Dynamic Energy-Efficient Routing Protocol for Wireless Sensor Networks

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Dedication

I would like to express deepest appreciation towards **My father prof. Numan Amro and Mother Ghada Wahab and to Sarah, Rana, Ehab for their sincere and true support.**

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Table of Contents

List of Tables

List of Figures

ACRONYMS

ADC	Analog to Digital Converter
ADV	Data Advertisement
APTEEN	Adaptive Periodic TEEN
CDMA	Code Division Multiple Access
DD	Directed Diffusion
GAF	Geographic Adaptive Fidelity
GEAR	Geographical and Energy-Aware Routing
GPS	Global Positioning System
LAN	Local Area Network
LEACH	Low Energy Adaptive Clustering Hierarchy
MAN	Metropolitan Area Network
PAN	Personal Area Network
PEGASIS	Power-Efficient Gathering in Sensor Information System
REQ	Data Request
SPAN	Switched Port Analyzer
SPIN	Sensor Protocol for Information via Negotiation
TDMA	Time Division Multiple Access
TEEN	Threshold Sensitive Energy Efficient Sensor Network
UASN	Underwater Acoustic Sensor Network
VRS	Volcano Routing Scheme
WAN	Wide Area Network
WSN	Wireless Sensor Network

ملخص الدراسة

تمتلك الشبكات اللاسلكية (WSNs) مجموعة من عُقد المستشعرات المنتشرة في عدة مناطق لجمع البيانات ومراقبتها وتسجيلها والتي يمكن اعتبارها بيانات مهمة في مناطق لا يستطيع الإنسان الوصول إليها. القدرة الخاصة لهذه الشبكات جذبت الباحثين لدراستها. تحتوي شبكات (WSNs)على تنسيق حر ، وتعتمد على الشبكات اللاسلكية ، على طبيعتها التكيفية وحجمها الصغير الذي تم العثور عليه في تطبيقات متنوعة.

نستطيع أن نرى أهمية وجود (WSNs) في الرعاية الصحية ، والرصد ، والنقل ، والصناعة ، والأتمتة ، والمراقبة. وتحتوي (WSNs) على العديد من المحددات والتحديات مثل الذاكرة واستهلاك الطاقة والتنقل. وبالتالي ، فإن مجالات تطور (WSNs) عديدة. الهدف الرئيسي هو الحفاظ على الطاقة وحفظها لإطالة عمر الشبكة. ومن الصعوبة بمكان إطالة عمر الشبكة عن طريق تقليل استهلاك الطاقة في المستشعرات، حيث يتم تقليل توظيف الطاقة باستخدام اثنين من البروتوكولات المحافظين على الطاقة مع خوارزميتين واحدة لتوفير الطاقة والأخرى لتحسين انتقال البيانات بين المستشعرات.

يتم استخدام خوارزمية (VRS) لبروتوكول الانتشار الموجه (DD) المعروف بكفاءة استخدام الطاقة وذلك كونه احد أهم البروتوكولات المحافظة على الطاقة ضمن بروتوكولات البنية المسطحة، وخوارزمية التحسين مع LEACH لتحديد العدد الأمثل لمستشعرات المنطقة الواحدة المساعدة في عملية توفير الطاقة للشبكة بأكملها. كل ذلك يتم من خلال دراسة تفصيلية لـ (LEACH)و (DD) و (VRS)والتحسين على (LEACH) للوصول لأفضل طريقة للحصول على طاقة أكثر في الشبكة. نستفيد من الخوارزمية في تحسين قدرة (LEACH) في حفظ الطاقة واستخدام VRS للحصول على ميزة الموقع مع البروتوكول الهرمي المحسن. يفيد موقع المستشعرات من خلال معرفة موقعه وموقع المستشعرات المحيطة لمعرفة كيفية التعامل مع البيانات إذا كان هناك أي مستشعرات لا تستطيع التواصل بسبب عدم وجود طاقة فيها. ينقسم النموذج المقترح الجديد إلى جزأين ، الأول يتناول عملية حساب الطاقة والاستشعار لاستخراج أنماط البيانات ليتم استخدامها في البحث عن المعلومات المطلوبة. الجزء الثاني هو الجزء الديناميكي عندما تقرر الشبكة أي بروتوكول يعمل وفقًا لكمية البيانات المطلوبة. إذا كانت البيانات محدودة ، فهذا يعني أن (DD)تبحث في أنماط البيانات التي تم جمعها إذا كان حجم البيانات ضخمًا ، حيث تعمل الشبكة على تشغيل (LEACH) لإنشاء أنماط بيانات جديدة لعملية بحث جديد.

