LEACH-ERE, LEACH-ME, LEACH-M and CHEF protocols.

Simulation results show that the CHFL-ZRP outperforms CHEF and LEACH-ERE in terms of half nodes to die and networks life time. Also, it outperforms the LEACH and LEACH-C in terms of the throughput, end to end delay, average energy consumption, networks life time, and half nodes to die. While the MCHFL-ZRP outperforms the LEACH-ME and LEACH-M in terms of the average remaining-consuming energy and average end to end delay.

Contents

List of Abbreviations

ACO	Ant Colony Optimization
AD-ZRP	Ant-Based Dynamic Zone Routing Protocol
AODV	Ad hoc on-Demand Distance Vector
BAN	Body Area Network
BRP	Border Cast Resolution Protocol
BS	Base Station
CBM	Machinery Condition-Based Maintenance
CBR	Constant Bit Rate
CCO	Coordinating Clusters
CH	Cluster Head
CHEF	Cluster Head Election Using Fuzzy Logic
CHFL-ZRP	Cluster Head Selection Based On Fuzzy Logic Implemented on Zone Routing Protocol
CHUFL	Cluster Head selection protocol Using Fuzzy Logic
COG	Center of Gravity
DEEC	Distributed Energy-Efficient Clustering Algorithm for Wireless Sensor Network
EBUC	Energy-Balanced Unequal Clustering
EECS	Energy Efficient Clustering Schema for wireless sensor network
EEICCP	Energy Efficient Inter Cluster Coordination Protocol
EEPSC	Energy-Efficient Protocol with Static Clustering
FIS	Fuzzy Inference System
FLC	Fuzzy Logic Control
FND	First Node to Die
HEED	Hybrid Energy-Efficient Distributed clustering protocol

HEER	Hybrid Energy Efficient Reactive
HEER-SM	Hybrid Energy Efficient Reactive-Sink Mobility
HND	Half Nodes to Die
HT	Hard Threshold
IARP	IntrA-Zone Routing Protocol
ID	Identifier
IERP	Inter-Zone Routing Protocol
LEACH	Low Energy Adaptive Clustering Hierarchy
LEACH-C	Centralized Low Energy Adaptive Clustering Hierarchy
LEACH-M	Low Energy Adaptive Clustering Hierarchy Mobile Node
LEACH-ME	Low Energy Adaptive Clustering Hierarchy- Mobile Enhanced
LEACH-ERE	Low Energy Adaptive Clustering Hierarchy-Based on The Expected Residual Energy
MAC	Media Access Control
MANET	Mobile Ad-hoc Network
MCHFL-ZRP	Mobile Cluster Head Selection Based on Fuzzy Logic implemented on Zone Routing Protocol
MH	Multi-Hop
MHCM	Multi Hop Cluster Model
MHEER	Multi-hop Hybrid Energy Efficient Reactive Routing Protocol
MHEER-SM	Multi-hop Hybrid Energy Efficient Reactive Routing Protocol-Sink Mobility
MHFM	Multi Hop Flat Model
NAM	Network Animator
NDM	Neighbor Discovery/Maintenance Protocol

PDR	Percent of Delivered Data
PEGASIS	Power-Efficient Gathering in Sensor Information System Protocol
PRP	Proactive Routing Protocol
PSO	Particle Swarm Optimization Algorithm
QOS	Quality of Service
RF	Radio Frequency
RRP	Reactive Routing Protocol
SH	Single-Hop
SP	Setup Phase
SSP	Steady-State Phase
ST	Soft Threshold
TDMA	Time Division Multiple Access
TEEN	Threshold Sensitive Energy Efficient Sensor Network Protocol
TS	Takagi-Sugeno
TCL	Tool Command Language
TWSN	Terrestrial Wireless Sensor Network
VINT	Virtual-Inter Network Test-bed
WSN	Wireless Sensor Network
DoF	The degree of fulfillment
ZRP	Zone Routing Protocol

List of Symbols

a	The Metric Found for The Other Compared Protocols.
b	The Tested Metric for The Developed Protocol
C_{prob}	The Percentage of CHs Among All Nodes in HEED
$CE(S_i)$	Centrality of The Node (i).
CH_{prob}	Probability of Being A Cluster Head Node in HEED
$CO(S_j)$	Concentration of the CH node
d_j	Distance Between Head Nodes and Its Members
$D(S_j)$	The Summation of Distance Between Head Nodes and Its Members
E_c	The Total Consumed Energy.
E_{ci}	The Consumed Energy of The *ith* Node.
E_{max}	The Ultimate Energy
E_P	The Consumed Energy During Processing.
E_r	The Predicted Remaining Energy at Each Node
$E_r(S_i)$	The Residual Energy.
E_R	The Consumed Energy During Reception.
E_T	The Consumed Energy During Transmission.
$ECH_r(j)$	The Current Energy Remaining in Head Node j.
$ECH_{th}(j)$	A Specified Threshold Level for The remaining Energy
G	A Group of Sensors
i	The Node Number in The Cluster.
k	The Number of Clusters.
$L(S_i)$	The Location of Node S_i
m	Total Number of Transmitted Packets

n	Total Number of Nodes in The Field
$n_c(S_j)$	The Number of Nodes inside The Cluster j.
p	The Desirable Percentage of CHs
r	The Present Round
R	The Communication Range
S_i	The Normal Nodes
S_j	The Cluster Head Node
T_i^r	The Difference Between The Receiving and The Sending Time of The Packet (i).
T_i^s	The Difference between The Sending and The Receiving Time of The Packet (i).
$T(n)$	Threshold Limit in LEACH
v_{ij}	The Distance between Node (i) and CH node (j).
X_i , x_i	The Position of The Node in The X- axis.
x_{cj},y_{cj}	The Center of a Specified Cluster j
Y_i , y_i	The Position of The Node in The Y-axis.
Z	The Net of Successfully Received Packets
$\mu_A(x)$	Membership Function of Set *A*.
μ_{CE}	Membership Function for Centrality
$\mu_{ch}(S_i)$	The Membership Degree for Node S_i Chance.
μ_{CO}	Membership Function for Concentration
μ_{Er}	Membership Function of Energy

List of Figures

List of Tables

Chapter One

Introduction

1.1 Preface

The emersion of wireless sensor networks (WSNs) has resulted from the novel evolution between the development in digital electronics, microelectronics, micro mechanical systems, and the progresses in wireless communications technology. A large number of sensor devices are held. Each of which is eligible for sensing, transmitting and processing environmental information. Sensor nodes are limited by the computational power and communication capacities that they can provide. If the sensors are accurately networked and programmed, all signal processing tasks can be cooperatively fulfilled for the information to be collected from remote as well as hazardous areas vigorously. There are different WSNs applications such as biological detection, environmental monitoring, industrial diagnostics, surveillance, battlefield, smart spaces, etc. [1].

A WSN is composed of such sensor nodes that establish a network structure capable to communicate with other nodes either directly or indirectly. One or more than one node is dedicated to serve as a gateway base station (sink) for the WSN [2].

The efficiency of energy consumption represents the prime challenge that is facing designers in WSN. In general, the source of power in a sensor node is fundamentally supplied from a direct current battery which represents a limited source of power. It is not that easy to change or recharge the nodes' battery after the deployment of sensor nodes [3].

The transmission of data is the primary use of energy in WSNs. It is essential to control the energy consumption during the data collection phase. This is done by letting a minimum amount of nodes that are in direct communication with the base station, where collection of the application data is hosted. The developed algorithms for WSN clustering minimize the number of nodes that are engaged in transmitting with the sink station. This is done by grouping the deployed nodes into clusters or sectors. Each cluster is controlled by a head node called cluster-head (CH). Other nodes found in the cluster become members of that cluster. The cluster member nodes only communicate with the cluster head within a limited transmission range and hence energy consumption is minimized. The data collected at those cluster heads from their member nodes are aggregated into one packet and forwarded by the CH to the BS. It should be mentioned that only the cluster heads are responsible for sending the collected cluster data to the BS [1].

Since all the nodes are targeting their data toward the sink station, where processing and decision making take place, the base station deployment in a WSN is a major concern. For that, the issues concerning, power consumption, coverage of WSN and reliability are under investigation. It is generally assumed that the base stations are static in nature, although they are mobile in some scenarios to collect the data from the sensor nodes [4]. In order to achieve higher energy saving results, the mobility of the base station for increasing the WSN lifetime is monopolized [5].

1.2 Literature Survey

In the last decade, many researchers have intensively studied the energy consumption problem in WSN. In the following, a survey for the main approaches and protocols are addressed:

Younis & Fahmy, in 2004 [6] developed a "Hybrid Energy-Efficient Distributed clustering (HEED*)* protocol". CHs election and clusters formation, are based on two combined parameters: The primary, which depends on the remaining energy in the nodes. The secondary parameter represents the cost of the communication during the intra clustering. In applying this protocol, nodes determine the nearest cluster head node to be a member of its cluster. Also, the data aggregated by CHs are sent to the sink station using multi-hop route.

Ye et al, in 2005 [7] introduced an "Energy Efficient Clustering Schema for WSN (EECS). It consists of two phases: The phase of cluster head selection and the phase for forming the clusters. A constant level of member nodes is selected in the CH selection phase. Contention for CHs is evaluated according to the remaining energy in the nodes. The second phase represents a new algorithm for balancing the load between the CHs. Unlike LEACH, the CHs using EECS are scattered in an even way, it is regarded as a single hop intra cluster communication. EECS is much more energy efficient if compared to HEED, since it concentrates on the algorithm for setting up the clusters rather than on data transmission approach, in saving the energy.

Kim and Chung, in 2006 [8] proposed a "Low Energy Adaptive Clustering Hierarchy-Mobile (LEACH-M)". LEACH-M supports sensor nodes mobility in WSN by adding membership declaration to LEACH protocol. LEACH-M uses the same setup procedure of the LEACH protocol. The basic idea in the LEACH-M is to confirm whether a mobile sensor node is able to communicate with a specific cluster head, as it transmits a message which requests for data transmission back to mobile sensor node from cluster head within a time slot allocated in TDMA schedule of a cluster head. This protocol suffers from high packet loss because mobile node which is not near to any cluster cannot send data to any cluster head.

Zahmati et al, in 2007 [9] developed an "Energy-Efficient Protocol with Static Clustering (EEPSC)". It is a hierarchical static clustering protocol, Remarkably, EEPSC is considered as an enhanced (LEACH) protocol with modifications. It chooses the nodes with the highest energy to be as CHs. It utilizes the idea of transient heads, and makes use of a new selection phase for setup and responsible nodes.

Kumar et al, in 2008 [10] proposed "Leach Mobile Enhanced Protocol (LEACH-ME)". LEACH-M protocol has been enhanced based on a mobility metric “remoteness” for cluster head election. This ensures high success rate in data transfer between the cluster head and the collector nodes even though nodes are moving. The simulation experiment shows that the proposed enhanced protocol outperforms LEACH-M in average successful communication rate by a reasonable margin, at very high mobility. It is also clear that to achieve the level of extra performance, energy dissipation needs to be sacrificed at a tolerable level.

Kim et al, in 2008 [11] proposed a fuzzy logic approach in the selection of CHs in WSN (CHEF). The location and residual energy are taken into consideration, to determine the selected list of CHs. CHEF is like LEACH, where clusters are configured at each round. The localized CH selection mechanism is used by CHEF, where the sink does not in need to collect the data directly from all nodes. The simulated case studies show that the results demonstrated using the CHEF protocol outperforms the LEACH by 22.7%.

Torghabeh et al, in 2010 [12] developed a CH election based on using a 2-Level Fuzzy Logic. It is an efficient technique used to evaluate the chance of nodes to be a cluster head. In the local level (First Level), the competent nodes are chosen according to the count of neighbors and their level of energy. In the global level (Second Level), full cooperation of nodes is regarded in the network with three fuzzy variables. The variables are the vicinity to the BS, the distance between CHs, and the centrality. The results show that the developed protocol is better in conserving the energy, and prolongs the life time of the network by 54 % in comparison to LEACH and CHEF algorithms.

Okazaki and Fröhlich, in 2011 [13] introduced "Ant-based Dynamic Zone Routing Protocol (AD-ZRP)". It is a multi-hop and self-configuring hybrid routing protocol based on Ant Colony Optimization (ACO) and Zone Routing Protocol (ZRP). AD-ZRP design must consider several restrictions including energy consumption, processing power, memory, and bandwidth. AD-ZRP also consists of ZRP, but it is based on dynamic zones which, acting together with ACO, allows us to deal with the restrictions of WSNs and yet improve the route discovery and the route maintenance through pheromone. The proposed scheme obtained good results in terms of data delivery ratio, routing overhead, and congestion avoidance for environments of dynamic topology.

Rani et al, in 2013 [14] proposed an "Energy Efficient Inter Cluster Coordination Protocol" (EEICCP) for WSN. It has been proven to be a good protocol in reducing the energy consumption. It is manipulated by a division process for the network into levels of clusters. It uses a multi-hop approach for the CHs. Where CHs and coordinating clusters (CCO) are selected in a similar manner as in LEACH. For propagation, a line of sight must be available to EEICCP usage. It minimizes the level of the exponent and leads to minimum consumption in energy. EEICCP improves the reliability and the stability as compared with LEACH protocol.

Gajjar et al, in 2014 [15] presented a "Cluster Head selection protocol using Fuzzy Logic (CHUFL)". The approach in CHUFL is composed of two stages: Finding the neighbor stage and Steady state stage. During the first stage, each node broadcasts an information packet (containing its ID, location information) then the node stores it in its neighboring table. The second phase is partitioned into rounds. Every round begins with CH election followed by clustering, data gathering at CH and finally data transfer to sink station. This protocol helps reduce energy dissipation of CH by choosing closer CH to BS, having more residual energy and neighbors. The simulation result shows an improvement in CHUFL about 20 % in network life time (consumed energy) and 72% in the throughput, as compared to one of the energy efficient clustering protocol.

Akbar et al, in 2015 [16] proposed two routing protocols for Terrestrial Wireless Sensor Networks (TWSNs). "Hybrid Energy Efficient Reactive (HEER) and Multi-hop Hybrid Energy Efficient Reactive (MHEER) routing protocol". In MHEER, the node with the maximum energy in a region becomes cluster head (CH) of that region for that particular round (or cycle) of time and the number of the CHs in each round remains the same**.** Sink mobility scheme also implemented on HEER and MHEER by referring to them as HEER-SM and MHEER-SM. These techniques outperform the well-known existing routing protocols: LEACH, TEEN, and DEEC in terms of stability period and network lifetime. Simulation results show that HEER-SM and MHEER-SM yield better network lifetime and stability region as compared to the counterpart techniques.

1.3 Contributions

- In this thesis a cluster head selection scheme using fuzzy logic for WSN base on zone routing protocol (CHFL-ZRP) is proposed.
- ZRP is a hybrid protocol so it was chosen; the way it works reduce the overhead in clustering approach because it needs small amount of routing information at each node so it produce less routing traffic than a pure proactive or reactive schemes.

- Cluster heads are optimally elected for prolonging the network life time, by conserving more energy and by increasing the longevity of first node to die.
- Fuzzy logic is implemented on the core of zone routing protocol (ZRP).
- The BS moves in a hexagon shape by using predictable mobility approach.
- The proposed protocol considered the dynamic clustering approach by supporting the nodes mobility in addition to the sink mobility as implemented by the MCHFL-ZRP.
- CHFL-ZRP & MCHFL-ZRP will keep the sink station to be always controllable for being closer toward the largest number of head nodes. Hence, energy is preserved and the WSN network lifetime is extended.

1.4 Aim of the Thesis

The aim of this work is to develop an efficient protocol for extending the WSN lifetime by considering the mobility for the sink station. An energy efficient fuzzy clustering model is to be designed and implemented by using the NS-2 network simulator. The proposed work has to tackle both a fixed node environment and a mixed environment (fixed and mobile together).

1.5 Thesis Outlines

This thesis has been written in five chapters; the remaining chapters can be summarized as:

- **Chapter 2.** Has an overview of the problems regarding WSN's and its applications. There is also a brief background for cluster head selection methods and the available approaches that back up the sink mobility
- **Chapter 3.** Concentrates on the proposed network design approach and the simulation setup for various simulation scenarios.
- **Chapter 4.** Demonstrates the simulations output of the proposed protocol.
- **Chapter 5.** Highlights the conclusions got from the simulation results followed by suggestions for future work.

Chapter Two

Energy Efficient Clustering Protocols for WSN

2.1 Introduction

This chapter gives a brief description about the basic principles of WSN's components, challenges and its applications. It introduces the taxonomy of the clustering routing protocols and explains seven different protocols in the area of reducing energy consumption. Base station mobility schemes are also illustrated, finally ZRP's and fuzzy's logic overviews are expounded.

2.2 WSN Architecture

Wireless sensor network consists of thousands of small nodes or devices which are called sensors. They are used to connect the digital with the physical world in terms of collecting and finding out natural phenomena and transforming them in a form capable of being stored, processed and acted upon [17]. WSN is a structure composed of elements of measuring, computing, and communication which gives those in charge the capabilities of monitoring, implementing, and reacting to events and observable facts occurring in a certain area.

The four fundamental elements found in WSN are: sensors, interconnected network, a central point of information clustering, and finally resource computation at that point (or sometimes further) to tackle correlation of data, trending of events, querying of status, and mining of data [18]. As shown in Fig.2-1, sensor node includes many units such as power, sensing, processing, transmission, in addition to a location-tracking system and a mobilizer [19].

A typical WSN is composed of a small, cheap, and resource constrained sensor in addition to a few base stations or sinks [20]. Its main task is to measure and gather information from a field specified, processing it to be then transmitted hop by hop to the base station which works as a gateway where the application is situated [21].

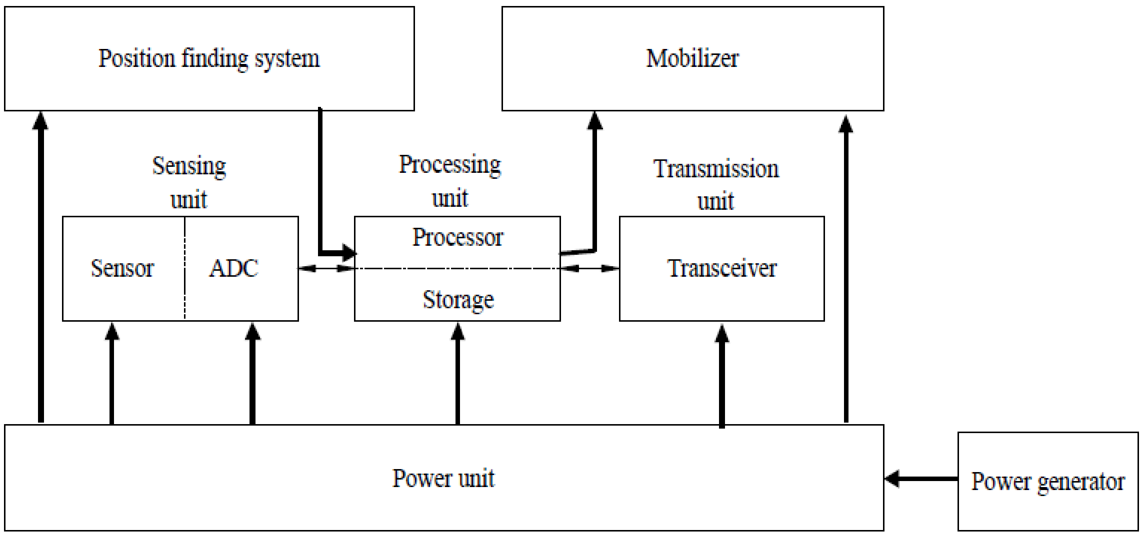

Figure 2-1: Elements of WSNs [19].

A sink is a powerful entity that may work as an outlet to other networks, a data processing or storage center, or even an access point for the user's intervention.

It has been already mentioned in chapter one that sensors are strictly restricted in term of energy. Since their model is deployed, it is very hard, if not impossible, to recharge sensor nodes in order for them to have considerably lower communication and computation capacities than any other types of networks such as cellular or

MANET. It is important to know that the energy is going to be consumed while sensing, processing, mobility and transmission. The great amount of power is consumed during transmission. One can control the transmission more than other functionalities in order to reduce the power consumption. The transmission depends on how to route the data from node to node which is the task of the network layer of each node. The network layer in WSNs is most probably utilized to serve the routing of the data that come in [20, 22].

2.3 Challenges of WSNs

Wireless Sensor Networks have aroused a large number of challenges that still need to be faced. The major issues and the most important design restrictions affecting the performance of WSN are described here: [17, 23]

1. Resource restrictions. Inlaid sensing devises are compelled regarding energy, processing capacities, memory, and the data rate to be achieved.
2. Wireless Radio Communication Characteristics: depending on wireless networks and communications has raised several challenges to the designer of WSN. For instance, attenuation restricts the range of radio signals. In other words, a radio frequency (RF) signals fades (i.e., decreases in power) while they spread through a medium or being passed through barriers.
3. Security: In sensor networks, security issue is regarded as much an essential factor as performance and low energy consumption in many applications, because sensor networks are still a growing technology, they wish to supply a stronger, perfect

protection against illegal activities and, at the same time, maintain the systems stability.

4. Self-Management: In nature, many sensor network applications must be operated in remote areas and, at the same time, affect environments negatively, without infrastructure support or the capacity to maintain and repair. Consequently, sensor nodes must be *self-managed* in a way to be configured, cooperate with other nodes, and adapt to failures, changes in the environment, and changes in the environmental stimuli without human intervention.
5. As being heterogeneous, WSN is composed of equipment with different hardware capabilities. For instance, sensors may have more than one hardware resource if more computation and storage are required. Furthermore, there are some WSN applications that may have specific performance and quality needs. The WSN's protocols are often affected by both heterogeneity and performance requirements.
6. Other Challenges: various additional challenges may affect the design of sensors as well as WSNs. For instance, a group of nodes are probably framed onto a moveable object, like a vehicle or a robot resulting in constant network topologies being changed, which need repetitive modifications at the rest of the system layers, involving routing (e.g., changing neighbor lists), MAC (e.g., changing density), and data collection (e.g., changing overlapping sensing regions).