تمت محاكاة البروتوكول الديناميكي الجديد وتمت دراسة أدائه باستخدام (NS3) تم استخدام بروتوكول (DD,LEACH) كعلامة اختبار لتقييم الأداء. تظهر نتائج المحاكاة أن البروتوكول الديناميكي له أداء أفضل من استخدام بروتوكول (LEACH,DD) كل على حده من حيث الطاقة والعمر.

Abstract

Wireless sensor networks (WSNs) hold a group of spatial sensor nodes circulated to collect, monitor, record data which can be considered as an important data in critical areas that human cannot reach.
The special ability for these networks attracted a respectable amount of study. WSNs have unrestrained figuration, and they depend on the wireless networks, for their adaptive nature and tiny size WSNs found in various applications.

We can see the presence of WSNs in healthcare, monitoring, transportation, industry, automation, and surveillance. However, the WSNs have many limitations and challenges like memory, power consumption, mobility. Hence, WSNs have so many areas to evolve and develop. The major goal is to conserve and save energy to prolong the network lifetime.
Because it's hard to prolong the network lifetime by minimizing the node consumption of energy, the energy employment is minimized by using two energy efficient protocols with two algorithms one to save energy and the other to optimize the transition of data between nodes.

We are using Volcano Routing Scheme (VRS) for the Directed Diffusion (DD) protocol which is known as an energy efficient that helps flat structure protocols to conserve energy, and the optimization algorithm with the LEACH to select the optimal number of sink nodes that will help the process of saving energy for the whole network.
All of that is done starting with a detailed study of the LEACH, DD, VRS and the enhancement on the LEACH to see if there is anything advanced to save the network energy.

We make use of the optimization algorithm to enhance the LEACH and use the VRS to have the location advantage with the optimized hierarchical protocol. The location benefits the nodes by knowing its location and the neighbor's location to know how to deal with the data if there are any dead nodes.
The new proposed protocol is divided into two parts the first one is manual, dealing with the energy computation and sensing operation to extract the data patterns to make the lookup tables. The second part is the dynamic part when the network decides which protocol to operate according to the needed amount of data.
If the data is limited, it means the DD is searching in the lookup tables if the data

amount is huge the network is operating the LEACH to construct a new lookup table.

The newly dynamic protocol has been simulated and its performance has been studied using NS3 simulator. The LEACH protocol has been used as a benching mark to evaluate the performance.
Simulation results show that the dynamic protocol has better performance than LEACH standing alone in terms of energy and lifetime and we can see it as a percentage ranges from (20-25percent).
Keywords: Energy Efficient, Dynamic Routing, VRS, WSNs, LEACH, DD.

Chapter 1

Introduction

1.1 Thesis Overview

The internet is providing seamless communication without geographical barriers. The days when communication was strictly limited to writing letters and waiting for postal services to deliver them are gone.
Technological advancements influence various sectors such as health-care, industrial automation, agriculture, transportation, and education. In addition to its major job to close the communication gap. The advantage of wireless communication has made network connected at any time and any place and the data is not restricted to a geographic place to be in. Its uploaded everywhere on the cloud. The latest technological advances in the wireless were WSNs [1][3].
The WSNs technology are a class of special wireless ad hoc networks. A wireless ad hoc network is a collected group of wireless nodes, which communicate in a direct way over a mutual wireless channel [1].
There is no more infrastructure needed for ad hoc networks. It is a scattered network without any organized structure or any known topology. Therefore, every single node is equipped with a wireless transceiver, and it has to be able to act as a router for itself, to process packets to their final destinations [2].
The major strong point of these networks is that they have the ability to self-organize their infrastructure of the routing after they have been deployed the major difference between popular ad hoc networks and WSNs are the area of application [15]. For WSNs, to monitor and to collect data are the main point, while popular ad hoc networks concentrate more on the communication aspects.
WSNs usually hold a major number of widely far distributed devices which are equipped with sensors (instruments that measure quantities in our environment) to monitor physical or environmental phenomenon. These devices work autonomous and are logically linked by self-organizing means [14].

WSNs allow the ability to observe the previously unobserved at a fine resolution over large spatiotemporal scales.
So we can keep an eye on the environment in every second in the day WSNs processors in various modes (sleep, idle, active), power source (AA battery or Coin batteries, Solar Panels), memory used for the program code and for in-memory buffering, radio used for transmitting the acquired data to some storage site, sensors for temperature, humidity and light [1].
Attractive functionality of sensor nodes in a WSNs include effortlessness installation, fault indication, energy level diagnosis, high reliability, easy coordination with other nodes in the network, control protocols and simple network interfaces with other smart devices [15]. Therefore there are so many routing protocols to do the data transmission and the computation needed to deliver the data from the source to the destination the protocols are divided into two categories based on the network structure and the route determination and some of them: SPIN[14], DD[56], LEACH[49], PEGASIS[20], SPAN[21], GEAR[22], GAF[19].
In this thesis, a new dynamic routing protocol is proposed to prolong the network lifetime. Which enhance the performance of the network to deliver the needed data to the destination and we can see that in the metrics which give us a view of the energy consumption and the throughput and the data transmission process.

1.2 Problem Statement

The problem of WSNs is their limitations that occur while using such as cost, size, limited power. We are trying to find a solution for the power consumption problem because it is the most important one to prolong the network lifetime, hence it is hard to reach those sensors easily where they are planted in nature.
The sensors are helping by saving patterns for the WSNs and collected data from the environment, where the WSNs are implemented in. That helps in several crucial areas like volcanoes, oceans, earthquakes and so on.
VRS is helping in directing the data packets to the specific location using the shortest path is energy conserving, so we don't have to deal with any problem for losing the packets along the way.
Moreover, the LEACH is conserving the energy using the CH rotation at every round according to the nodes energy.
By this we are able to solve the disadvantages for the separate two protocols(LEACH, VRS) which are as follows for the LEACH:

- The nodes are part of the corresponding cluster in step with the published signal intensity that exhausting the CH energy.
- CHs range can't be ensured.

- Best distribution can't be ensured.
- CHs communicate with the SB in signal hope mode.
- Nodes with high and low energy have the identical priority to be a CH.
- Once CH dies the gathered information would ne'er reach the destination.

For the VRS as follows:

- Needs continuous stream of packets from supply to destination.
- Packets rearrangement would possibly happen.
- Performs higher in an exceedingly network that a nonstop stream of packets are generated at every supply node.

1.3 Motivation

WSNs are small devices that are used to collect data from critical locations which cannot be arrived by humans and they depend on limited energy sources like battery and there is so many research that discussed the energy-efficient protocols previous researches handled just one protocol at a time to save the energy.
So we proposed a new approach to use two protocols in a dynamic way using two energy-efficient protocols from two categories using the right network structure according to specific conditions such as the amount of data, the network state also the node state from the point of view of energy.

1.4 Objectives and Benefits

Our goal is to find a new routing protocol to prolong the network lifetime as long as possible, without losing the data in the sensors.
The vital downside in WSNs is energy consumption that the superintendence of the energy and the way it's consumed is that the space of study. how to distribute the energy among the network all the previous researches have studied the improvement on the network victimization separate protocols for the LEACH studied the way to improve the information transmission and for the VRS the way to stop the issues associated with flooding.
The main objective is to develop a dynamic energy-efficient routing for the WSNs, from that we are summarizing a new objective as follows:

- State art of WSN.