2.4 Applications of WSN

The reasons behind the popularity of WSNs is due to their capability of solving the issues found at various application areas. A wide range of diverse applications are successfully implemented using WSN, including [24 25 26]:-

a. **Military**

   In military, WSN spread in battle-fields to observe the appearance of soldiers and tanks, tracing them, in order to have a close supervision of opposing forces, and identify the enemy unit movements on land and sea.

b. **Environmental Applications**

   Environmental WSNs have grown to observe several applications related to researches in earth science. It could involve glaciers, oceans, forests, sensing volcanoes, etc.

c. **Area Observation:** In this application, sensors are spread in a field where certain phenomena are to be controlled. When identified by the sensors, the event being monitored would be then reported to a sink, which, by its turn, takes a suitable action.

d. **Structural Monitoring:** WSNs are used to observe the mobility of establishments and their facilities such as tunnels, bridges, embankments, fly-overs and other things like that, to make engineering applications possible to monitor assets remotely. Without the need for costly site visits.

e. **Agricultural Sector:** with the use of WSNs, the farmer feels free from wiring maintenance in a complicated surrounding. Automated watering system would provide more effective water usage and, at the same time, reduce waste.

f. **Home Intelligence** WSNs can be utilized to supply smarter as well as more appropriate living environments for Mankind. For instance, such WSNs can be used to read remotely house-related utility meters such as electricity, gas, water, to be sent then to a far area through wireless communication.

g. **Industrial Monitoring**: WSNs present a great improvement for machinery condition-based maintenance (CBM), where, there are a lot of benefits with regard to saving money and effort. The cost of wiring in wired systems plays an important role in the number of sensors being installed.

h. **Medical Applications:** sensors are used to form Body Area Network (BAN), which is composed of many sensors put nearby the human body, for signal measurements such as heart beat rate or breathe rate.

2.5 WSNs Topologies

As a vital part of WSNs, topology management is always used to save energy while network connectivity is to be maintained [17].

As seen in Fig.2-2, there are four types of WSN topologies. A single-hop and multi-hop, both flat and clustering model. In a single hop model (Fig.2-2a & Fig.2-2b), all sensors send their information directly to the BS. These architectures are not that useful for large-scale areas, because of the high costs of transmission in terms of energy consumption and in the worst case, the sink may be out of the transmission range. Regarding (Fig.2-2c & Fig.2-2d) which represent the multi-hop flat model (MHFM), the overhead and consumed energy may increase as all nodes ought to share the same information such as routing tables.

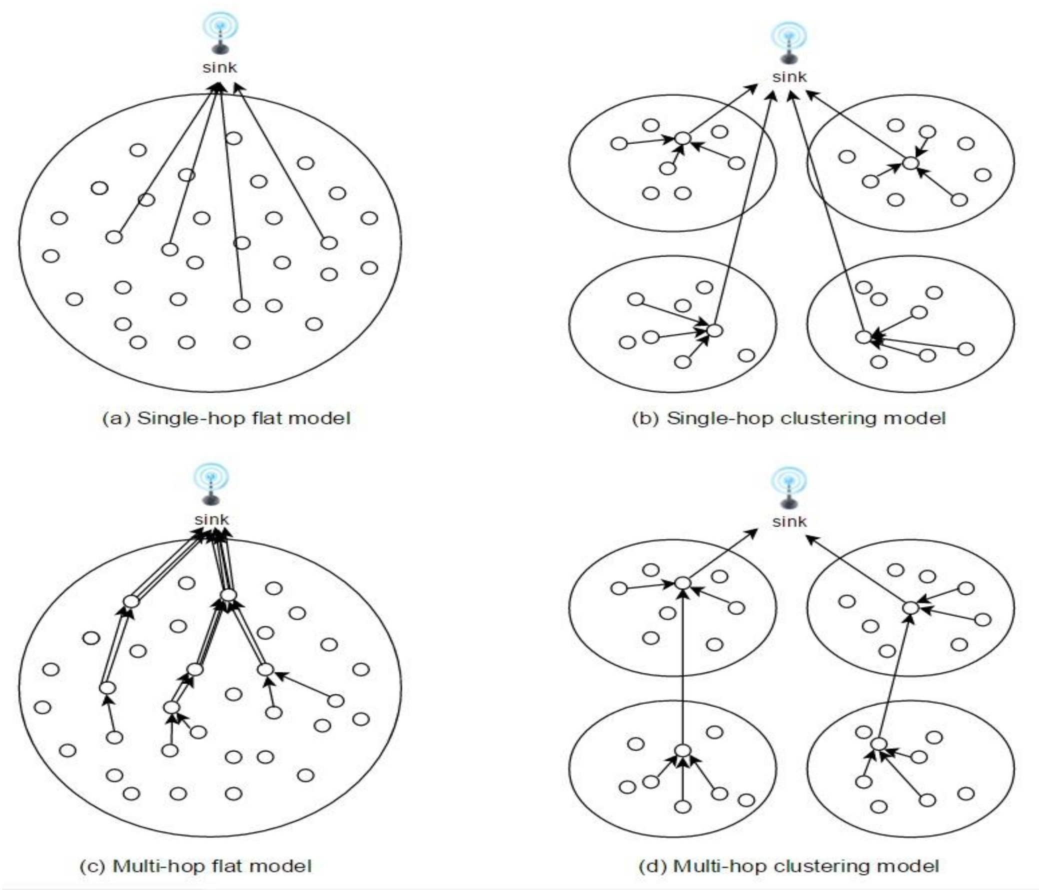

Figure 2-2: WSN Topologies [27]

In contrast, concerning a multi-hop clustering mode (MHCM), low overhead and energy consumption can be maintained with the help of particular sensor nodes due to the data aggregation of cluster heads (CH) and then being transmitted to the sink.

In addition, in a multi-hop flat model, individual nodes share and manage wireless medium, which leads to slow-motion effectiveness in the use of resources. In MHCM, the allocation of resources can be done individually to each one of the clusters to decrease collisions between them, and can be re-used one by one. Thus, MHCM is convenient for WSN that spread in distant regions [27].

2.6 Clustering Algorithms

Conventional routing protocols as explained in the section before are insufficient in terms of saving power and balancing loads. Clustering is sample of layered protocols where the network is composed of several clusters of sensor nodes [28].

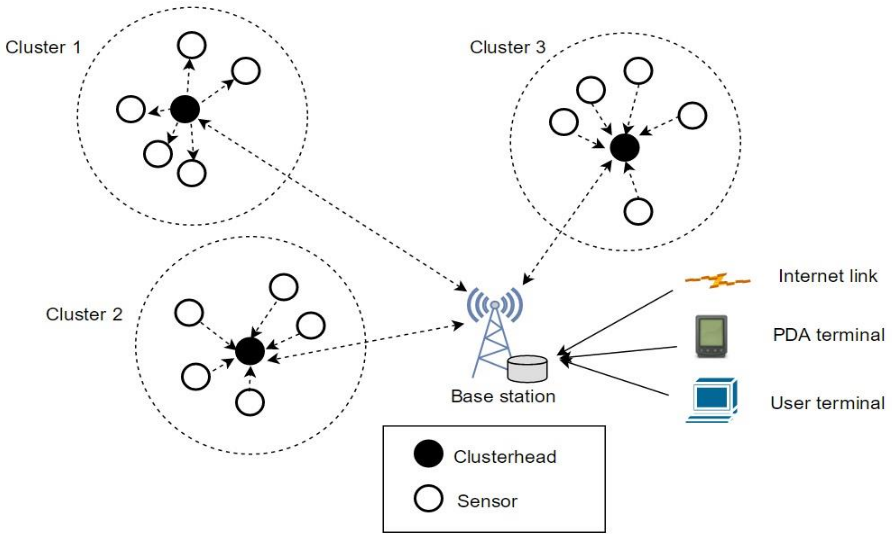

Figure 2-3: Clustering Overview [28]

As shown in Fig.2-3, WSNs in a clustering approach can be regarded as having the parts mentioned as follows:

- Cluster: it is a group of sensors.
- Member Nodes: they are cluster-found nodes allocated geographically adjacent to a similar cluster according to their communication range [29].
- CH: there is only one head node for each cluster. The functionalities of ordinary nodes are usually managed by CHs.
- Base Station (or sink): it is a relay between the network and the end-user [30].

2.7 Taxonomy of Clustering Methods in WSNs [31]

There are four main features of clustering in WSNs. They are cluster properties, CH attributes, clustering process and overall proceeding of the algorithm.

2.7.1 Cluster Characteristics [32]

Such characteristics have the relationships with the attributes of the generated clusters, their structure or whether they are associated with others. The most essential properties are as follows:

- **Cluster count**: relies on a certain number of clusters, its schemes are divided into two types: variables and fixed.
- **Cluster size**: As the consistency of the sizes is being considered, there are two levels of clustering schemes in WSN: uniform and non-uniform ones
- **Inter & IntrA-Cluster schemes**: both of them involved in two categories: single-hop (SH) & multi-hop (MH).

2.7.2 Cluster-Head Characteristics [32]

Being essential, in inter-cluster communication and configuration, CH properties may make the clustering methods different. Some of these properties are:

- **Mobility:** A cluster head can be static or dynamic.
- **Existence**: relies on if there is CH within a cluster, clustering can be classified under CH based and non-CH based clustering [31].
- **Functionality:** CH has four functionalities: collection, transmission, administration and structure maintenance.
- **Uniformity of energy:** Based on such a property for sensors, clustering attitudes in WSNs involves two types: homogeneous or heterogeneous ones. The former class do not differentiate nodes even if there were super ones. The latter sub-divide those nodes as super and normal ones. Super nodes have higher power than normal ones and, as a result, have a better opportunity of CH election.

2.7.3 Clustering Process [31]

- ***Control Manners*:** clustering routing, in such process, is classified under three methods: distributed, centralized, and hybrid ones. In the first one, nodes locally share information for CHs determination and clusters construction. In the second method, the selection of CHs and formation of clusters is being controlled by a central node which is similar to the base station.
- ***Execution Nature*:** cluster formation in sensor network is divided into two types: repetitive or probabilistic one. In the

latter approach, the likelihood addicted to all of the sensors is employed to define the sensors roles. i.e., a node has to remain till a repetition count is satisfied or for the role of specific nodes decision before the decision for repetitive clustering behaviors. In other words, each sensor node can separately decide on its own.

- ***CH selection factors:*** clustering approaches, relied on the CH selection parameters, are grouped as adaptive, deterministic, and random. For adaptive manner, CHs can be selected from the deployed sensors with higher weights included such as residual energy, communication cost, *etc*. For "deterministic" Particular inherent sensor properties are taken into account, like identifier (ID) and adjacent nodes that they have. Random modes, fundamentally act for safe hierarchal schemes, CHs are selected at random, irrespective of certain factors like remaining energy, communication cost and others.
- ***Proactivity*:** routing methods in WSN are categorized into three approaches: reactive, hybrid, and proactive ones. Concerning the first approach, there are no existing predetermined paths for the route to be elected as the packet is required to be delivered to the sink from its source. The hybrid approach is regarded as a composition of both reactive and proactive approaches. In the proactive method, all paths between the source and the sink are determined and, if necessary, maintained before they are really required without any regard to the data traffic.

- ***Objectives*****:** Based on various goals, WSN hierarchal schemes are classified into groups. A few of which fit for constructing the cluster. For example, data collection, balancing the load, fault-tolerance, guarantee of connection, life-long expansion, QOS, and many others.

2.7.4 Entire Proceeding of Algorithm [31]

- **Algorithm Stages**: In general, an entire hierarchal scheme consists of two essential phases: the formation of cluster and the transmission of information. The first one is mainly detailed, while data transmission is concerned less or done by a relatively easy way.

2.8 Clustering Algorithms Based on Energy Efficiency:

2.8.1 Low Energy Adaptive Clustering Hierarchy (LEACH) [20, 33]

It is the first clustering approach for WSN. The functionality of LEACH is classified into rounds, where each of which starts with a setup phase (SP) that the clusters organization occurs in, and then a steady-state phase (SSP) that transmission of information to the sink happens in. At the SP, a sensor determines if there is a chance of being a CH for the present round. To become a cluster-head, each node n chooses a random number between 0 and 1. If the number is less than the threshold T(n), the node becomes the cluster-head for the current round. The threshold is set at Eqn. (2.1):

$$\boldsymbol{T(n)} = \begin{cases} \frac{p}{1-p(r \bmod \frac{1}{p})} & , if\ n \in G \\ 0 & , otherwise \end{cases} \tag{2.1}$$

P refers to the desirable percentage of CHs. On the other hand, r represents the current round. G is a group of sensors, never considered as CHs in the final $1/p$ rounds, $T(n) = 1$ for all nodes that have not been a cluster-head. The sensors that are CHs in round 0 would not be regarded as CHs for the next $1/p$ rounds. Thus, the likelihood that the rest of the sensors are CHs which have to increase, as there are no more nodes qualified to be cluster-heads.

The CH transmits Time Division Multiple Access (TDMA) schedule to the members of the cluster. This guarantees that there is no collision among messages. After that, SP would be finish and SSP (data gathering) can start. During the SSP, the sensor measures and sends its data packet to CHs.

The head nodes collect the arriving information from their members. As a result, CHs transmits the collected data to the sink directly (single-hop). LEACH does not support the movement of sensors and also does not say about the localization of nodes making it difficult to cope with modern's demand. Despite the fact that LEACH is not considered a highly power proficient scheme, it has been what is called “Mother of other Cluster based Protocols”.

2.8.2 Centralized Low Energy Adaptive Clustering Hierarchy (LEACH-C) [34]

Based on LEACH scheme, Heinzelman and other scholars set forward the operation with a centrally-controlled procedure, usually called Centralized LEACH (LEACH-C), which is a modified copy for traditional LEACH algorithm. Firstly, at the SP, residual energy of WSN as well as the position of the nodes must be known by BS. Based on this information, sink station employs a certain way to choose the CHs and classifies sensor nodes to their clusters, which simply diagnoses a better head node of the clusters. Thus, the performance of the LEACH approach can be enhanced by solving those limitations which it has. LEACH-C is not essentially superior to the LEACH; it is more expense based on sink control centrality. Every sensor sends its packet to the sink which would select the head node to classify clusters. Then CH transmits those packets to its members. All these need extra energy cost which will affect the performance of the protocol.

2.8.3 Hybrid Energy-Efficient Distributed Clustering (HEED) [32]

HEED is a multiple hop clustering scheme. Selecting CHs depends upon two vital factors: One of them relies on residual energy in the nodes, while the second is the cost of intra-cluster communication. The scheme dependents on two major stages: cluster formation stage in which the "Hello" messages could be exchanged by the nodes to find out their neighbors and the static stage which includes the CHs determination. Then, the sensors join their suitable head node, on the basis of transmission range. Different from LEACH, it does not choose the cluster head at random. Each node calculates its likelihood to be a cluster head as:

$$CH_{prob} = C_{prob} \frac{E_r}{E_{max}} \tag{2.2}$$

Where E_r represents the predicted remaining energy at each node, E_{max} refers to the maximum energy, which is similar for all WSNs and C_{prob} is the percentage of CHs among all nodes. The value of CH_{prob}, however, is not allowed to fall below a certain threshold that is selected to be inversely proportional to E_{max}. Distribution or density of nodes, node capabilities and location-awareness were not assumed in HEED. The purposes of HEED are;

- Balancing the consumed energy to extend the network longevity.
- Producing well-deployed cluster head nodes and concise clusters.

2.8.4 Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN) [31, 32]

It is a hierarchical protocol designed for reactive networks which responds on demand to events occurrence in the pertinent factors concerned like temperature. In this algorithm, the sensors measure their surrounding constantly, but the energy degradation is less if compared to that in the proactive approach, since data transmission is done less frequently. In TEEN, a two-tier clustering aspect is constructed as explained in Fig.2-4 and two types of thresholds are broadcasted by the cluster head entire its cluster; (HT) hard thresholds and soft threshold (ST). The former threshold is a threshold value for the sensed attribute. It is the absolute value of the attribute beyond which the node sensing this value must switch on its transmitter and report to its CH. The latter threshold is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit. Sensor nodes captured information continually from the environment. If the information value is beyond HT or the varied range of characteristic value beyond ST, the node would send sensing information to a cluster head. So data transmission is done less recurrently which can reduce more network traffic and prefer the energy saving. The nodes will never communicate if the thresholds are not crossed. Thus, TEEN does not uphold periodic.

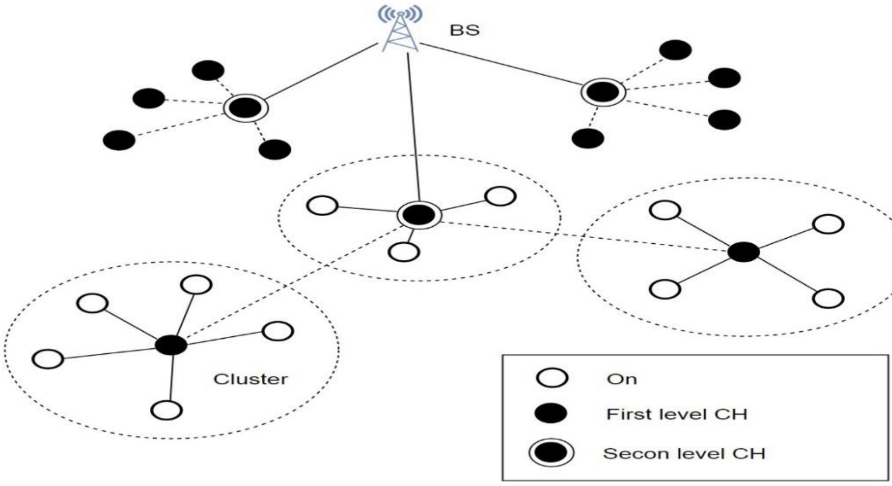

Figure 2-4: The Two-Tier Clustering Topology being illuminated in TEEN [31]

2.8.5 Energy-Balanced Unequal Clustering (EBUC) [30]

EBUC is a centralized approach that organize network in unequal clusters and CHs relay data of other CHs via multi-hop routing fashion. Particle swarm optimization algorithm PSO could be made at BS in order to have highly-powered sensors for selecting the Cluster Head and for shaping clusters with non-uniform fashion as seen in Fig.2-5. Clusters closer to the sink can be very small to consume less energy in the communication between head nodes and their members and, thus, the nodes are ready for data gathering at the sink. It consists of two phases: SP where sensors transmit their level of energy and location information to the sink which measures mean level of energy of each sensor and gets benefit of such data for determining CHs and their members. The sink evaluates the energy dissipated of a sensor at the end of the round utilized for the following round. As a result, sensors need not transmit the data messages to the sink station again. Inter cluster multi hop aspect depends on a cost function using the distance among head nodes, distance of relay CH to BS and residual energy of relay CH, finally BS broadcasts information about clusters and multi-hop routing. The second one is the SSP where head node broadcasts TDMA schedule to the cluster. A sensor node transmits the information to the head node in accordance with the agreed TDMA time slot. Cluster heads collect the information collected to be then sent to BS through multi-hop inter-cluster aspect.

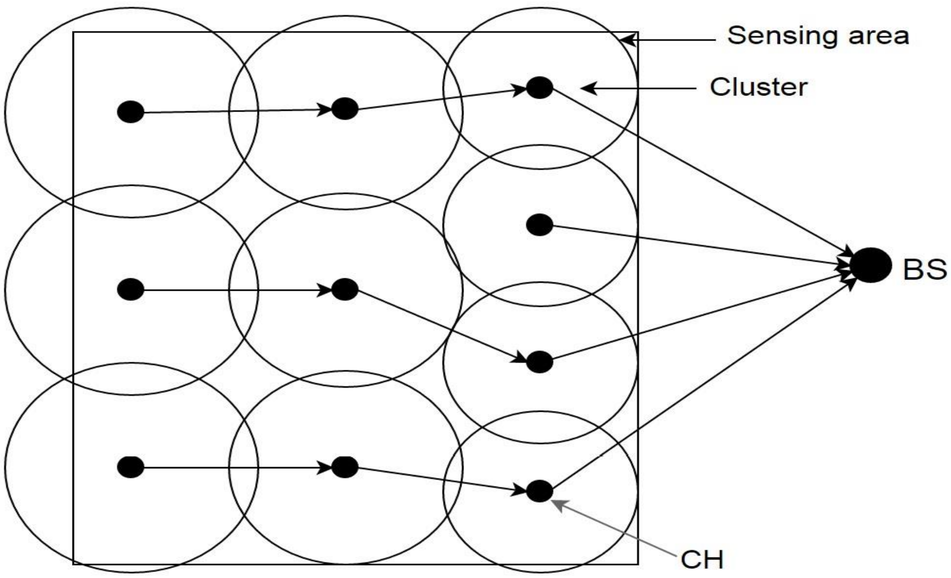

Figure 2-5: Cluster Formation in EBUC [30]

It seems that the protocol works only when the sink is situated away from the field already identified. Due to its difference in size with fixed time period, smaller clusters, compared to the nodes of bigger ones, begin transmitting more of the data to their CH and, at the same time, consumes more energy.

2.8.6 Power-Efficient Gathering in Sensor Information System Protocol (PEGASIS) [35, 36]

It was originally presented in 2001. It is an approach based on a chain supplying the enhancement over LEACH protocol. In PEGASIS, every sensor contacts with the nearest neighbor only and a node in a chain for every round is transmitted to the sink to decrease the power indulgence in each round. In contrast to LEACH, it uses multi-hop routing, instead of using multiple sensors, in terms of chains formation and choosing a sensor for the sink to be sent. Every node relies on signal strength of its adjacent node to compute its distance so that the closest node can be located. The leader node is usually chosen after the chain being formed depending on its residual energy; it can be regarded as a gateway between its chain and the sink and, at the same time, in charge of sending the data collected to BS.