- Improve the lifetime of the WSNs by prolonging the node lifetime. By putting the sensors on sleep mode and activated when needed.

1.5 Main Contributions

In this we will present the main contribution of the thesis:

- Propose a new protocol using two structures for the WSNs instead of one protocol with one structure each time, which is not used with this kind of networks due to energy consumption problems.
- Make use of the optimization algorithm to prolong the WSNs lifetime.
- Make use of the location of the nodes to sense and collect data from the needed nodes, with that we do not operate the whole network while the data is in a known location, which saves the nodes energy while harvesting data.

1.6 Structure of the Thesis

This thesis is organized to show the details of WSNs in energy- efficient manner, and it is presented as follow. A review of WSNs and how the technology evolved to reach the wireless networks from wired networks and how it would be helpful in everyone's life on a daily basis.
Chapter 1 is an introduction to the thesis, discussing the problem statement and the main contributions. In Chapter 2 the WSNs types are presented along with the WSNs application, how they are used and where and the process of operating the WSNs in the controlling and monitoring. That will lead us to the WSNs component and the node component in particular at the end WSNs challenges are discussed briefly.

Chapter 3 proposes a review of the existing routing protocols and their types according to the structure, route destination and location. Some of the improvements on LEACH protocol as an energy efficient protocol in addition to the DD are also presented.
and it has a description of the dynamic routing using VRS to be implemented on the proposed protocol using the DD protocol as a second energy efficient protocol to switch it with the LEACH for our newly proposed protocol.
Chapter 4 presents the methodology of the network proposed protocol solving the optimizing problem with LEACH protocol and operating VRS with the DD to help the network prolong its lifetime.

Chapter 5 presents the empirical side of the thesis. Chapter6 presents the analysis for the simulation comparing my results with the LEACH and DD each one stands alone. Chapter 7 presents the thesis summary, conclusion, and recommendations.

1.7 Summary

This chapter is about the problem statement, the objectives of the thesis studying this specific problem and benefits, then the thesis structure, and main contributions that we are going to present.
The next chapter is discussing the background of the WSNs.

Chapter 2

Background

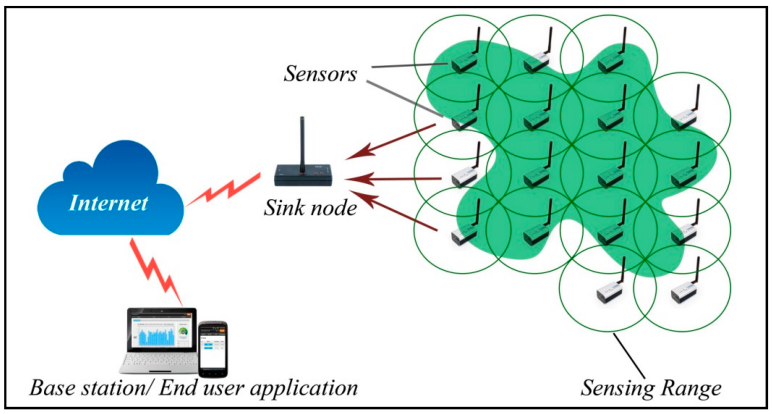
In this chapter, we are presenting an overview about the WSNs, by presenting the types of the WSNs and where they are used in which applications we are making use of them to ease our lives. Additionally to some of the characteristics and some of the advantages.
After that we are focusing on the hardware components and some of the node specification, we tend to finish with the WSNs challenges and therefore the routing classes utilized in WSNs. Finally, we are presenting the network structure in details.
The energy-efficient cluster-based hierarchical (Low Energy Adaptive Clustering Hierarchy) and flat (Directed Diffusion) routing protocols of Wireless Sensor Networks are studied to improve the quality of network performance by prolonging the network lifetime. The distinguishing features of these protocols are exploited to merge them in a grid topology to make the network switch in a dynamic way which protocol to operate according to the network energy state.
Finally, the presented approach will be simulated via NS3 to show the results. This chapter is organized as follows. In Section 1.1, we outline an overview of the work presented in this thesis. In Section 1.2, we discuss the applications of WSNs. In Section 1.3, hardware components of a Wireless sensor node, in Section 1.4 WSNs types, in Section 1.5routing categories, WSNs advantages, in Section 1.6 network stricture , in Section 1.7 characteristics of WSNs, in Section 1.8 WSNs advantages, in Section 1.9 WSNs challenges, in Section 1.10 problem statement, in section 1.11 motivation And the research objectives are presented in 1.12, finally, 1.13 thesis structure and 1.13 summary.