2.8.7 Distributed Energy-Efficient Clustering (DEEC) [30]

DEEC is an energy-efficient clustering plan for heterogeneous WSNs. In this algorithm selecting a head node is probabilistic dependent upon the ratio of the remaining energy of every sensor and the average energy of the overall network. Therefore, the sensors having high remaining energy could get more possibilities for a head node to be elected than those with low-level energy. DEEC regards two-tier heterogonous network. The non-uniformity of sensors is dependent upon nodes power. Sensors can be divided into two kinds: *Advanced nodes* and *Normal ones*. The former, unlike the latter, have high primary energy. The preliminary and remaining energy of the sensors are taken into account for selecting a head node which, by its turn, need universal network knowledge. To be away from that, a perfect value of network life-time is evaluated to be helpful to measure the reference energy that is consumed by every sensor during every round.

2.9 Base Station Mobility in WSN

Lately, sink substitution has begun to be deemed as an approach for improving the performance of WSNs in terms of energy, the amount of data transferred in a data channel in a second, in addition to retrieval time. Normally, the sink is situated outside the sensing area. Therefore, all other sensors would employ high power for their data to be sent to the remote sink and this will lead to higher energy consumption to be sent. In certain situations, the sink can be put in the core of a sensing area. Yet, in this case, a sensor founded at the edge of the sensing area, unlike sensors that lie near the sink, would expend more energy for the data to be sent to the sink. This will generate unbalanced energy consumption among all sensors and, above that, decrease the network energy efficiency. To have a better situation, the most convenient site of the sink is the main concern in this case since it is usually a node with high processing power, a high storage capacity, making no energy restriction, the sink can be used to gather data from each sensor in the sensing area by getting closer to the sending node [37].

As shown in Fig.2-6, there are two main categories of mobility models for the sensors: Homogenous and Heterogeneous models. Both of them were further sub-classified so that each studied mobility model can be grouped properly [38].

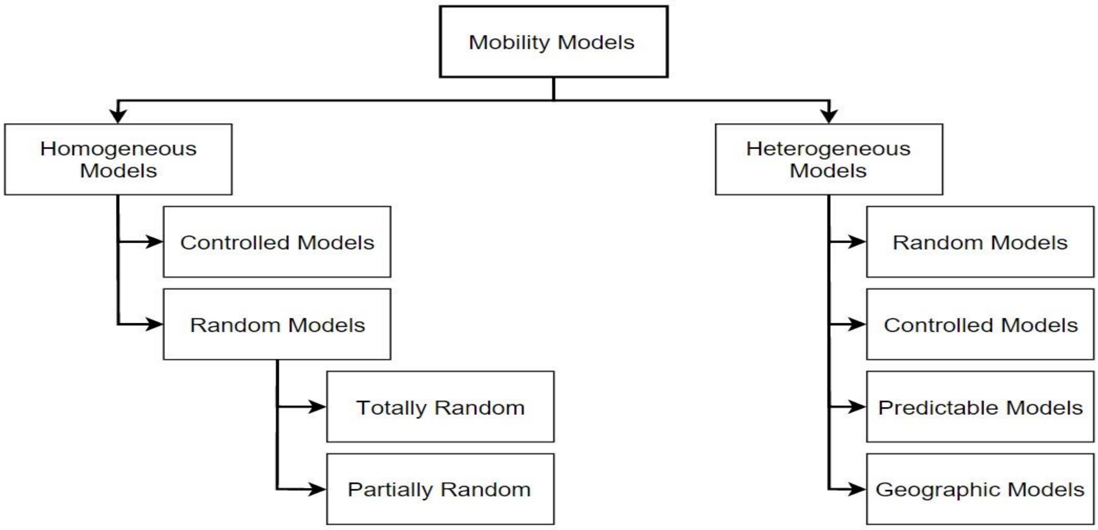

Figure 2-6: Classification of Mobility Modules [38].

2.9.1 Homogenous Mobility Models [38]

It is dependent upon having some moving sensors employing similar movement approach to get into the network. It can be observed that this category can be divided into two main sub categories namely, random models and controlled models.

A. Homogenous Random Mobility Models

Mobility models can be classified into two categories:

- **Partially Random**

  In this method, moving nodes are dependent upon each other to detect the direction of the movement. Here, there are two groups of nodes where each group has a leader devoted to it. In each group, the leader is moving at random and select a destination with velocity.

- **Totally Random**

  The mobility models that can be classified under this category are nomadic, virtual track-based, reference velocity group and structured category. Hence, the groups of the moving nodes in accord with these models travel randomly within the environment in a way that such sensors spread.

B. Homogenous Controlled Mobility Models

In this category there are two kinds of models: the Column mobility and group force. Controlled mobility model is usually used when the movement of nodes is restricted by certain characteristics of environment such as barriers**.**

2.9.2 Heterogeneous Mobility Models

It is called so because the network is composed of two kinds of nodes: static and dynamic. In this model, a moving node moves separately of any other nodes found in the network.

A. Heterogeneous Random Mobility Model

It is a very simple model, based on classifying the movement of the moving node into two periods: pause and motion. In the period, the moving node would select the direction randomly and begin moving with a random speed. The mobile node gets into the pause period after reaching the new position and remains in that position for the same period of time used previously. Despite being simple, this model suffers from poor selection of velocity and uniform distributions.

B. Heterogeneous Controlled Mobility Models

It was originally presented to be a substitute to the random mobile nodes movement. The whole performance of the WSN can be significantly improved. Nevertheless, sensors could suffer from buffer abundance while awaiting the mobile base station to be in its communication range.

C. Predictable Mobility Models

It has been introduced where the path used by the mobile sink is known by sensors. Hence, a sensor node gets into sleep mode to save energy until the anticipated time for data transfer is set. Then, the sensors go into active mode and begin transmitting its data to the mobile BS. By using those models, network lifetime can be extended as sensors turn to sleeping or power saving mode. This take place when the mobile element is not predicted to be in its proximity, this model are considered in this thesis.

D. Geographic Mobility Models

Restricting the motion is another way to control the movement of mobile nodes in accord with the geographic nature of the environment that a mobile node or a sink spreads in. In these models, the obstacles and other barriers such as reaching the end of a path or the boundaries of the studied environment are considered by the mobile base station.

Both the controlled and geographic mobility models can be utilized when mobile nodes are needed to be confined within the area of deployment of the network and when the movement of mobile nodes is controlled by certain characteristics of environment such barriers.

Finally, it can be concluded that homogenous mobility models have the ability to be used in case of a necessity to modify the network so as to get the best coverage and connectivity of the environment while, heterogeneous mobility models can be used when it is necessary to have a mobile base station or those moving within the network to gather information from static sensors**.**

2.10 Zone Routing Protocol (ZRP)

It is a composition of two protocols, proactive and reactive so it called hybrid protocol. It uses good characteristics of the both protocols. ZRP have been introduced to reduce the overhead control of PRP and minimize the retrieval time produced from path finding in RRP [39].

PRPs attempt to continuously estimate the paths in a network. So that when a packet needs to be forwarded, the route is already known and can be immediately used, example of proactive protocol is LEACH. Reactive protocols, however, arouse routes definition method upon request (on demand). Hence, in case a path is required, some global search methods are used. AODV protocol classified under the reactive protocols. The benefit of the proactive plans is that, once the route is required, little delay could be expected till the route is specified. In reactive approaches, due to the fact that route information is unavailable as soon as a data-gram is taken, the delay to determine a route can be quite significant.

The ZRP restricts the range of the proactive method to the node's local neighborhood. However, in spite of being universal in nature, searching throughout the network is done by querying efficiently selected nodes in the network, in contrast to that of all the network nodes.

2.10.1 ZRP Overview [40]

The architecture of the ZRP shown in Fig.2-7. It is composed of the following elements:

- Network layer: the existing Protocols are "IP Internet Protocol" and "ICMP Internet Control Message Protocol"
- ZRP Entities are "IARP intra-zone routing protocol, IERP inter-zone routing protocol and BRP border cast resolution protocol".
- Additional protocols are "NDM Neighbor Discovery/Maintenance Protocol"

Note, it is assumed that basic neighbor discovery operation is implemented by the MAC layer. Thus the NDM protocol remains unspecified here.

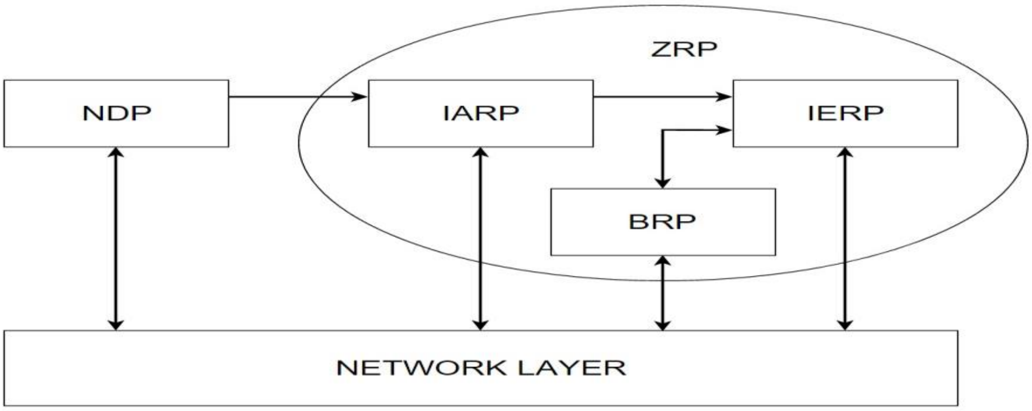

Figure 2-7: ZRP Architecture [40]

2.10.2 IARP Intra Zone Routing Protocol

The IARP may be derived from a variety of existing globally PRP that provide a complete view of network connectivity [40]. ZRP's IARP depends on an underlying NDP to identify the presence and absence of neighboring nodes, and therefore, link connectivity to the nodes. The data processing about neighbors is required to construct a routing zone of a given node. A neighbor is confined as a node with which direct communication can be organized. Neighbor discovery is attained by either the Intra zone Routing Protocol or simple “Hello” packets. Node discovery is attained with periodic transmission of beacon packets or with indiscriminate snooping on the channel to identify the communication hustle [41].

2.10.3 IERP Inter Zone Routing Protocol

The IERP is responsible for finding routes between nodes located at distances larger than the zone radius. The IERP is distinguished from standard flood-search query/response protocols by exploiting the routing zone topology. A node is able to respond positively to any queries for its routing zone nodes [40]. The IERP uses a RRP for the nodes communication in distinct zones. Route queries are sent to peripheral nodes using the BRP Since a node does not resend the query to the node in which it received the query originally, the control overhead is significantly decreased and excessive queries are also underrated [41].

2.10.4 Border cast Resolution Protocol (BRP)

The Border cast Resolution Protocol (BRP) provides the border casting packet delivery service. The BRP uses a map of an extended routing zone, provided by the local (IARP), to construct Border cast (multicast) trees along which query packets are directed. (Within the context of the hybrid ZRP, the BRP used to guide the route requests of the global (IERP)). The BRP uses special query control mechanisms to steer route requests away from areas of the network that have already been covered by the query. The BRP is a packet delivery service, not a full featured routing protocol. Border casting enabled by local (IARP) and supports global (IERP) [42].

2.11 Review of Fuzzy logic Systems

Fuzzy logic is based on the idea that all things admit of degrees. It attempts to model the sense of words, decision making and the common sense.

Unlike Boolean logic having two values, fuzzy logic is multi-valued and uses continuum of logical values or degrees of membership between 0 and 1[43].

Fuzzy logic approach has been successfully applied to a broad scope of applications in various domains .There are mainly two types of a ruled base fuzzy system. One is the Mamdani type FLC, and the other is the Takagi-Sugeno (TS). Structure for the both types are the same, the only difference is related to the definition of the output in the consequent field of the rule base. TS type uses a crisp values for the output in the rule base, where it is a fuzzy linguistic in the case of Mamdani type [44]. This thesis uses the most commonly used fuzzy inference technique (Mamdani method) as shown by Fig.2-8 the FIS which performs its task in four steps:

i. Fuzzification of the input variables: taking the crisp inputs from each of these and determining the degree to which these inputs belong to each of the appropriate fuzzy sets.
ii. Rule evaluation: taking the fuzzified inputs, and applying them to the antecedents of the fuzzy rules.
iii. Aggregation of the rule outputs: the process of unification of the outputs of all rules.
iv. Defuzzification: the input for the defuzzification process is the aggregate output fuzzy set and the output is a single crisp number.

During defuzzification, it finds the point where a vertical line would slice the aggregate set *chance* into two equal masses. The COG (Center of Gravity) is calculated and estimated over a sample of points on the aggregate output membership function, using the following formula: [43]

$$COG = (\sum \mu_A(x) * x / \sum \mu_A(x)) \quad (2.3)$$

Where, x is any element in the universe of the discourse and $\mu_A(x)$ µ is the membership function of set *A*.

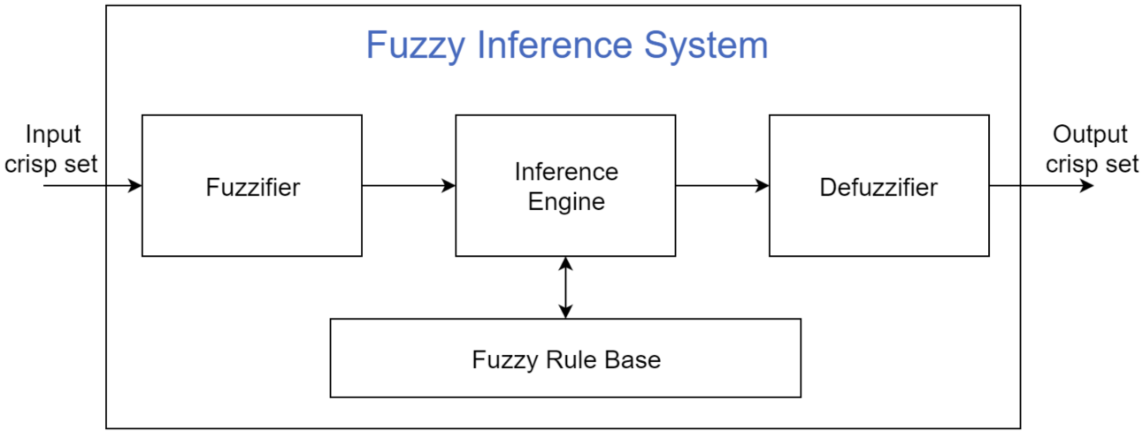

Figure 2-8: FIS Block [44]

Chapter Three

Proposed WSN Clustering Protocol

3.1 Introduction

This chapter introduces the design and the software simulation procedures of the proposed WSN's clustering protocol while studying the impact of BS movement on the network lifetime. A brief introduction on WSN simulation tools in general, with explanation behind NS2 choosing is presented. A fuzzy logic based cluster head selection is proposed and implemented on zone routing protocol (CHFL-ZRP). Based on this, the chapter focuses on presenting two proposed protocols, in order to cover the environment of fixed nodes & mixed nodes (fixed and mobile together as in MCHFL-ZRP).

3.2 WSN Simulation Tools

There are many different and possible platforms for the simulation and testing of WSNs routing protocols, choosing the right one is a very important task. A comparison between some of the most popular WSN simulators is summarized in Table 3-1. WSN simulators fall under one of the following three categories: Monte Carlo, Discrete-Event and Trace-Driven simulations. The second and third one, are commonly used in WSN. The widely used simulator in WSNs is the discrete-event, because of its easiness in simulating multi jobs that can run to various types of wireless sensor nodes. It includes a long list of pending events and global variables, which are simulated by many routines, such as initial, input, trace, and output routines [45].

Table 3-1: Network Simulator Comparison [46].

No.	Trend	Net Simulator Type			
		OMNET++	**NS-2**	**GloMoSim**	**NCTUns**
1.	**Simulation Technique**	Discrete Event	Discrete Event	Discrete Event	Discrete Event
2.	**Interface**	C++, NED	C++, OTCL	C	C
3.	**GUI**	Yes	No	Limited	Yes
4	**Modules Available**	Wired, Wireless and Ad-Hoc Networks	Wired, Wireless, Ad-Hoc and WSN	Wired, Wireless and Ad-Hoc Networks	Wired, Wireless and Ad-Hoc Networks
5.	**Open source License**	Yes	Yes	Yes	Yes
6.	**Emulation Support**	Limited Support	Limited Support	No	Yes
7.	**Extendable**	Yes	Yes	Yes	Yes
8.	**Scalability**	Large	Small	Large	Medium
9.	**Documentation and User Support**	Medium	Good	Poor	Good

A comparison detail between WSN simulators also presented in Appendix-A. In this thesis, NS-2 is selected as the appropriate simulation tool because [45]:

- NS-2 has an extensibility feature that popularly went far for implementing WSNs.
- The design approach is object-oriented; hence, it permits for direct formation and testing of novel protocols.
- It furnishes a set of important features for WSN deployment; such as battery models, channels for sensor, light protocol stacks, support of hybrid simulation and generation TCL language for setting scenarios.
- It supports a visualization tool named NAM (Network Animator).
- A high number of different protocols available publically since the NS-2 provides an easy way for developing protocols.

3.3 Network Simulator V2 Platform:

NS-2 simulator was established under the project of Virtual-Inter Network-Test-bed (VINT) in 1995 [47]. As a tool, which is an open source, NS-2 is useful in supporting and developing different network types, routing protocols, traffic models and various network elements. Simulators help in saving time, energy and money in designing a network scenario, as there is no need for buying elements and connecting them together to test an algorithm [48]. NS-2, considered as a discrete event simulator, object-oriented, written in OTcl with C++, and open source that keeps the cost of simulation [49]. Simulation kernel, models, protocols and other components are implemented in OTcl, but are also reachable from C++, OTcl scripts are used for configuring the simulator, network topology build up, identifying scenarios, recording simulation results, etc. [50]. The reason behind using two languages is that the C++ can efficiently implement the design, but it is not easy to visualize and show graphics. The simplified NS-2 user's view is summarized by Fig.3-1 [47].

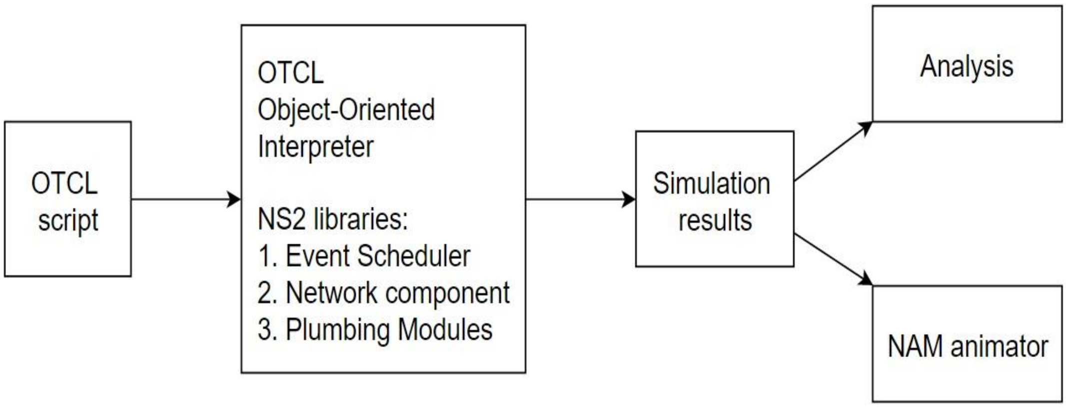

Figure 3-1: Simplified User's View of NS2

3.4 The Proposed WSN Clustering Protocol

In this thesis, an energy efficient algorithm for cluster-head selection is proposed, and so far named as (CHFL-ZRP). It is composed of two phases: formation of clusters, which is performed in the set up phase, while the data collection is performed in the steady state phase. To preserve the energy of WSN, design approaches based on clustering is a good solution. A small amount of selective nodes called Cluster Heads are allow to communicate with the base station. The selection of cluster head nodes are performed in this thesis by using the fuzzy logic approach. It is based on three input identifiers: energy, centrality and concentration of each node. The sink or the BS that gathers the data from CH nodes assumed to be mobile, rather than being fixed, as used in most of clustering protocols. More details about the operation of the proposed algorithm is explained in the next sub-sections.

3.4.1 CHFL-ZRP

It is a hybrid (proactive-reactive) clustering routing protocol, intra-cluster communication, a proactive single-hop and inter-cluster communication, a reactive multi-hop, which considered as a centralized clustering scheme.

The operation of the CHFL-ZRP is divided into two phases: the first one is the set-up phase (cluster head selection and cluster formation) and the second one is the steady state phase (data gathering phase).

a) Setup Phase:

Throughout the setup phase, the cluster-heads are determined by using fuzzy logic approach. Then the clusters are formed accordingly. Initially, the field of interest is divided into k equitized clusters. Concerning the density and the layout of nodes in the network, the distribution of the node is made randomly in the field.

The BS is responsible for initiating the order of starting the setup phase. The decision will be based on one of the following situations:

- The first (initial) setup phase at round zero.
- A new set up phase according to a cluster head request, this may take place during any round as the energy remained in CH become less than a specified threshold level ECH_{th}:

$$ECH_{th}(j) = \propto \times ECH_r(j) \tag{3.1}$$

Where ECH_r represents the current energy remaining in head node (j) and $\propto$ is taken to be 0.5 for best performance by trail and error. The setup phase is composed of two steps: the first is the head node selection and the second is the cluster formation.

1-Cluster Head Selection

Initially the square area of the WSN field is divided into (k equal size) clusters. In regards to the density and the layout of nodes in the network, the distribution of the node is made randomly in the field as shown in Fig.3-2.

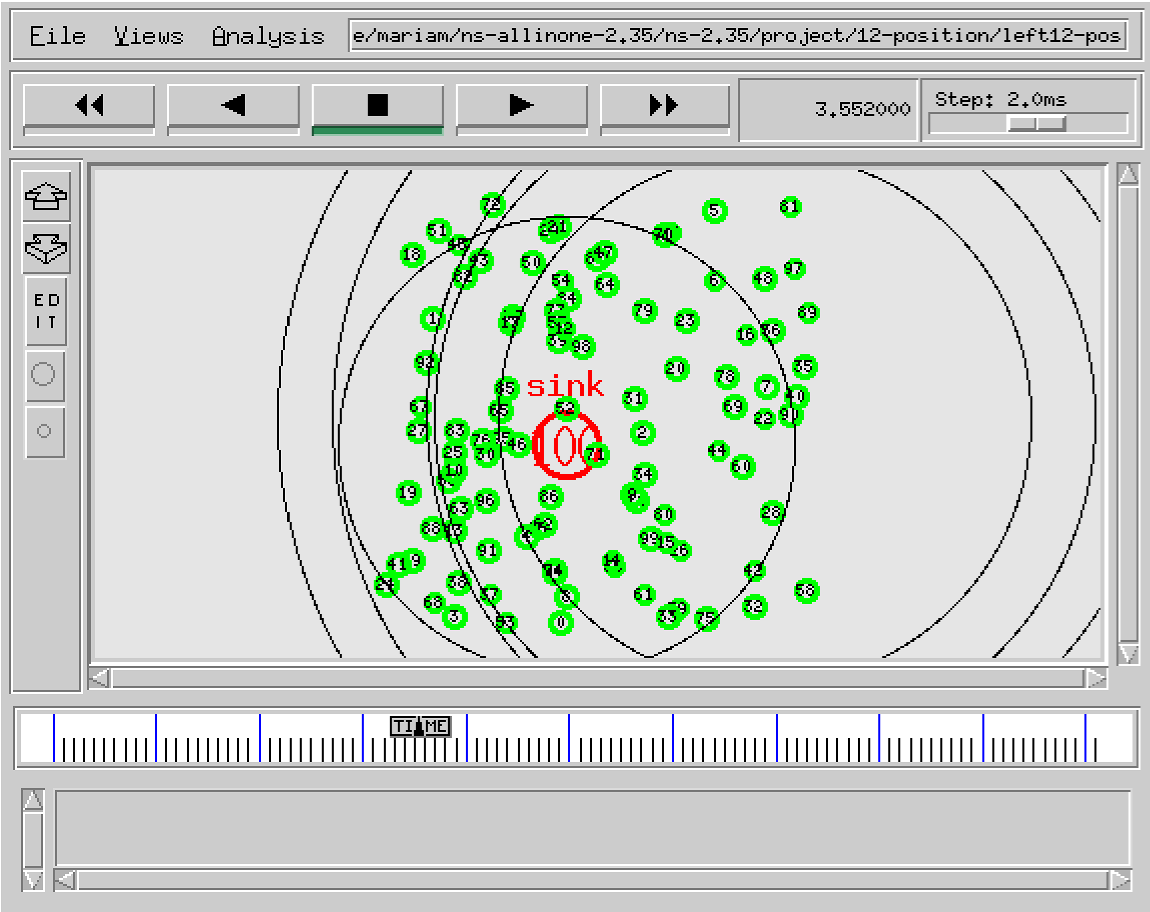

Figure 3-2: Network Topology and Node Distribution

The following steps are performed during this stage for each node (S_i) to determine:

A. Node's location information: each node is assumed to be capable to find its location by using the GPS, using the following Eq.:

$$L(S_i) = (X_i, Y_i) \qquad \forall\ i = 1, \dots . n \tag{3.2}$$

Where $L(S_i)$ is the location of node S_i, X_i & Y_i is the position of the node in the X & Y-axis respectively and n represents the sensor nodes deployed in the field, by performing the following function:

```
double
ZRPAgent::update_position();{
X=iNode->X();
y=iNode->y();
return x;
return y;
}
```

B. The residual energy: each node is capable to determine its residual energy $E_r(S_i)$. The residual energy is tracked and calculated inside the WSN. When a request is buildup to read the residual energy, the following function is performed:

```
double
ZRPAgent::update_energy();{
Er(Si) =iNode->energy_model()->energy();
return Er(Si);
}
```

C. Concentration: A "Hello" packet is developed for neighbor discovery on the ZRP agent. This packet will be used whenever a request is made to build a neighboring table inside the transmitting node. The node that receives the hello packet of other node is the neighbor of that node. The concentration $CO(S_i)$ is determined at each node based on the neighbor table generated from "Hello" packet as mentioned earlier. It is calculated according to the following developed equation:-

$$CO(S_j) = \frac{n_c(S_j)}{D(S_j)} \tag{3.3}$$

$$D(S_j) = \sum_{i=1}^{n_c(S_j)} d_j \tag{3.4}$$

$$d_j = \sum_{i=1}^{n_c} \sqrt{\left(x_j - x_i\right)^2 + \left(y_j - y_i\right)^2} \tag{3.5}$$

Fig.3-3 shows the relation for the nominated node (the one to be a cluster head (S_j)) and the other nodes from the neighbor table which are lying within its transmission range (R) where:

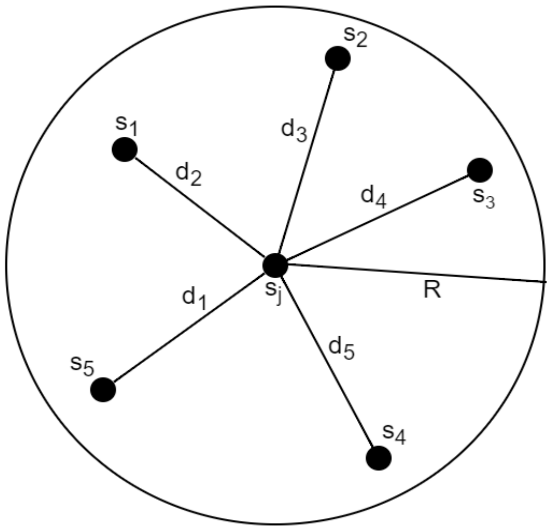

Figure 3-3: The CH and Other Regular Node within Its Transmission Range

n_c= Indicates the number of nodes inside the cluster j.

$D(S_j) =$ Indicates the summation of the distances d_j between S_j and its neighbors S_i.

x_i & y_i Represent the x and y positions of S_i nodes in a specified cluster j.

x_j & y_j Represent the x and y position of S_j CH nodes in a specified cluster j.

Whenever the calculated concentration $CO(S_i)$ is high; this indicates that number of the selected neighbor nodes (S_j) are large, hence the communication distance became smaller which resulted in consuming less energy

D. Centrality of the node: Centrality is calculated for each node as the difference between the location of node (i) and the center of the cluster (j) of squared distances from other nodes to the candidate node using the following equation:

$$CE(S_i) = \sqrt{\left(x_{C_j} - x_i\right)^2 + \left(y_{C_j} - y_i\right)^2} \quad (3.6)$$

$$\forall\, i \neq j \text{ where } i = 1, \ldots . n_{C_j}$$

$$j = 1, \ldots . . k$$

Where x_{C_j} & y_{C_j} is the center of a specified cluster j. The lower distance means higher value of centrality, resulting in the lower amount of energy required to transmit the data.

The determined information advertised from the nodes to the BS through the developed (location-energy-concentration) packet according to the format shown in Fig.3-4. It will be used to transmit energy, location and concentration of each node.

Packet Type	No. of Neighbors	Seq. Number
Source Address	Destination Address	
Energy		
X-Position		
Y-Position		
Time Stamp		

Figure 3-4: Packet Format Generated By Each Node For CH Selection.

Where:

- Packet type: 16 bits length which is used to specify the type of received packet.
- Sequence number: 8 bits length. Every time a new packet is transmitted, the sequence number is incremented.
- No. of neighbors: 8 bits length. It is used to point the number of neighbors indicated from the neighbor table of each node.
- Source address: 16 bits assigned to the source ID at which the packet is generated.
- Destination address: 16 bits assigned to the node ID of the received side.
- Energy: 32 bits length. It is used to save the current residual energy of the nodes.
- X&Y-position: 32 bits field is used to assign the position of the nodes on the x-axis and y-axis at the WSN field respectively.

- Time stamp: 32 bits length. It is assigned at the time the packet is to be transmitted.

The fuzzy logic algorithm is started at the BS in a centralized manner after receiving the (location, energy and concentration) packet of each node.

Gupta et al. [43] introduced a method to overcome the problems associated with LEACH. It utilizes three identifiers in the cycle of the cluster-head selection. The fuzzy inference model is characterized by the type of the inference engine. In this thesis Mamdani model is chosen due to its simplicity as mentioned in chapter two. The four stages are performed as follows:

Step 1: Fuzzification

After the BS received the information packet from all the nodes, the fuzzy system starts predicting the chance of this nodes by applying these crisp values μ_{Er}, μ_{CO} and μ_{CE} in accordance to a defined fuzzy sets assigned to each variable as shown in Fig.3-5. The type of membership functions are chosen to be of triangles form, for simplicity.

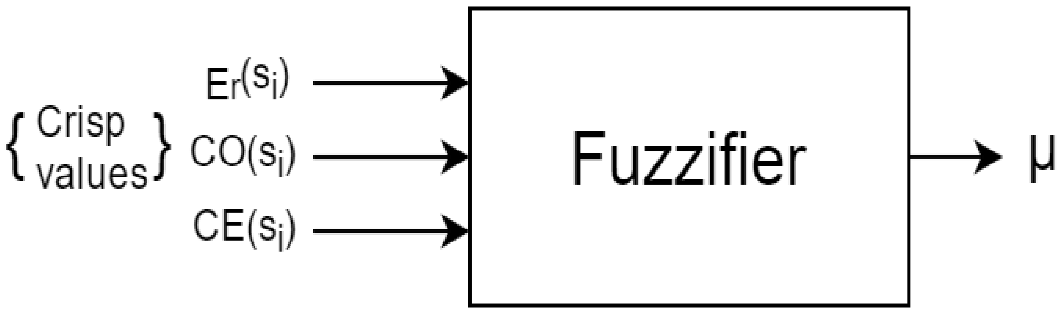

Figure 3-5: Fuzzifier Block Diagram

Three fuzzy sets are defined for each of the input variables $(E_r(S_i), CO(S_i)\ \&\ CE(S_i))$ as shown in Fig.3-6 to Fig.3-8, the UOD of the residual energy taken to be varied between [0,3] as minimum and maximum values respectively, while the centrality and concentration tested in the formed figures for 4-clusters case study. Where μ_{Er} represents the membership function of the energy input variable $E_r(S_i)$, μ_{CO} is membership function of the concentration input variable $CO(S_i)$ and μ_{CE} indicates the membership function of the centrality input variable $CE(S_i)$. The generated values of the memberships are passed to the rule base which is represented by Table 3-2.

The "chance" which represents the output is defined by seven membership function as shown in Fig.3-9 for best qualification.

Step 2: Rule Base Evaluations

Evaluation of the rule base is computed after the fuzzification process on the linguistic variables.

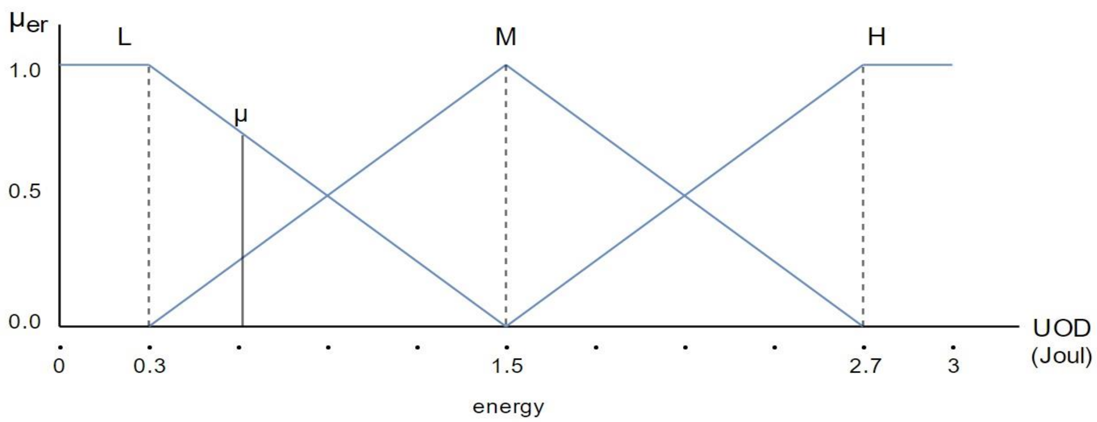

Figure 3-6: The Energy Fuzzy Sets.

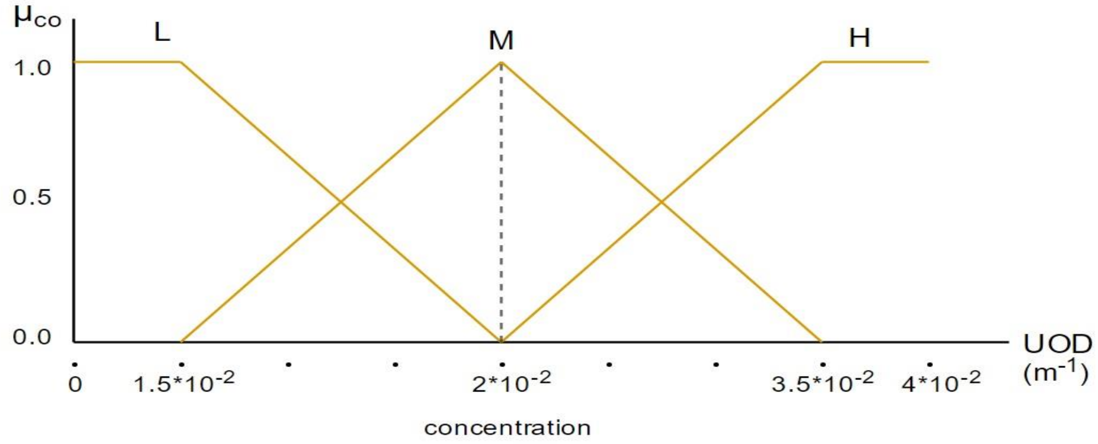

Figure 3-7: The Concentration Defined Fuzzy Sets.

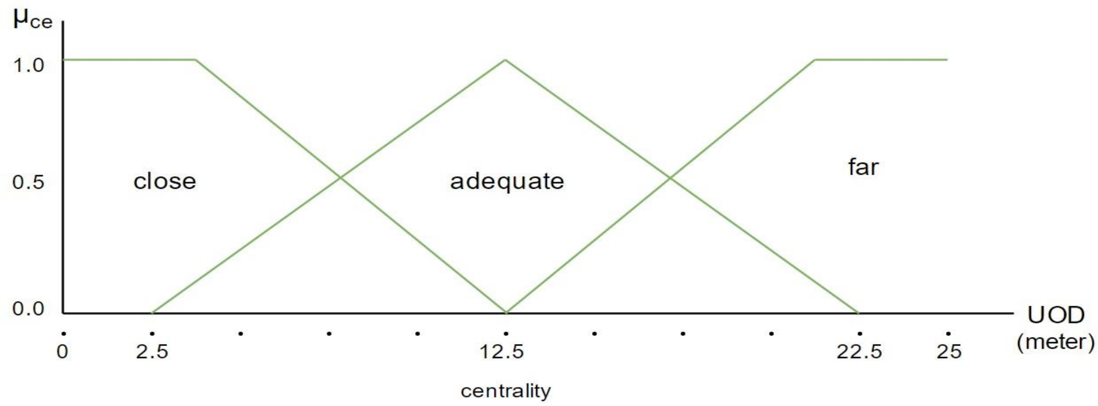

Figure 3-8: The Centrality Defined Fuzzy Sets.

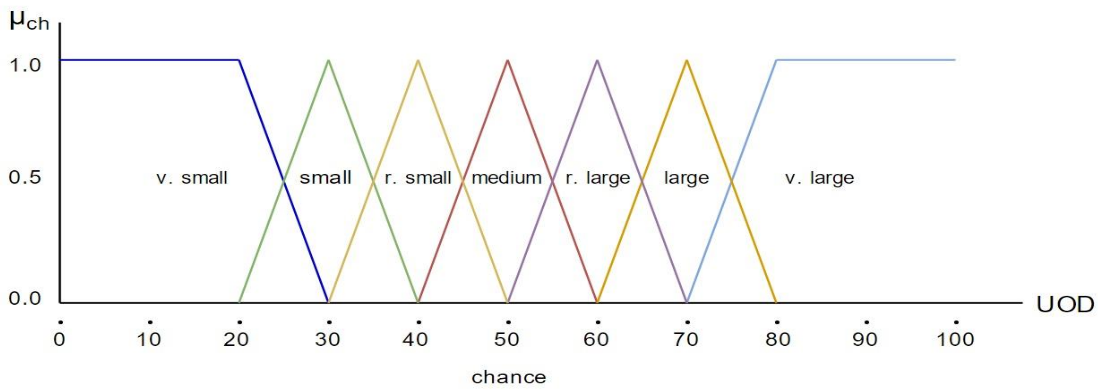

Figure 3-9: The Chance Defined Fuzzy Sets.

Table 3-2: Fuzzy Rule Base Table [43].

	Centrality	Concentration	Energy	Chance
1	Close	Low	Low	Small
2	Adequate	Low	Low	Small
3	Far	Low	Low	very small
4	Close	Medium	Low	Small
5	Adequate	Medium	Low	Small
6	Far	Medium	Low	Small
7	Close	High	Low	rather small
8	Adequate	High	Low	Small
9	Far	High	Low	very small
10	Close	Low	Medium	rather large
11	Adequate	Low	Medium	Medium
12	Far	Low	Medium	Small
13	Close	Medium	Medium	Large
14	Adequate	Medium	Medium	Medium
15	Far	Medium	Medium	rather small
16	Close	High	Medium	Large
17	Adequate	High	Medium	rather large
18	Far	High	Medium	rather small
19	Close	Low	High	rather large
20	Adequate	Low	High	Medium
21	Far	Low	High	rather small
22	Close	Medium	High	Large
23	Adequate	Medium	High	rather large
24	Far	Medium	High	Medium
25	Close	High	High	very large
26	Adequate	High	High	rather large
27	Far	High	High	Medium

The fuzzy rules are calculated using the produced membership values $\mu_{Er}(S_i),\ \mu_{Co}(S_i)\ and\ \mu_{CE}(S_i)$. Evaluating the premise part of each fuzzy rule using the logical (AND) operator is simply calculated using the conjuction T-norm of the product operator. Hence, a single premise membership value representing the degree of fulfillment (*dof*) or rule firing strength is produced.

After the *dof* has been calculated for each rule, the consequent (result) of every rule which represent the chance will take the value of the *dof* , hence:

$$\mu_{ch}(S_i) = \mu_{Er}(S_i) * \mu_{Co}(S_i) * \mu_{CE}(S_i) \tag{3.7}$$

Where $\mu_{ch}(S_i)$ represents the membership degree for node S_i chance. A sample of one of the rules in the rule base is in the following form:

Rule 12:

[IF Centrality is Far AND Concentration is Low AND Energy is Medium THEN Chance is Small].

Step 3: The Rule Outputs Aggregation

Aggregation is the process of unification of the outputs of all rules. The aggregation is a step of combining all fuzzy outputs obtained from rule base, then a new fuzzy set is generated for the chance list.

Step 4: Defuzzification

This step combines the consequent (result) of all the fired rules (fuzzy outputs of the rules) into one crisp value. This output is representing the chance for the node (i) to be a CH for the inputs of its concentration, centrality and energy. This is done by using the center of gravity *(COG)* defuzzification function as given by Eq. (2.3).

Finally, the sink broadcasts the cluster-head ID list packet resulted from fuzzy calculation in addition to its current position. All nodes receive this message. Any node finds a match will consider itself a CH for the instant round. All other nodes will remain as ordinary nodes. Cluster head selection steps are performed by blocks (1-9) of the flow chart shown in Fig.3-10.

2- Cluster Formation

After the determination of the CH nodes, the base station announces to the regular nodes to select in which cluster to join as a member of its group. It will select the nearest head node by calculating the distance between itself and the CH list received from the BS node according to

$$v_{ij} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \ , \ \forall \, i \neq j \, , \quad i = 1, \ldots n+1$$

$$j = 1, \ldots k \qquad (3.8)$$

Where v_{ij} represents the distance between node (i) and CH node (j). It will send back its decision to the corresponding CH to be a candidate of its cluster. When the nodes send its decision, If the node is nearest to the BS (node $n+1$) than to any CH, then it will join the BS directly. After the setup phase is complete, the steady state phase is started.

b) Steady State Phase:

At this stage all ordinary nodes are triggered by the BS to send their data packet to the appropriate CH. Data gathering phase is executed in steps (10-14) as shown in the flow chart of Fig.3-10. This phase demonstrates the roles of Inter-cluster communication where:

Each CH node sends its aggregated generated data packets to destination (BS) or to the next hop CH in accordance to the minimum distance from each.

When the CHs nodes receive the hello packet message from the BS, it will calculate the distance between itself and the BS, if BS lies in its communication range it will communicate with it directly. The nodes will be switched to sleep mode operation, while the BS is in movement, until the BS broadcasts hello packet containing its new location. Then all CH nodes will update the location of the BS inside its routing table.

Inter-cluster communication will be accomplished by using the reactive approaches. When the BS node is paused for a specific time period, it sends advertisement hello packet.

Any node that receives the beacon packet transforms its state from sleep to active to be ready to transmit data to the destination either directly to the BS or via intermediate CHs (multi-hop inter cluster communication). Therefore it is easy to identify route discovery to the destination. The source head node sends a packet to destination cluster. In destination, the destination head node receives a packet from source head and then transmits a packet to BS node.