2.1 WSNs Overview

In our daily life we need to communicate with each other and transmit data and share services on a daily basis, in business, education and in every aspect of our life. Network makes information and services available to everyone on the network, regardless the physical location of the resources or users, and these networks are divided into several types such as Personal Area Networks(PAN) it is organized around an individual person, Local Area Networks(LAN) are used to connect computers in small areas, such as building, Metropolitan Area Network(MAN) are used to connect computers in a city or town, finally Wide Area Networks(WAN) connects numbers of computers over a long area such a country or a continent, all these networks are wired links which provide reliable data transmission but requiring a high installation cost, which is inconvenient [1].
So the dismissal was wireless communications to cope these blocks. Wireless networks connect devices and computers using radio waves or any other wireless media, there are diverse wireless communication standards which allow full mobility [2]. With the recent technological advances in communications, especially in wireless and integrated digital electronics and micro electro mechanical systems, it became possible to develop multi-functional sensor nodes, which is small-sized, tiny, low power and cost [1][3].
Wireless sensor network is a group of specialized autonomous sensors and actuators [3] with the capabilities of sensing, wireless communications, and computations [4]. So wireless sensor network is a network of sensing devices connected together to the base station by wireless means [1] to monitor and control physical or environmental status at diverse locations, and to push through data and to control the commands to a desired actuator through the network[1][6][17].
A wireless sensor network holds numerous nodes ranging from a slight ten to various hundreds or thousands, each node is connected to one or more nodes, these nodes are designed to perform functions, such as sensing and the nodes doing it called a sensor node, relaying data its node called a router, exchanging data with other networks is the base station or sink node, which is similar to a gateway in the traditional network [2][6].
We can say that a wireless sensor network is the outcome of the series of sensor techniques, entrench techniques, distributed information processing, and communication mechanisms [1][6].
Also, it has attractive functionality of sensor nodes in a WSNs includes effortlessness installation, fault indication, energy level diagnosis, high reliability, easy coordination with other nodes in the network, control protocols and simple network interfaces with other smart devices.
In WSNs, based on the sensing range and environment, the classification of sensor nodes are four groups, namely specialized sensing node, generic sensing node,

high bandwidth sensing node, and gateway node. We can see the typical scenario for the WSN in Fig(2.1)

Figure 2.1 WSNs Typical Scenario[17].



2.2 WSNs Applications

Wireless sensor networks have a collaborative nature bring several benefits over networks which include self-organization, rapid deployment, flexibility, and inherent intelligent processing capability, on the other hand, these remarkable features of WSNs present new challenges in the hardware design, communication protocols and application design, so WSNs technology has to address these challenges with its nature for the limited resources [25].
We can address with energy efficient operation to maximize the network lifetime and for the harsh environmental conditions the WSNs have to support the adaptive network operation to enable end users to cope with dynamic wireless-channel conditions and varying connectivity by using signal processing algorithms and communication protocols, the unreliable communication in WSNs due to error-prone, WSNs should be reliable to function properly and depending on the application requirements, so the sensed data must reliably deliver to the sink node which WSNs can handle it with robustness to node failures and that requires a fault tolerance improved by a high level of redundancy [3].
Wireless sensor networks have found their way to a wide variety of application and system with vastly varying requirements and characteristics they may consist of many different types of sensors like seismic, low sampling rate, magnetic, thermal, visual, infrared, acoustic and radar which are able to control and monitor a wide range of conditions, that include temperature, humidity, pressure, soil makeup, lighting conditions, noise levels, vehicular movement, mechanical stress