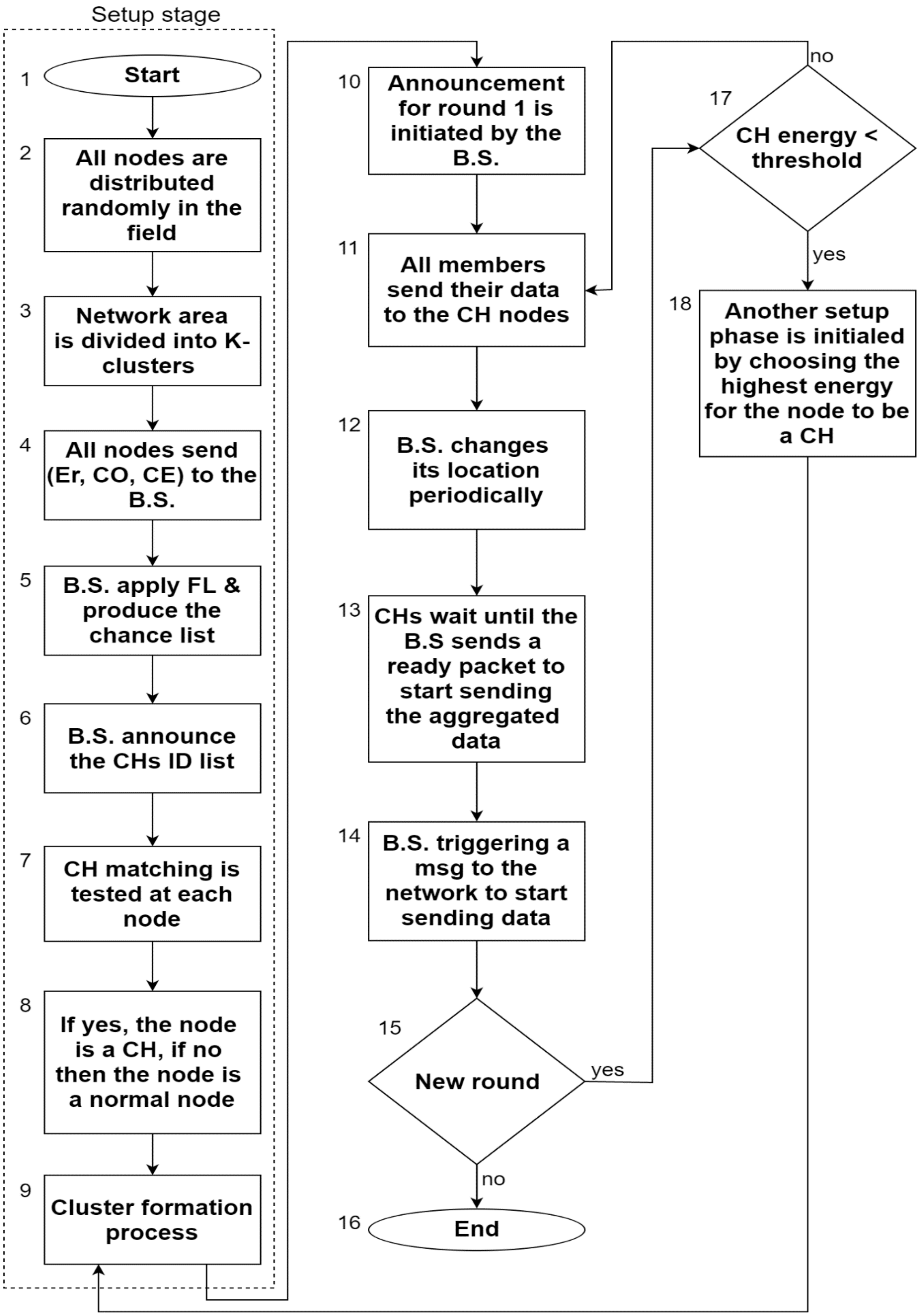

Figure 3-10: Flow Chart Summarizing CHFL-ZRP Operation

3.4.2 MCHFL-ZRP (For Mobile Sensor Nodes):

This protocol is a modification on CHFL-ZRP where it works for fixed and mobile environment. When the sensor nodes are changing their position, the network's topology structure cannot be determined because the cluster formation is changed. Due to mobility existence, the route may broke at any time. So each node has to have enough information either to communicate with the sink or a cluster head.

There is a problem associated with the mobility that need to be solved which appears when the nodes are able to move, the route from normal node to CH may get broken, so the sensor node may not be able to reach the destination. And also the node may moves to a far new location exceeding the transmission range of its head, thus, will lead in packets losing [51].

On fixing the above problems a clustering timer is introduced C_t. Initially the protocol assumed to work with fixed environment; every clustering timer, the sink broadcasts a request packet message to all the sensor nodes. As soon as they receive the message from BS, they all begin to move from their original position towards the new position then send their energy levels & new locations to the sink station for new re-clustering.

When the moved node is a CH node it will send announcement non-CH packet to its members. The sink saves the new location and energy level, BS re-calculates fuzzy logic algorithm to re-select a new CH node and then start the operation from (step 4 in the flow chart) shown from Fig.3-11.

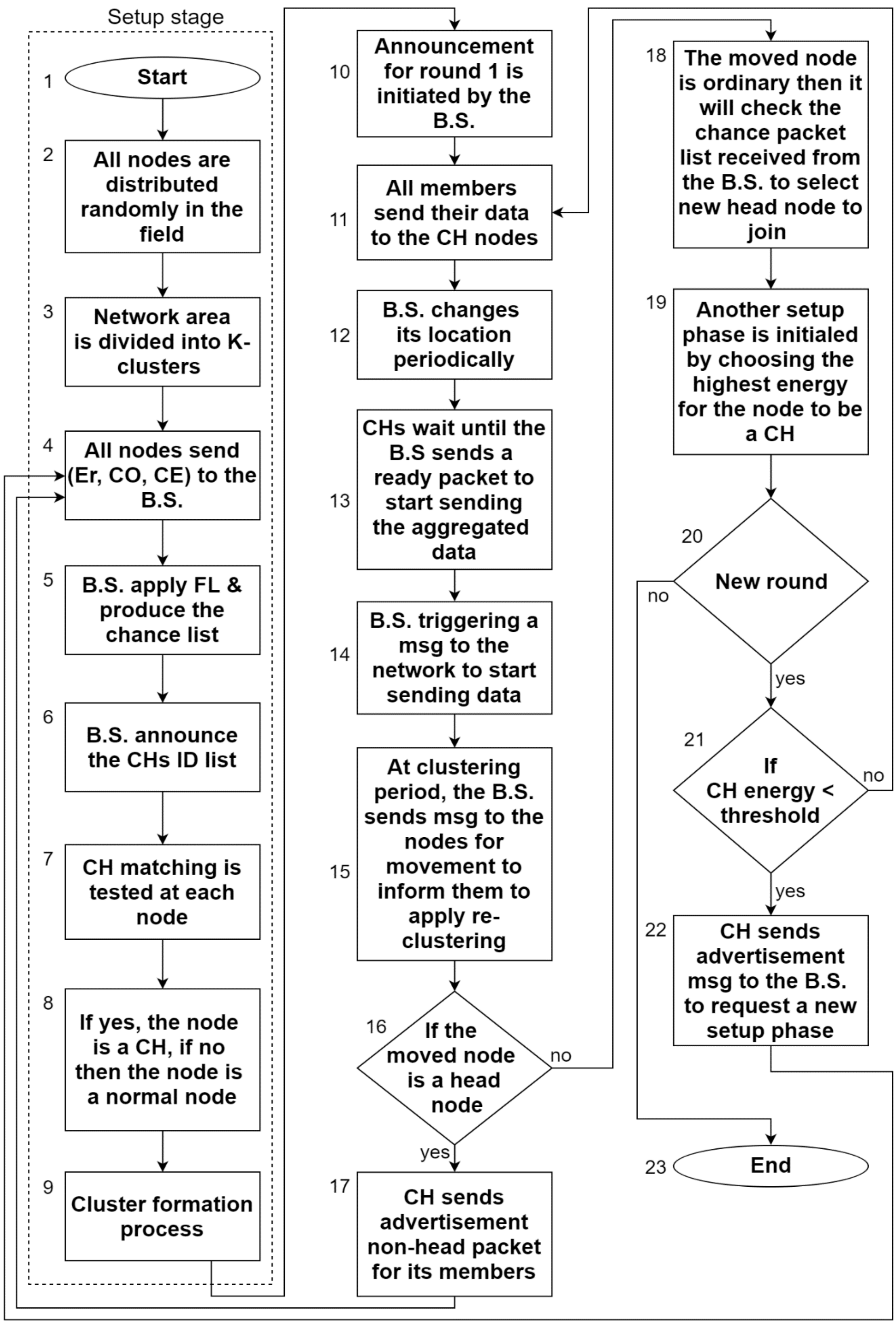

Figure 3-11: Flow Chart Summarizing MCHFL-ZRP Operation

If the regular node is the moving one, then it recalculates the best new CH to join with by checking CH-list it previously received from the BS, using Eq. (3.6). The moving node should send a CH decision packet to inform the corresponding CH, to be a new member of its cluster. These stages tracked from (step15 through 18) in the flow chart of Fig.3-11.

CHFL-ZRP differs from MCHFL-ZRP in applying the fuzzy calculations where the first one applies it only at the first round while the second one re-calculates fuzzy algorithm if the head node moved to another cluster as shown in the flowchart of Fig.3-11, the second difference is in supporting mobility in MCHFL-ZRP.

3.5 Sink Mobility Pattern

A predictable mobility pattern is considered in this protocol to show the enhancement in the lifetime of the network when sinks move on a predetermined path. It moves along the surroundings, of a hexagonal shape. Multi-test cases are examined for data aggregation when BS stops in the hexagon's vertices, either to clockwise or anti-clockwise movement. Fig.3-12 shows the mobility pattern. These pattern of hexagonal movement are tested for small, medium & large diagonal (hexagonal diagonal HD) where:

Small hexagonal HD_S =XX (3.9)

Medium hexagonal HD_M =2XX (3.10)

Large hexagonal $HD_L = 3XX$ (3.11)

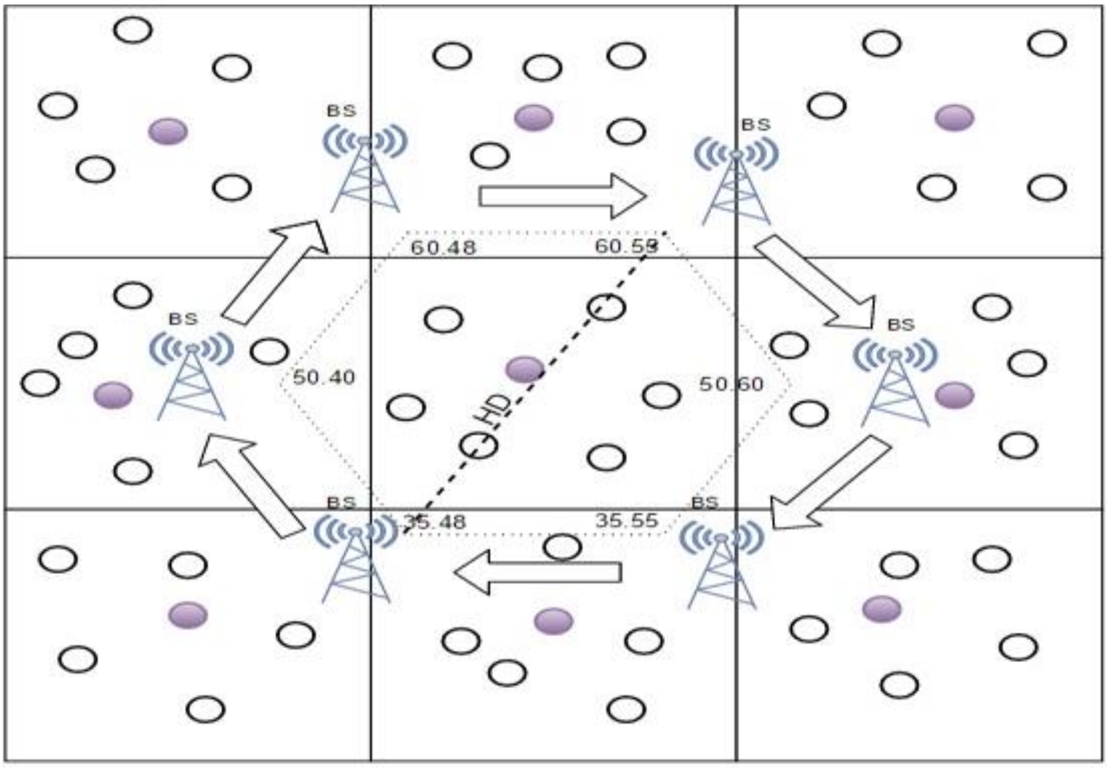

Figure 3-12: BS's Movement

3.6 Implementation of the Developed Packets

The overall developed work implemented inside NS2 by utilizing its environment for the employment of each task in proportion to the appropriate application programming language. Fig.3-13 shows the implementation overview for the overall protocol. The overall developed packets for achieving the fully proposed work with its various scenarios can be summarized here:

a. Sensors generated packets: represent two packets generated from the sensors:
   i. One to the CH node (CH-join decision) packet.
   ii. And the other to the BS node (Location, energy and concentration) packet.

b. CH generated packet: packet generated from the head nodes toward the BS for data aggregation purpose.

c. BS generated packets: packets generated from the BS node to all other nodes in the field.

   i. "Hello" packet to start setup phase.
   ii. "Hello" packet to start the steady state phase.
   iii. "Hello" to put the node in sleep mode operation (when start moving).
   iv. "Hello" packet to wake up nodes.
   v. "Hello" packet chance-list.

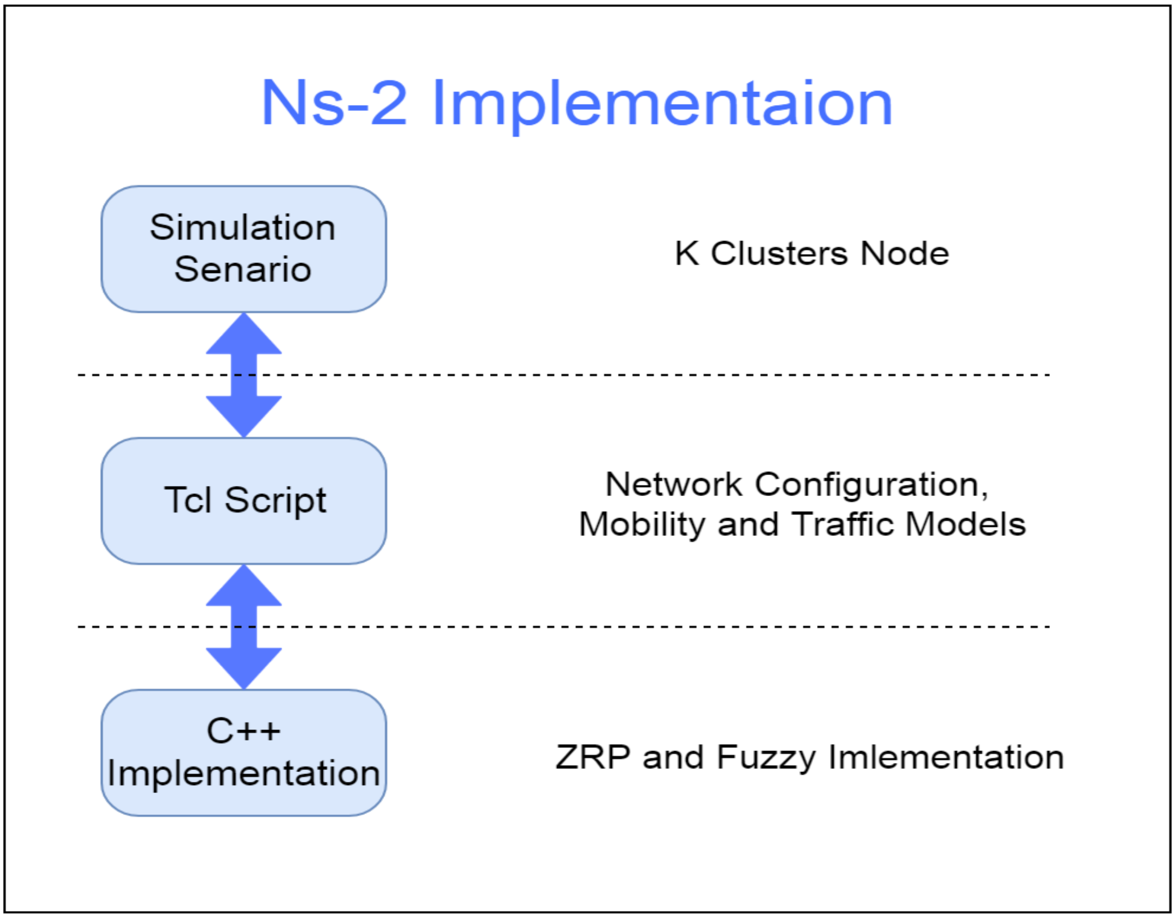

Figure 3-13: Implementation Overview of the Protocol

3.7 Comparison of the Proposed Protocols with Other Approaches

A summary comparison of the proposed protocols with other proactive, reactive and hybrid approaches by considering their general features and characteristics is presented in Table 3-3.

Table 3-3: Comparison between LEACH, HEED, TEEN and the Proposed Protocols

Protocols Names	Data Delivery Model	Proactivity	Control manner	Energy Efficiency	Location Awareness
Proposed Approaches	Cluster Head	Hybrid	Centralized	Very High	Yes
TEEN	Active Threshold	Reactive	Distributed	Very High	No
HEED	Cluster Head	Hybrid	Distributed	High	No
LEACH-C	Cluster Head	Proactive	Centralized	High	No

Chapter Four

Simulation Tests and Results

4.1 Introduction

To test and analyze the proposed protocol (for energy consumption), several experiments and simulation tests are performed. Ns-2 is used as a network simulation platform. Fuzzylite library is used to create fuzzy logic algorithm by utilizing object-oriented programming, it is a free and open-source, programmed in C++ and Java for multiple platforms (Windows, Linux, Mac, iOS, Android). This chapter shows the simulations of CHFL-ZRP & MCHFL-ZRP protocols for different types of scenarios (fixed and mobile), several cluster sizes and for different sink mobility range sizes. Finally, different performance metrics will be evaluated for the proposed protocols and compared with other protocols.

4.2 Performance Metrics

Performance metrics are used to analyze and test the network according to certain defined parameters to check the behavior of the simulated scenarios. It shows the amount of improvement of the proposed protocols in comparison with other protocols. Most of WSN clustering protocols evaluation tests are mainly focusing on evaluating the FND (first node to die), HND (half nodes to die) in the network and the average dissipated energy; because without power there is no activity for the sensors inside the network. The stability period of clustering protocol is checked for the following:

- First Node to Die (FND): The time that the first dead node appears.
- Half Nodes to Die (HND): The period from the start of the network operation to the time that half the number of nodes are dead.

After checking the network lifetime for the proposed protocol in comparison to other protocols. Several types of performance metrics including throughput, PDR, end-to-end-delay and average energy consumption will be determined as follows [45]:

1-Average Throughput: Throughput measures the successfully received data packets per unit time using the following equation.

$$\text{Avg. Throughput} = \left(\frac{\text{Z}}{total\ time}\right) \quad (4.1)$$

Where Z represents the net of packets which are successfully received.

2- End to End Delay: Represents the period between the receiving and sending data packets.

$$Avg.\, end\ to\ end\ delay = \sum_{i=1}^{m} \frac{(T_i^r - T_i^s)}{m} \quad (4.2)$$

Where $(T_i^r \& T_i^s)$ represents the difference between the receiving and the sending time of the packet and m in the total number of transmitted packets.

3- The average consumed energy: Energy consumption occurs in packet transmission, packet reception, and processing by each node during network operation. Energy consumption in each node (i) is calculated by using the following equation:

$$E_{ci} = E_{Ti} + E_{Pi} + E_{Ri} \tag{4.3}$$

Where E_c is the total consumed energy, E_T is the consumed energy during transmission, E_P is the consumed energy during processing and E_R is the consumed energy during reception, (i) is the node number.

The average dissipated energy is determined by ratio of the total network energy consumption to the (n) nodes. Thus;

$$\text{Avg. energy consumption } = \sum_{i=1}^{n} \frac{E_{ci}}{n} \tag{4.4}$$

Where E_{ci} represents the consumed energy of the *ith* node and *n* represents the whole WSNs nodes.

4- PDR: represent the successfully percent of the delivered packets.

$$\text{PDR} = \frac{z}{m} \times 100\% \tag{4.5}$$

4.3 Simulation Model

4.3.1 Simulation Environment

The simulation studies of the proposed protocols have been done on NS-2.35. NS2 and the supported fuzzy library are installed on Linux operating system (Ubuntu 14.04 distribution).

4.3.2 Mobility Model

The random way point model is used to generate nodes movement and predicted mobility pattern is used for sink movement. Dynamic clustering protocol must take the action when the node motion case to break the cluster if the moved node is a CH node. Generally, all types of nodes (CH and ordinary) starts its movement from random location towards random destination in a random speed.

4.3.3 Traffic Model

The source agent traffic used for the simulations are assumed to be UDP agent that support constant bit rate (CBR) application traffic sources. Only 500 byte data packet size is used because the larger packet suffer from higher loss and the smaller suffer from high overhead. Each cluster has source nodes, gateway node (CH) and final destination node (BS). The packet's sending and receiving rate is constant for each of the source node and the CH node in order to equate the energy consumed in data carrying.

4.3.4 Simulation Environment and Parameters

The overall goal of this thesis is to demonstrate that the sink movement and the number of clusters in the field have direct influence on the WSN network lifetime using FND metric, and to compare the performance of the developed protocol with other protocols. The geographical WSN area assumed to be (100*100)m^2. IEEE 802.11 MAC protocol was used in the experiments for the MAC layer in each node. IEEE 802.11 works in 2.4 GHz frequency. The initial energy available for each node is set to 3 Joules, while the corresponding value for the base station (BS) is set to be work for long time period. For the MCHFL-ZRP mobility condition is also considered and random way point model is used, the node speed is varied between 0 to 10 m/s (equivalent to about 0 to 36 km/hr approximately). The BS are mobile throughout the overall simulation time. The type of antenna in all nodes is assumed to be Omni directional antenna. The energy model is considered to be battery model. All simulation parameters mentioned are presented in Table 4-1.

The used numbers of clusters are taken to be 4, 9, 16 and 25, with changing the diagonal size of hexagonal shape as shown in Fig. 4-1 for the sink movement. This yields different scenarios, to show the performance of each scenario when changing the above parameters.

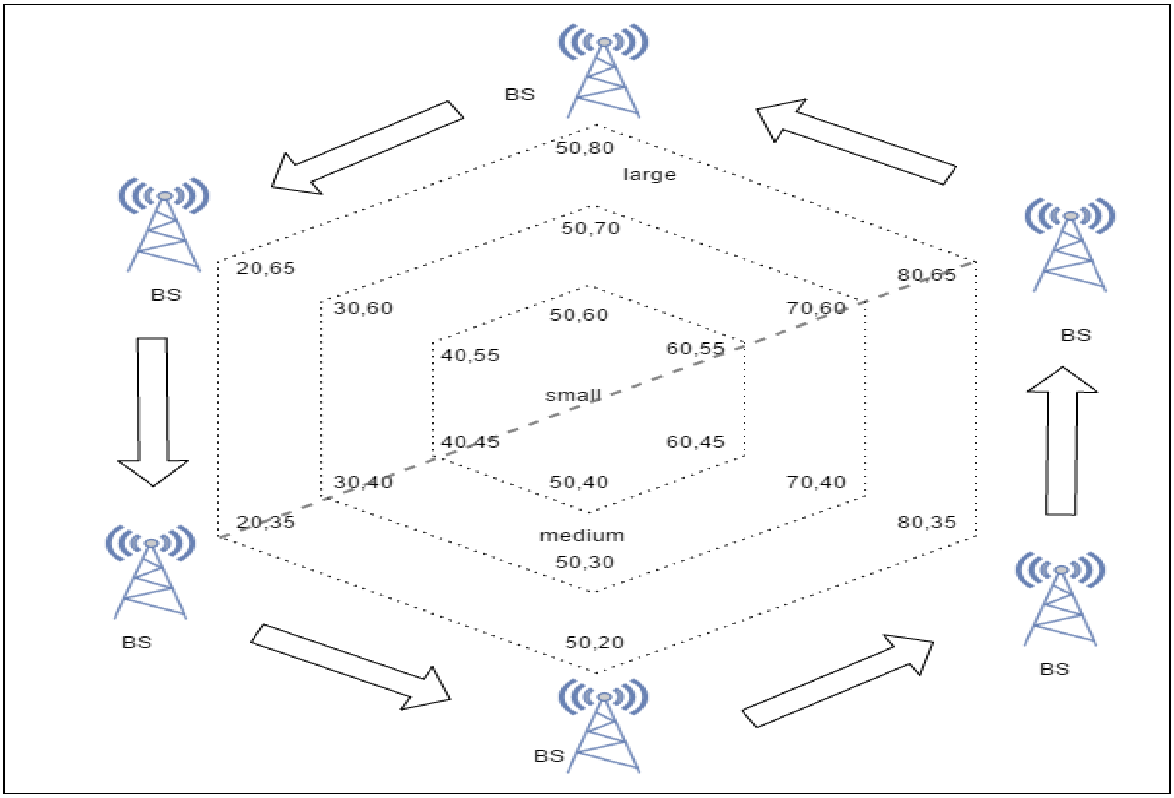

Figure 4-1: Various Hexagon Diagonal Size

Table 4-1: WSN Simulation Parameters for the Proposed Protocols

Parameters	Values
Simulations area	100*100 m^2
Simulation time	Till HNDs appear
Routing protocol	ZRP
Initial energy of nodes	3J
Number of nodes	100
Bit rate	1 Mb/sec
Packet length	500 Byte
Node speed	0 to 10 m/sec
Base station speed	5 m/sec
MAC layer	IEEE 802.11
Channel Type & Radio Propagation Model	Wireless Channel with Two-Ray-Ground model
Antenna model	Omni directional antenna
Energy model	Battery

4.4 Simulation Tests for the Proposed Work

This section shows the tests conducted for CHFL-ZRP in different cluster numbers with fixed and mobile BS, then shows its impact on the network life time and the average energy consumption.

4.4.1 Optimal Number of Clusters in the Network:

The experiments and simulation tests shows the division of the network area into various number of clusters can affect the network's energy dissipation so that determining the optimal number of clusters with the most appropriate sink diagonal size in the field is very important tasks.

With 4-clusters scenario, Fig.4-2 & Fig.4-3 show that the small hexagon range is the best for the network lifetime in 4-clusters scenario.

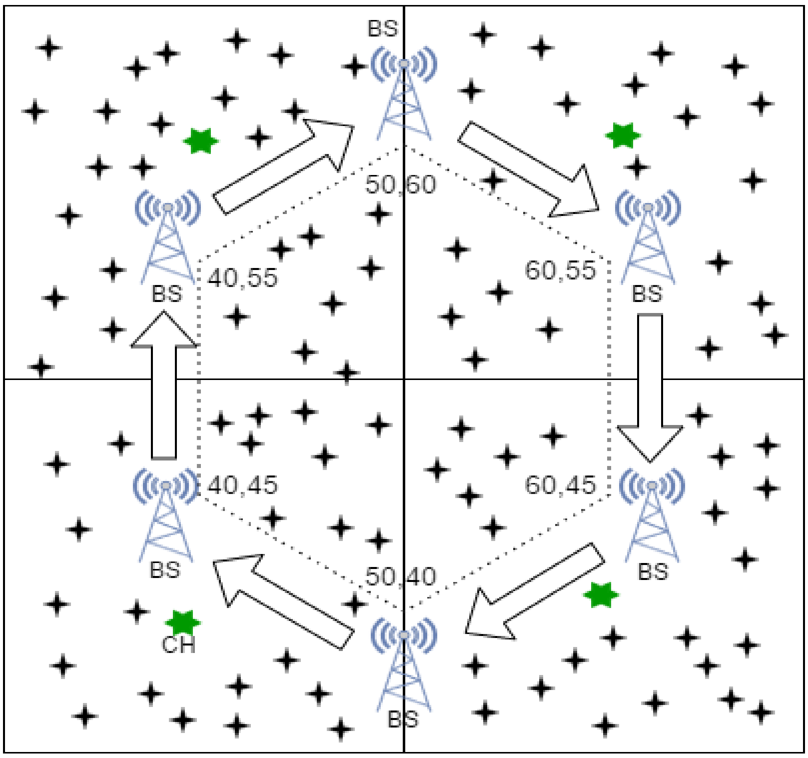

Figure 4-2: Small Hexagonal Sink Movement with 4-Clusters

When the network is divided into 4 clusters the small diagonal size would be near to large number of head nodes so the energy consumption is reduced. The resulted values in Table 4-2 show that the best case over all is with small diagonal hexagonal size where it delays the FND as compared with other diagonal size and with the fixed BS.

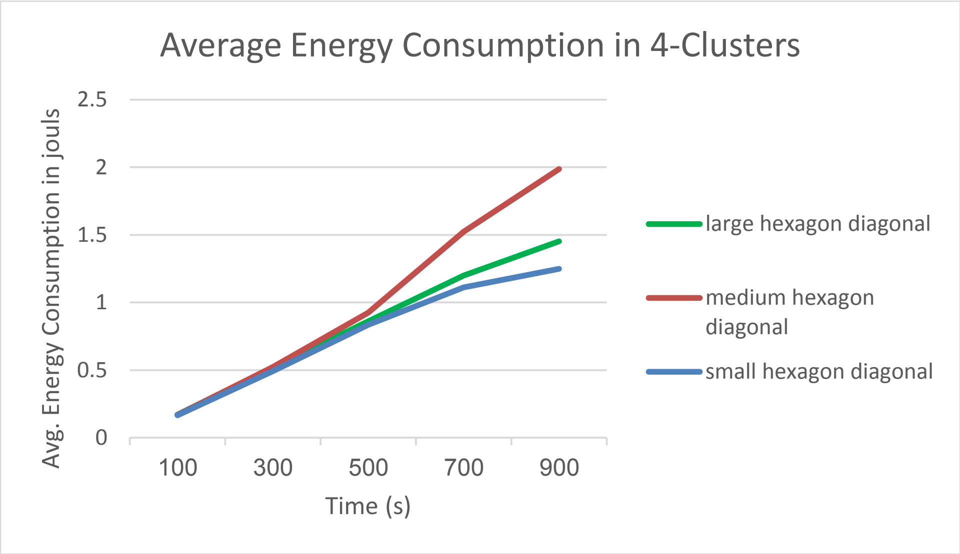

Figure 4-3: Average Energy Dissipation 4-Clusters

In the 9-clusters scenario Fig.4-4 & Fig.4-5 show that the small hexagon range also can be considered as the best for the network lifetime.

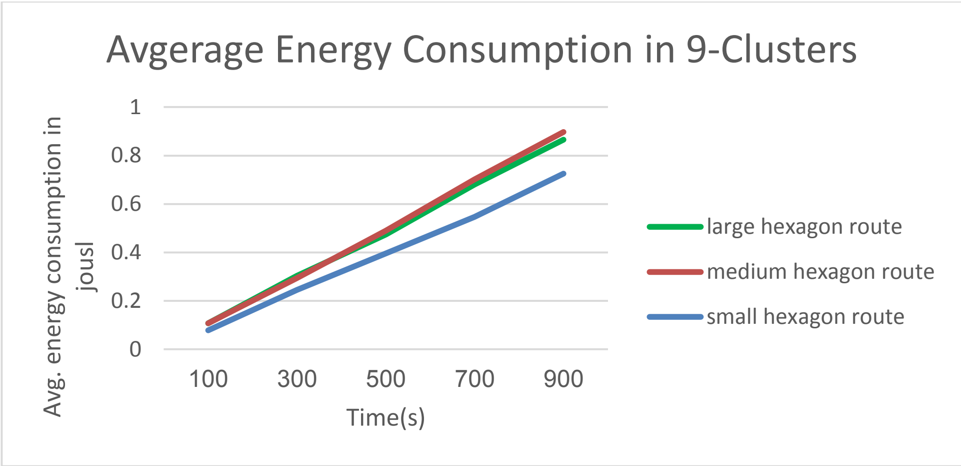

Figure 4-4: Average Energy Dissipation 9-Clusters

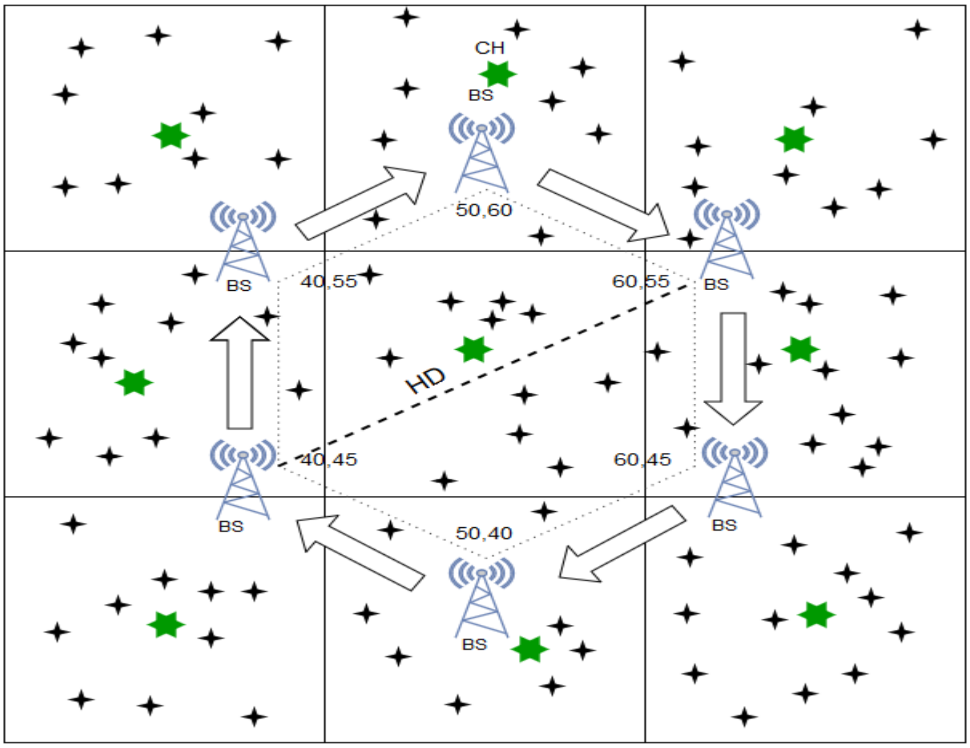

Figure 4-5: Small Hexagonal Sink Movement with 9-Clusters

While within 16-clusters scenario, Fig.4-6 & Fig.4-7 show that the large hexagonal range is the best for the network lifetime, since the consumed energy is twice in the small & medium diagonal size.

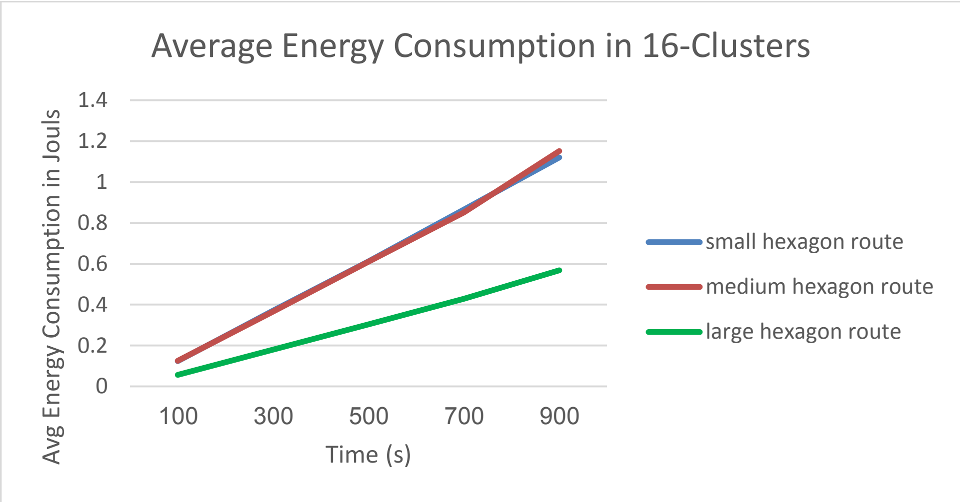

Figure 4-6: Average Energy Dissipation for 16-Clusters

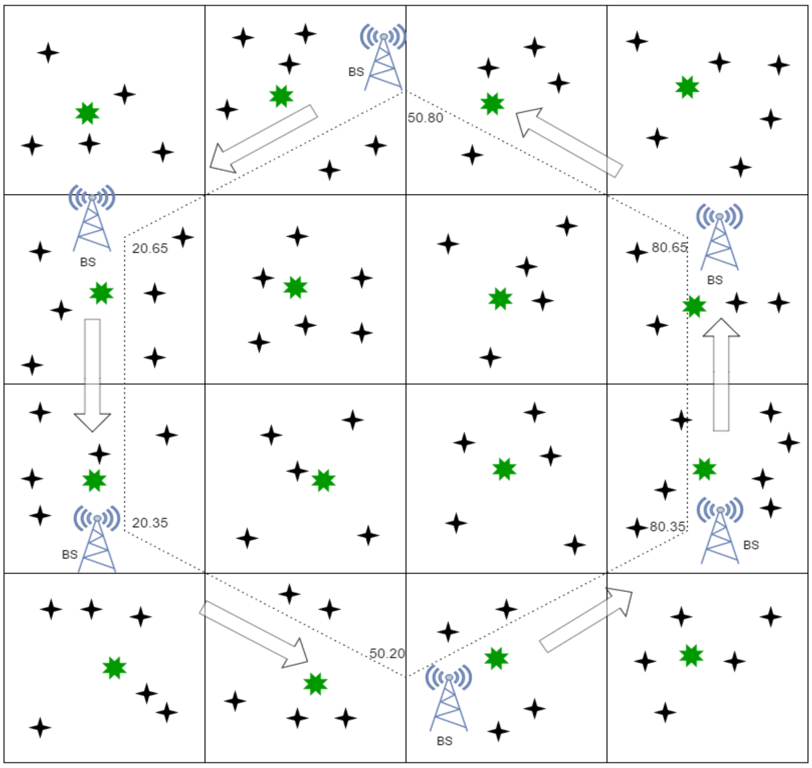

Figure 4-7: Large Hexagonal Sink Movement with 16-Clusters

Finally, the network area is further divided into 25-clusters, the results of Fig.4-8 & Fig.4-9 show that the networks lifetime is in its best case with medium hexagon diagonal size.

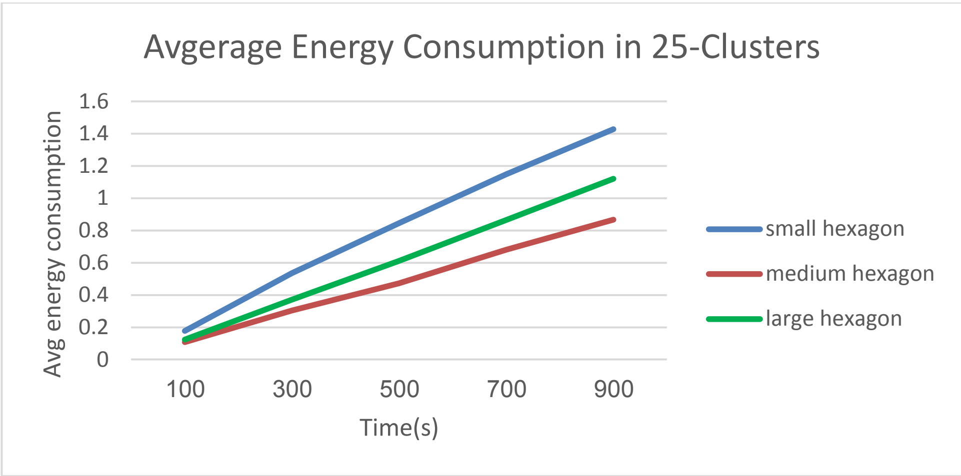

Figure 4-8: Average Energy Dissipation for 25-Clusters

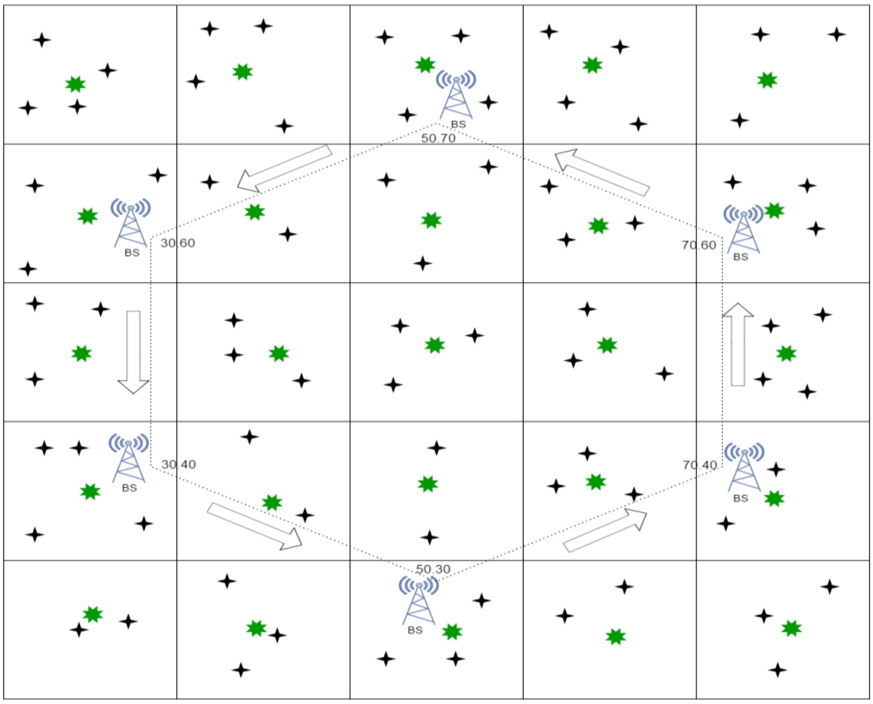

Figure 4-9: Medium Hexagonal Sink Movement with 25-Clusters

By taking the best case for all of the clusters size and comparing them together with regards to the average consumed energy in the whole network, Fig.4-10 illustrates that the average energy dissipation in its best case within 16-clusters scenario-large hexagonal diagonal size.

Upon referring to the network life time (especially FND metric), it indicates that the 16-clusters scenario is the best because the load equally distributed among CH nodes and at the same time the distance between head nodes become less than it within the 4 & 9 clusters scenarios, while in 25-clusters scenario increasing the multi-hop transmission and reception so the average energy consumption is increased, whereas the average consumed energy in 4-clusters is twice as much as in the 16-clusters scenario.

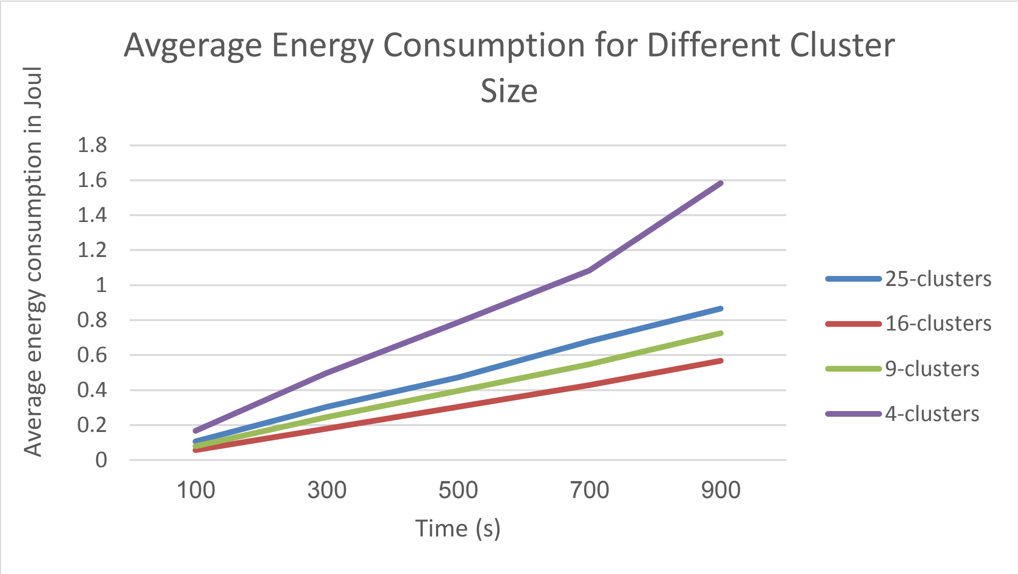

Figure 4-10: Average Energy Dissipation for Different Clusters Size

Table 4-2 shows that the performance evaluation of the network add a good rate of improvement in 16-clusters scenario as compared to the 4, 9, 16 & 25-clusters scenario with assurance that the mobile sink resulted in a better performance than the static.

The various test cases not only consider several sink movement but also use different stop positions for the BS to demonstrate its impact on the network life time and to clarify the enhancement behind the use of mobile sink.

Table 4-2: Network Life Time with Different Clusters Size for CHFL-ZRP (fixed and mobile BS)

	Sink position	FND at:	HND at:
4-clusters scenario	50,40 fixed BS	250	1210
	20,60 fixed BS	454	2719
	80,30 fixed BS	501	1208
	Small- hexagon mobile BS	922	3103
	Medium- hexagon mobile BS	556	3010
	Large- hexagon mobile BS	559	3033
9-clusters scenario	50,40 fixed BS	259	2202
	20,60 fixed BS	455	5744
	80,30 fixed BS	500	2205
	Small- hexagon mobile BS	1050	3699
	Medium- hexagon mobile BS	788	3023
	Large- hexagon mobile BS	800	3902
16-clusters scenario	50,40 fixed BS	1000	3043
	20,60 fixed BS	1052	3010
	80,30 fixed BS	1288	3206
	Small- hexagon mobile BS	1210	1555
	Medium- hexagon mobile BS	2249	5033
	Large- hexagon mobile BS	3530	5074
25-clusters scenario	50,40 fixed BS	500	3324
	20,60 fixed BS	922	3110
	80,30 fixed BS	1001	3318
	Small- hexagon mobile BS	1113	1426
	Medium- hexagon mobile BS	2010	3230
	Large- hexagon mobile BS	2001	3243

4.4.2 Optimal Pause Time for the Sink:

Due to the mobility of the sink station, choosing the optimum pause interval for the sink at every stop position is very important for applying its impact on the average delivered packet. Fig.4-11 shows that the throughput is in its best rate when the sink pause for 10-second interval.

It is worth mentioning that the throughput does not follow the same pace of the consumed energy; it was observed that the value of throughput is much better with four clusters and possible to be up to twice what they are in the 16 cluster scenario.

The result shown in Fig.4-11 tested for 16-clusters scenario-large hexagonal diagonal size.

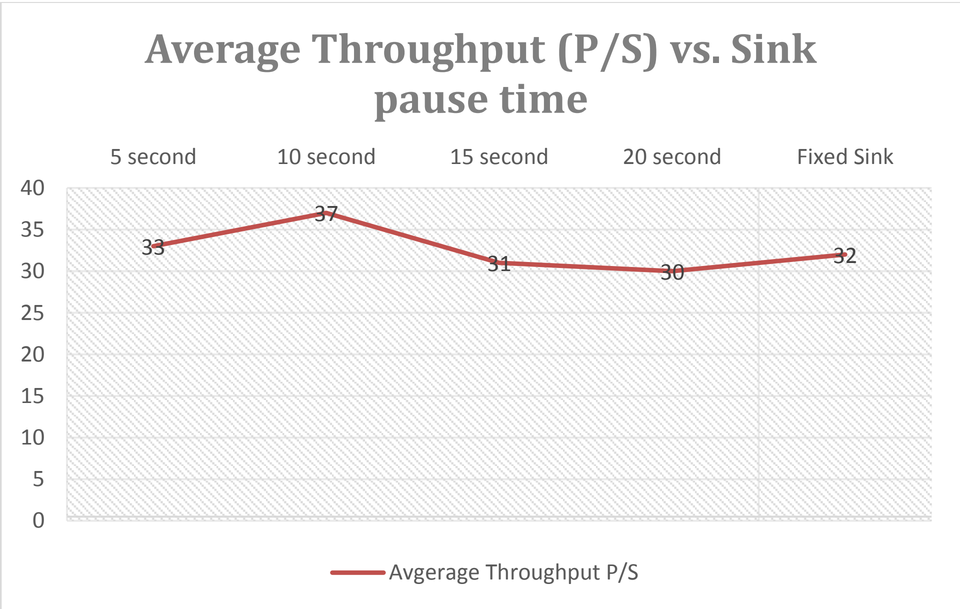

Figure 4-11: Throughput vs. Sink Pause Time

4.5 Evaluation and Comparison for CHFL-ZRP

This section shows the result and the experimental simulation to evaluate the proposed protocol and compare it with LEACH, LECAH-C, CHEF and LEACH-ERE. The simulation parameters changed to be as in [52] for the fair of comparison as shown in Table 4-3.

Table 4-3: Simulation Parameters for the CHFL-ZRP comparison

Parameters	Values
Simulations area	100*100 m^2
Proposed Routing protocol	CHFL-ZRP (Fixed and Mobile BS)
Initial energy of nodes	2J
Number of nodes	100
Bit rate	1 Mb/sec
Packet length	500 Byte

The comparison of the proposed with other protocols done based on the following metrics:

1- HND: Fig.4-12 shows the half number of alive nodes per round. The result shows that the best performance in reducing the energy consumption is when the mobility of the BS is considered, whereas the distance between cluster-head and BS decreases, energy dissipation also decreases.

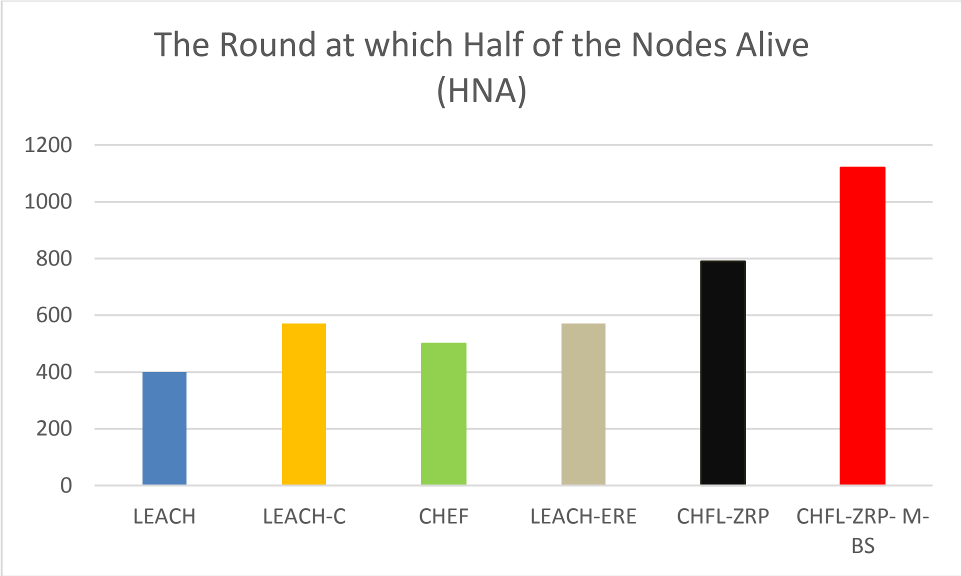

Figure 4-12: Half of Alive Nodes per Round for each Clustering Approaches.

2- Number of Alive Nodes: Fig.4-13 shows a trajectory comparison of alive node with time. The figure shows that the proposed protocol is more stable than the others because the delay in the appearance of the first death node as compared with the other protocols.

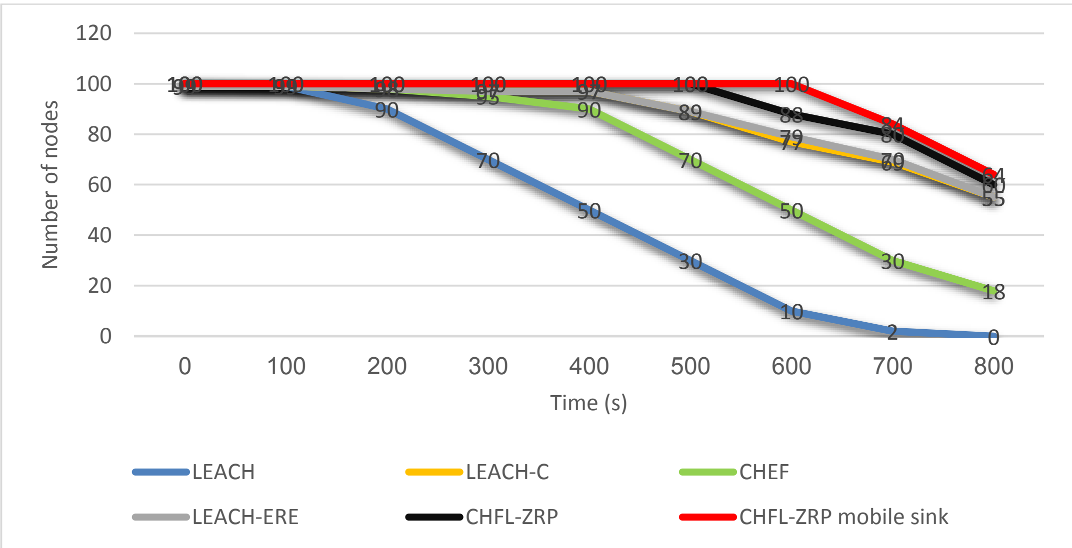

Figure 4-13: Trajectory of Alive Sensor Nodes Per Round

The following metrics tested and compared only with LEACH & LEACH-C due to their availability and the simulation parameters for all protocols are taken as in Table 4-1.

3- Average End to End Delay:

Fig.4-14 shows that the average end to end delay is enhanced in the case of mobile BS due to the load distribution of sink mobility. While in LEACH-C the average end to end delay is more stable than LEACH because BS selects the CHs in case of LEACH-C.

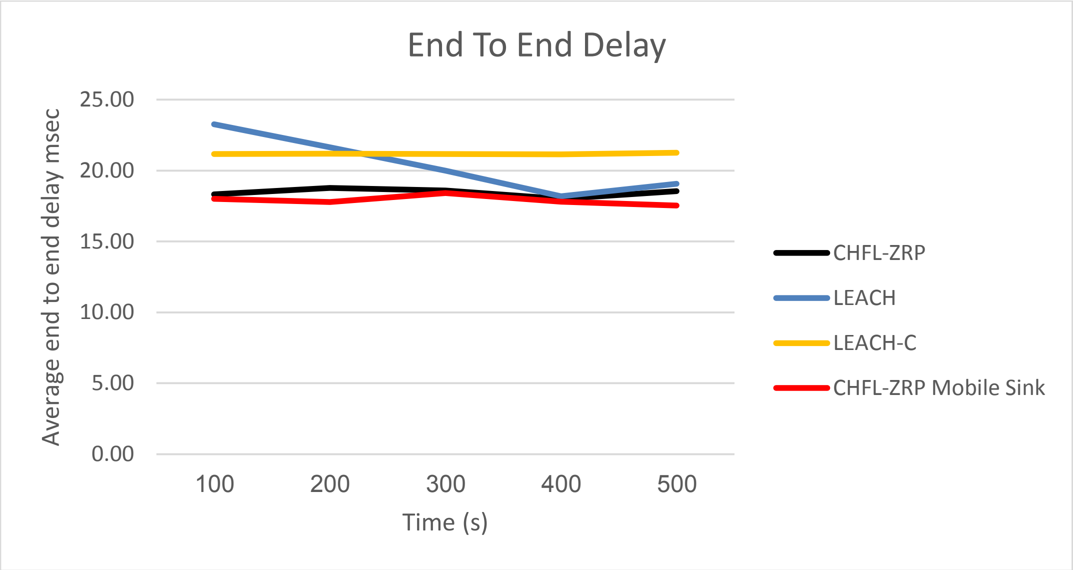

Figure 4-14: Average End to End Delay Per-Round

4-Average Throughput: Fig.4-15 shows that the average throughput of the proposed protocol in the case of fixed BS at the beginning of the simulation is better than the overall other systems, then it begins to fall because of the traffic load increment, the average throughput of LEACH-C outperforms LEACH. In LEACH and LEACH-C the nearest nodes to BS are not loaded because the CHs nodes communicated directly to BS in a SH pattern so the average throughput is almost fixed.

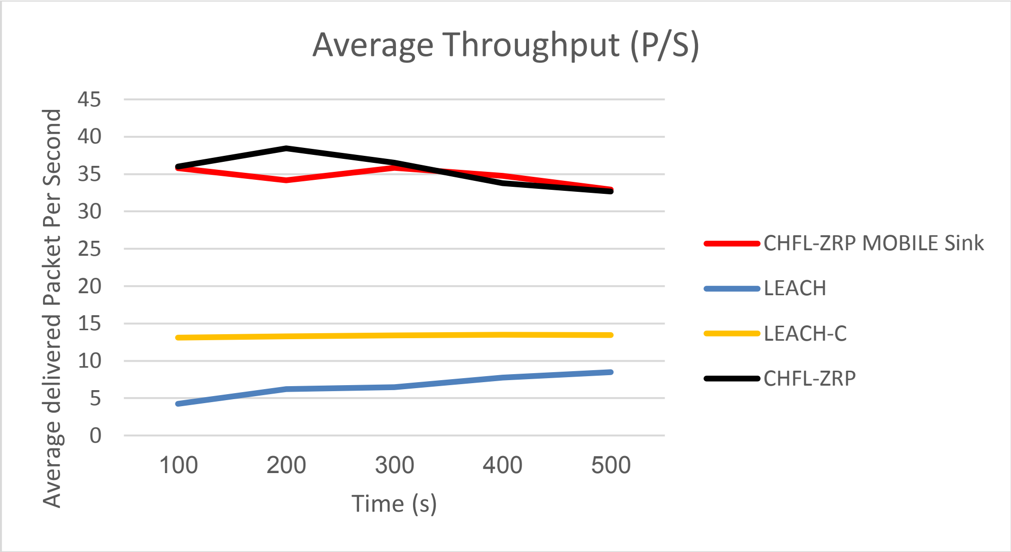

Figure 4-15: Average Throughput

5- Average energy consumption: Fig.4-16 declares that the average consumed energy of the CHFL-ZRP in the case of mobile BS outperforms the others due to the utilized parameters in selecting the cluster head node as compared with the selection scheme of the other protocols and also due to the sink mobility that distribute the loads among CH nodes.

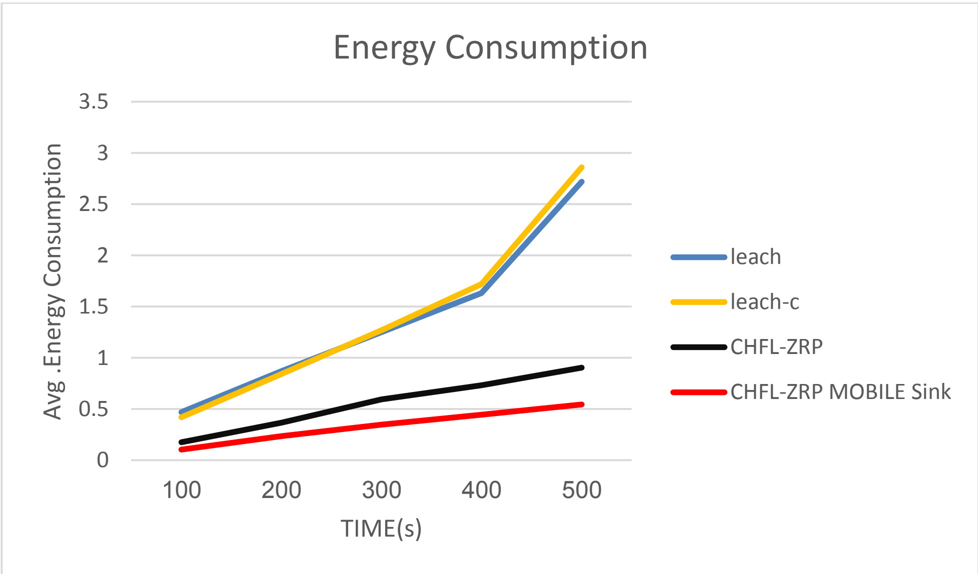

Figure 4-16: Average Energy Consumption

4.6 Evaluation and Comparison for MCHFL-ZRP

This section shows the results and the experimental simulation to evaluate the proposed protocol and compare it with mobile leach LEACH-M, and enhanced mobile leach LEACH-ME, These protocols are the same as the work of the LEACH, with some changes for supporting mobility and mechanism for re-clustering. Simulation parameters are taken to be as much as possible like what taken in [53].

1- Average End to End Delay: Fig.4-17 shows that the average delay in the proposed protocol with mobile sink is smaller than it is with fixed sink and the rest of protocols, this is due to the mobility of the BS make it be near larger number of CH nodes than in the fixed BS that ensure the direct communication between them. The delay for LEACH-ME is smaller than LEACH-M for different rounds, this is due to the high spatial and temporal dependency between the CHs and node members within respective clusters.

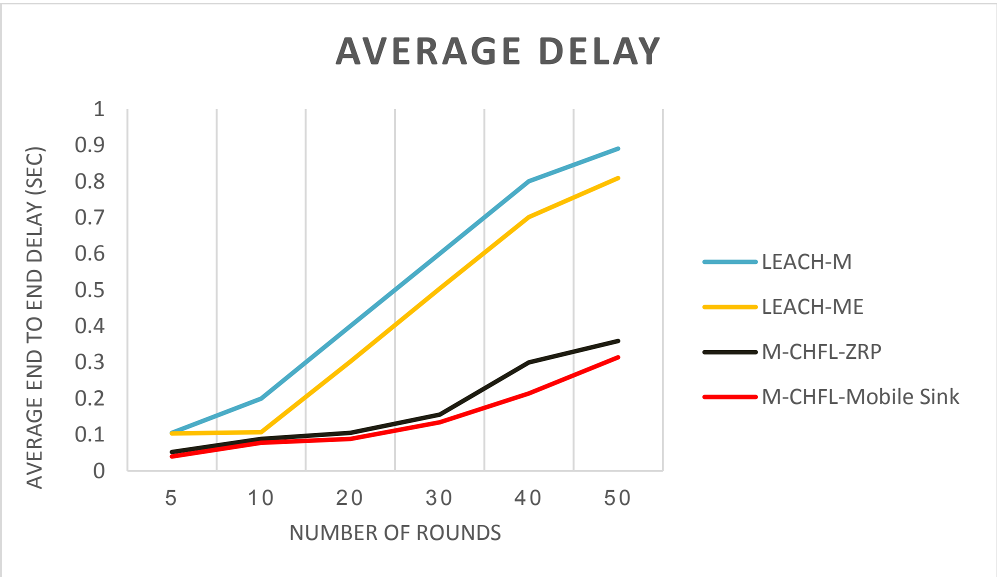

Figure 4-17: Average End to End Delay

2- Average energy consumption: (Fig.4-18a & Fig.4-18b) shows that the average dissipated energy of M-CHFL-ZRP with mobile sink is enhanced as compared with the others, due to the existence of the cluster head nodes in the center of the field resulted from fuzzy calculations and the sink mobility scheme that reduce the distance between itself and CH nodes for data transmission.

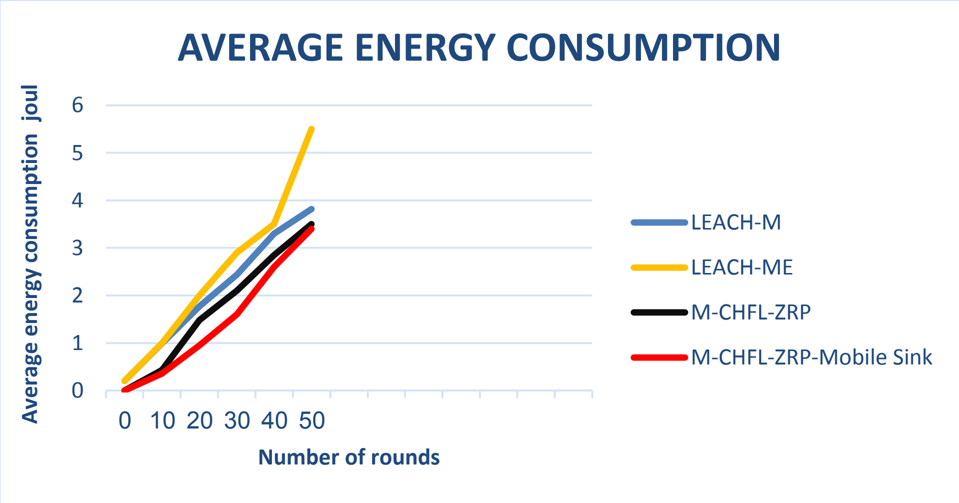

Figure 4-18-a: Average Energy Consumption

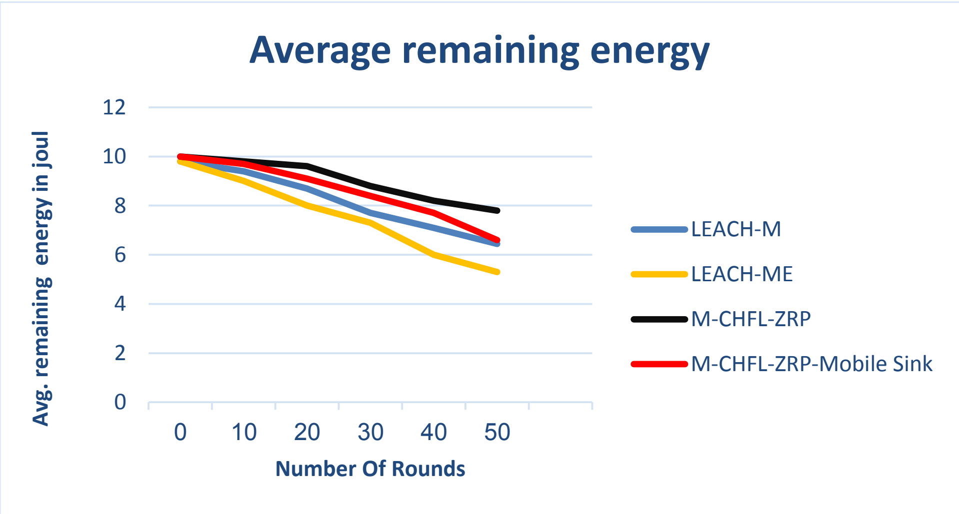

Figure 4-18-b: Average Remaining Energy

3- Average Packet Delivery Ratio:

Fig.4-19 shows the average packet delivered for two cases of the proposed protocol, note that the PDR in mobile sink scenario is enhanced due to the distribution of the traffic load among the nodes.

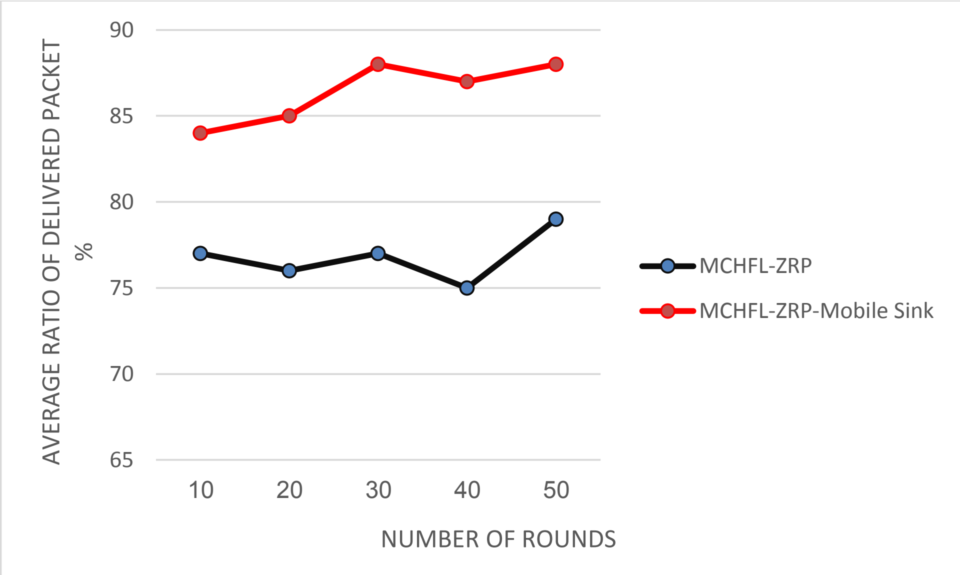

Figure 4-19: Average Packet Delivery Ratio

4.7 Discussion and Results Assessment:

The percentage enhancement of the developed protocols (CHFL-ZRP & MCHFL-ZRP) with sink mobility over other compared protocols for the calculated metrics was calculated using the following formula:

$$\text{Percentage Enhancement} = \frac{b-a}{a} \times 100 \qquad (4.6)$$

Where b is the tested metric for the developed protocol with sink mobility and a is the metric found for the other compared protocols.

Table 4-4 represents the percentage enhancement for the proposed CHFL-ZRP-Mobile Sink protocol with other protocols not considering the sink mobility as mentioned in sections 4-6.

Table 4-5 represents the percentage enhancement for the proposed MCHFL-ZRP-Mobile Sink protocol with other mobile node protocols not considering the sink mobility as mentioned in sections 4-7.

Table 4-4: Percentage Enhancement for CHFL-ZRP-Mobile Sink Protocol over other compared protocols

Metric	LEACH	LEACH-C	CHEF	LEACH-ERE	CHFL-ZRP
HNDs	66.3%	44.11%	53.75%	48.02%	33.3%
Networks Life Time	59.66%	40.02%	45.5%	35.66%	18.33%
Throughput	87.5%	62.5%	not available	not available	14.28%
End To End Delay	29.7%	18.91%	not available	not available	8.82%

Table 4-5: Percentage Enhancement for MCHFL-ZRP-Mobile Sink Protocol over other compared protocols

Metric	LEACH-M	LEACH-ME	MCHFL-ZRP
Avg. Consumed (remained) Energy	44.4%	28.5%	12.5%
PDR	not available	not available	15.9%
End To End Delay	53.5%	39.4%	10.02%

From the results of all scenarios, the following points are worth to be mentioned:

1. Selecting the optimal number of clusters with the optimal sink mobility pattern in term of energy consumption and the best pause interval with regards to the packet delivery leads to get good performance for the proposed protocols.
2. Evaluations and testing of the proposed protocol shows that the best case overall in term of energy consumption is when

the network contains 16-clusters and large hexagonal diagonal sink movement.

3. The energy consumption and network life time metrics of the proposed protocols are greatly enhanced as compared to the other mentioned protocols in this thesis, this brings to the cluster head selection approach, multi-hop transmission between CHs nodes, and the predictable mobility approach in the sink station.
4. Finally, the use of NS2 suffer from lack of knowledge in the number of rounds operation because the run time calculated in seconds; so that this thesis suggests to calculate the round number by dividing the number of received packet at the sink station on the number of clusters in the network, for example consider that the packet received are 9134 during 1000 second by dividing it on (16-clusters) the result is approximately 570 rounds.

4.8 Characteristics and Features of the Proposed Protocols

The proposed work in this thesis has many features, which can be summarized as:

a. It is a hybrid clustering protocol.
b. The two scenarios are single-hop intra-cluster & multi-hop inter-cluster communications.
c. In the proposed protocols, CH (Cluster Heads) selection depends on fuzzy logic approach.
d. The proposed protocols are centralized clustering algorithms.

e. MCHFL-ZRP supports mobility in the nodes, besides BS is mobile.
f. Each node can be a CH more than one time.
g. CHs location close to center enables member nodes consumes less energy in communicating with their CHs.

Chapter Five

Conclusions and Suggestions for Future Work

5.1 Conclusions

An energy efficient WSN clustering protocols based on a modified ZRP is developed for a mobile network. Two proposed protocols are designed and implemented and found to be suitable to work with both mixed and fixed nodes environment (MCHFL-ZRP & CHFL-ZRP) respectively. Both introduced protocols are enhanced with a predictable sink mobility scheme for data gathering mechanism, which determine the best movement state in regards to the life span of the network.

The percentage enhancement for the proposed protocols over other compared protocols such as LEACH, LEACH-C, LEACH-ERE, CHEF, LEACH-M, LEACH-ME are measured in terms of some well-known metrics (HND, Avg. consumed energy, Network life time, Throughput, PDR, and End to End delay). Table 4-4 and Table 4-5 summarize the improvement and proves the effectiveness of the proposed protocols.

As the goals of the thesis being achieved, some of the most important points obtained from the results can be concluded as follows:

1. The ZRP protocol is considered as a flat based routing protocol; in this work ZRP is enhanced to work as a cluster based routing protocol by implementing the efficient fuzzy logic algorithm for cluster head selection.
2. Single-hop intra cluster communication is found suitable for the communication between the CH and its members. Since, in most cases it located at the center of the network field. While the multi-hop inter cluster communication will balance the energy consumption among the CH nodes because it reduces the transmission range among them with the BS node.
3. Incorporating a predictable sink mobility scheme help to improve the network performance where the traffic load per node is reduced, besides there are more chances for any node to be closer to BS. This includes both the fixed and mobile nodes scenarios.
4. The continuous movement of the sink produces good and bad performance, so choosing the most efficient range movement of the BS was part of the functions of the proposed work.
5. The enhancements are not limited to the energy, rather than that, they showed an increasing in the throughput and decreasing in the delay as compared to leach protocol.
6. The development of fuzzy logic and the developed equation of concentration helped to enhance the Gupta [43] work.
7. The use of a central control (centralized protocol) in the base station, which has sufficient power, memory and storage capacity and, thus, the limitations of resource restriction at each node are overcame.

8. As a conclusion, the CHFL-ZRP with mobile sink outperforms LEACH, LEACH-C, CHEF, and LEACH-ERE in terms of networks life time by (35% - 59%), HNDs by (44% - 66%), throughput by (62% - 87.5%) and delay by (18% - 29%). While MCHFL-ZRP with mobile sink outperforms LEACH-M and LEACH-ME in terms of average consumed and remained energy by (28% - 44%).

5.2 Suggestions for Future Work

The proposed clustering schemes can be modified and improved by considering the following:

1. For an enhanced results, an optimization algorithm using evolutionary computing such as the Genetic Algorithm, Particle Swarm Optimization (PSO), or the Ant-Colony Optimization (ACO) can be implemented on the route of the sink station to determine the speed, number of stop points, duration of stopping, and the location of stop points of the sink station for best energy consumption.
2. The developed design approach can be implemented on another routing protocol.
3. The proposed work have only considered the homogeneous WSN. Further studies can be made by considering heterogeneous WSN as well.

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Appendix A

Simulation Tools

1. WSN Simulation Tools [46]

In this section we will make a brief explanation and comparison between some of the most popularly used simulators for WSNs.

a- NS-2 (Network Simulator version 2) / Mannasim: NS-2 has been developed under the VINT (Virtual Inter Network Testbed) project in 1770. NS-2 is the most widely used WSN simulator. It is a generic, discrete event simulator, written in C++ and OTcl and open source that saves the cost of simulation. It requires additional framework like Mannasim which is wireless sensor networks simulation environment based on the NS-2. Mannasim extends NS-2 to introduce new modules (sensing model, several application models, energy model, Mica2 PHY model).

Features: It provides communication protocol models (TDMA), ad-hoc and WSN specific protocols such as directed diffusion or SMAC (Sensor MAC). It is extensible simulator, so several projects can be added to support WSN such as; SensorSim, Mannasim etc.

Drawbacks: NS-2 needs advanced skills with writing scripting language (C++ and TCL) and modeling technique and is more complex and time-consuming support, it does not support Graphical User Interface (GUI).

b- OMNeT++ (Optical Micro-Networks Plus Plus) / Castalia: OMNeT++ was introduced in 2001. Like NS-2 and NS-3, OMNeT++

is also a discrete event simulator. It is an extensible, modular, component-based C++ simulation buildings, OPNET can also be used to define packet formats.

Drawbacks: OPNET is only available in commercial form (source code of the software and additional packages are not available for free, users have to pay to get the license to use the required packages). OPNET does not include detailed models for WSNs. Energy models are not directly supported by OPNET. WSN routing protocols are not supported by OPNET.

c- GloMoSim (Global Mobile Information System Simulator) / QUALNET: GloMoSim was introduced in 1799. It is a scalable and parallel discrete event simulation environment for large wireless and wired communication networks. GloMoSim was designed as a set of modules in an architecture structured into eight layers. Each module simulates a specific protocol in the protocol stack. QUALNET is the commercial version of GloMoSim.

Features: GloMoSim is used in a parallel environment. Like Ns-2, GloMoSim is also designed to be extensible, with all protocols implemented as modules in the GloMoSim library. GloMoSim was successfully implemented on both shared memory and distributed memory computers. QUALNET provides a comprehensive environment for designing protocols.

Drawbacks: GloMoSim currently supports protocols for purely wireless mobile networks. GloMoSim does not offer power models. GloMoSim is effectively limited to IP networks. GloMoSim is used to simulate WSNs but the accuracy of results is questionable.

d- NCTUns stands for National Chiao Tung University network simulator / The NCTUns uses a distributed architecture to support remote simulations and concurrent simulations. It also uses open-system architecture to enable protocol modules to be easily added to the simulator. Functionally, it is divided into eight separate components some of most important components are described: The first component is the fully integrated GUI environment by which a user can edit a network topology, configure the protocol modules used inside a network node, specify mobile nodes' moving paths, plot performance curves, play back animations of logged packet transfers, etc.

Features: It provides easy to use GUI Environment. Its distributed and open-system architecture design supports remote simulations and concurrent simulations, and allows new protocol modules to be easily added to its simulation engine. NCTUns provides better functionality and performance.

Drawbacks: The connection through dispatcher with the simulation server is not stable. Indeed it is frequent that the coordinator becomes busy. In this case, it notifies its state to the dispatcher, this will not be able to select the appropriate simulation machine. Therefore it is necessary to start again the coordinator, the dispatcher and the client. The programming is not supported by the NCTUns. So simulation parameters set only by graphical user interface. The manipulation at every node has to be done node by node, or all the nodes to the same time.

Appendix B

Fuzzy Logic Design in C++

1. Fuzzy Logic Design with C++

The designed fuzzy logic was implemented with MATLAB program. The fuzzy input fuzzy sets, output fuzzy sets and fuzzy inference rules were all implemented with MATLAB. The code of the implemented fuzzy system was converted to C++ code by using the fuzzy lite library (www.fuzzylite.com). The steps for converting a fuzzy lite from MATLAB code is explained below:

1. Design the fuzzy system input and output variables and the fuzzy inference rules … etc. in MATLAB.
2. Export the designed fuzzy system as a Fuzzy Inference System (.fis).
3. Import the FIS file to the fuzzy lite library using its GUI application (qtfuzzylite).
4. From the qtfuzzy lite application export the system as a FuzzyLight functions.
5. Add the requested libraries and definitions for the exported functions to be executable.
6. Add the code to the required application for example NS-2 and include the fuzzy light library while compiling the program.

2. Code for the Designed Fuzzy system

The fuzzy system was implemented for the cluster head selection:

```
double fuzzy_global(double center, double energ, double non ){
fl::Engine* engine = new fl::Engine;
```

```
engine->setName("Global_level");
```

//Input Variables

```
InputVariable* inputVariable1 = new fl::InputVariable;
inputVariable1->setEnabled(true);
inputVariable1->setName("energy");
inputVariable1->setRange(0.000, 0.100);
inputVariable1->addTerm(new fl::Traiangle("low", 0.0, 0.5, 1, 1.5));
inputVariable1->addTerm(new fl:: Traiangle ("medium", 0.3, 1.5, 2.7));
inputVariable1->addTerm(new fl:: Traiangle ("high", 1.5, 2.22, 3));
engine->addInputVariable(inputVariable1);
fl::InputVariable* inputVariable2 = new fl::InputVariable;
inputVariable2->setEnabled(true);
inputVariable2->setName("NON");
inputVariable2->setRange(0.000, 60.000);
inputVariable2->addTerm(new fl:: Traiangle ("low", 0.15, 0.19, 0.02));
inputVariable2->addTerm(new fl:: Traiangle ("med", 0.15,0.02,0.35));
inputVariable2->addTerm(new fl:: Traiangle ("high", 0.02, 0.32, 0.04));
engine->addInputVariable(inputVariable2);
fl::InputVariable* inputVariable3 = new fl::InputVariable;
inputVariable3->setEnabled(true);
inputVariable3->setName("centrality");
inputVariable3->setRange(0.000, 8000.000);
inputVariable3->addTerm(new fl:: Traiangle ("close",0,6.5,12.5));
inputVariable3->addTerm(new fl:: Traiangle ("adeq",2.5,12.3,22.5))
```

```
inputVariable3->addTerm(new fl:: Traiangle ("far",12.5,18.5,25));
engine->addInputVariable(inputVariable3);
```

//Output Variables

```
fl::OutputVariable* outputVariable = new fl::OutputVariable;
outputVariable->setEnabled(true);
outputVariable->setName("chance");
outputVariable->setRange(0.000, 100.000);
outputVariable->fuzzyOutput()->setAccumulation(new fl::Maximum);
outputVariable->setDefuzzifier(new fl::Centroid());
outputVariable->setDefaultValue(fl::nan);
outputVariable->setLockValidOutput(false);
outputVariable->setLockOutputRange(false);
outputVariable->addTerm(new fl:: Traiangle ("vsmall", 0, 15, 30));
outputVariable->addTerm(new fl::Triangle("small", 20,30,40));
outputVariable->addTerm(new fl::Triangle("rsmall",30,40,50));
outputVariable->addTerm(new fl:: Traiangle ("med",40.000,50.000, 60.000));
outputVariable->addTerm(new fl::Triangle("rlarge",50.000,60.000,70.000));
outputVariable->addTerm(new fl::Triangle("large", 60.000, 70.000, 80.000));
outputVariable->addTerm(new fl:: Traiangle ("vlarge",70.000,80.000, 90.000,));
engine->addOutputVariable(outputVariable);
```

//Rules

```
fl::RuleBlock* ruleBlock = new fl::RuleBlock;
ruleBlock->setEnabled(true);
ruleBlock->setName("");
```

```
ruleBlock->setConjunction(new fl::Minimum);
ruleBlock->setDisjunction(new fl::Maximum);
ruleBlock->setActivation(new fl::Minimum);
ruleBlock->addRule(fl::Rule::parse("if energy is low and NON is low and centrality is close then chance is small", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is low and NON is low and centrality is adeq then chance is small", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is low and NON is low and centrality is far then chance is vsmall", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is low and NON is med and centrality is close then chance is small", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is low and NON is med and centrality is adeq then chance is small", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is low and NON is med and centrality is far then chance is small", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is low and NON is high and centrality is close then chance is rsmall", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is low and NON is high and centrality is adeq then chance is small", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is low and NON is high and centrality is far then chance is vsmall", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is med and NON is low and centrality is close then chance is rlarge", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is med and NON is low and centrality is adeq then chance is med", engine));
```

```
ruleBlock->addRule(fl::Rule::parse("if energy is med and NON is low and centrality is far then chance is small", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is med and NON is med and centrality is close then chance is large", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is med and NON is med and centrality is adeq then chance is med", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is med and NON is med and centrality is far then chance is rsmall", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is med and NON is high and centrality is close then chance is large", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is med and NON is high and centrality is adeq then chance is rlarge", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is med and NON is high and centrality is far then chance is rsmall", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is high and NON is low and centrality is close then chance is rlarge", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is high and NON is low and centrality is adeq then chance is med", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is high and NON is low and centrality is far then chance is rsmall", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is high and NON is med and centrality is close then chance is large", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is high and NON is med and centrality is adeq then chance is rlarge", engine));
ruleBlock->addRule(fl::Rule::parse("if energy is high and NON is med and centrality is far then chance is med", engine));
```

```
ruleBlock->addRule(fl::Rule::parse("if energy is high and NON is high and centrality is close then chance is vlarge", engine));

ruleBlock->addRule(fl::Rule::parse("if energy is high and NON is high and centrality is adeq then chance is rlarge", engine));

ruleBlock->addRule(fl::Rule::parse("if energy is high and NON is high and centrality is far then chance is med", engine));
engine->addRuleBlock(ruleBlock);
```

// Coding the system

```
        engine->setInputValue("energy", energ);
          engine->setInputValue("NON",non);
        engine->setInputValue("centrality", center);
          double x;
          engine->process();
          x=engine->getOutputValue("chance");
          return (x);
}
```

الملخص

ان التطورات الحديثة في مجالات شبكة الاستشعار اللاسلكية جعلتها مناسبة لاستشعار معايير محددة متعلقة ببيئة معينة. ان توجيه البيانات لاسلكيا بطريقة كفوءة من حيث استهلاك الطاقة هي المهمه الرئيسية لطبقة الشبكة وبذلك فان التوجيه التجميعي هو احد التقنيات الاكثر كفاءة لتحقيق هذا المطلب في شبكة الاستشعار اللاسلكية.

لقد تم في هذه الرسالة تقديم بروتوكولي توجيه مركزي معتمدان على اساس التجميع لشبكة الاستشعار اللاسلكية مع حركة العقدة الجامعة : اختيار رئيس الكتلة المعتمد على اساس المنطق الغامض الذي تم تنفيذه على بروتوكول توجيه المنطقة (CHFL_ZRP) واختيار رئيس الكتلة المتحرك المعتمد على اساس المنطق الغامض الذي تم تنفيذه على بروتوكول توجيه المنطقة (MCHFL_ZRP). ان البروتوكولات المقترحة تعمل مع كلا من عقد الاستشعار الثابتة والمتغيرة حيث ان (CHFL_ZRP) يتم تطبيقه على البيئة التي تغطي عقد ثابتة فقط في حين ان (MCHFL_ZRP) يمكن ان يعمل مع عقد ثابتة او متحركة.

ان اختيار عقد رئيس الكتلة يعتمد على تنفيذ منهج المنطق الغامض بوساطة دمج ثلاث ميزات مستخرجة للعقد، المركزية، التركيز والطاقة المتبقية. لقد تم تنفيذ نمط قابل للتنبؤ لحركة العقدة الجامعة لاجل الية تجميع البيانات بوساطة قاعدة التجميع بنمط مسار سداسي واختيار الحجم القطري الانسب للشكل السداسي مع الاخذ بنظر الاعتبار لعمر الشبكة و معدل استهلاك الطاقة.

طبقت سيناريوهات المحاكاة المختلفة بأستخدام برنامج محاكاة الشبكة الاصدار(NS-2.35) والذي تم تنصيبه على نظام تشغيل اللينكس, توزيعةUbuntu-14.04 والذين طبقا على حاسبة افتراضية. وقد تم تنصيب النظام الكلي على نظام تشغيل Windows-8.1 ذو حزمة corei3 لوحدة المعالجة المركزية.

قسمت اختبارات المحاكاة الى جزئين, الاول يتضمن عدة اختبارات على CHFL-ZRP بروتوكول باعتبار وجود قاعدة التجميع الثابتة والمتحركة اضافة الى اختلاف احجام الكتل واختلاف في الحجم القطري الانسب لحركة قاعدة التجميع لاظهار تأثيرهم على وقت موت العقدة الاولى وكمية الطاقة المستهلكة. اما

الجزء الثاني تضمن اجراء اختبارات للبروتوكولين الثابت والمتحرك ومقارنتهما مع بعض المناهج المعروفة الاخرى والتي تشمل LEACH, LEACH-C, LEACH-M, LEACH-ME,LEACH-ERE, CHEF.

اظهرت نتائج المحاكاة ان CHFL-ZRP يتفوق على LEACH-EREو CHEF في شروط موت العقدة الاولى ومعدل عمر الشبكة, وايضا يتغلب على LEACH, LEACH-C في معدل الانتاجية, التأخير, و معدل الطاقة المستهلكة. بينما MCHFL-ZRP يتفوق على LEACH-M وLEACH-ME في معدل الطاقة المستهلكة والمتبقية وفي نسبة تسليم حزم البيانات.

بروتوكول عنقودي كفوء يهتم بالطاقة لشبكات الاستتشعار اللاسلكية مع تنقل محطة قاعدة التجميع

رسالة

مقدمة الى كلية هندسة المعلومات في جامعة النهرين

كجزء من متطلبات نيل درجة ماجستير علوم في

هندسة الشبكات و الشبكة الدولية

من قبل

مريم رشدي عبد الرضا

(بكالوريوس في هندسة الشبكات 2013 م)

شعبان 1437

أيار 2016