levels [7][5][1].
Sensor nodes can be used for event detection, event ID, location sensing and local control of actuators the main idea of micro-sensing and wireless connection to provide new application area such as [8][5]:
1.Environmental Monitoring:
Sensor network can be deployed to monitor the environmental parameters where this might have an effect on whatever needs to be controlled and this includes tracking the movement of birds, small animals and insects, earth and environmental monitoring in the marine, soil and atmospheric contexts.
2.Health Application:
The application for sensor networks provides interfaces for the disabled integrated patient monitoring, diagnostics, drugs administration in hospitals and for blood flow, respiratory rate.
3.Military Application:
WSNs can be used for sensing intruders on basis detection of enemy unit movements on land and sea and can work as an integral part of the military command, control, surveillance, computing communications and reconnaissance and targeting systems.
4.Home Application:
Provide a smart environment to adapt to the needs of the end users in terms of input-output capabilities.
5.Other Commercial Applications:
The commercial applications monitoring material fatigue, building virtual key monitoring product quality, constructing smart office spaces, robot control and guidance in the automatic manufacturing environment [3].

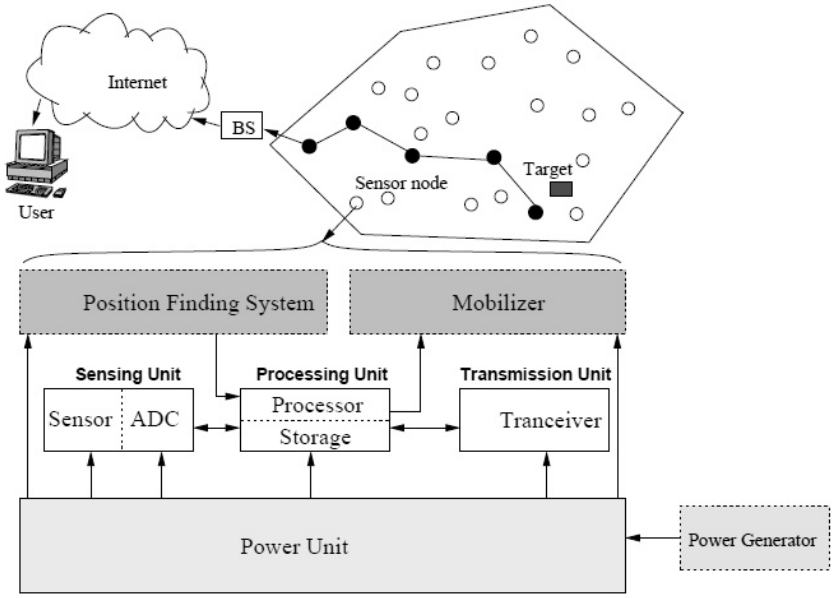
2.3 Hardware Components of a WSNs

WSNs utilizing the seven layer model which is an applied and sensible design that characterizes the system. To know how the WSNs work we need first to know how a wireless sensor network is constructed, the node consists of essential components such as [2]:
1. Sensing Units: they are composed of one or more commonly two sensors and actuators in the physical environment to monitor and have two sub-units sensors with analog to digital converters(ADC) the signals are converted then fed to the processing unit.
2. Processing Unit: it is associated with a tiny storage unit to administer the execution that makes the node collaborates with others to do the assigned sensing tasks, this unit is consists of a micro-controller or microprocessor.
3. Transceiver Unit: it connects the node to the wireless with a short-range radio

system.

4. Power Unit: normally it uses batteries, sometimes those batteries are supported with a power scavenging like solar cells to employ the energy-harvesting technologies [6] besides that there are some additional components significant to be in the sensor node because most of the routing techniques and sensing tasks demand a location finding system to find locations with high accuracy and a mobilizer, sometimes may be needed to move sensor nodes, when it is required to do the tasks assigned[9]. Which we can see it in details with Fig(2.2)

Figure 2.2 Node Components[7].



2.3.1 WSNs Node Types

The node types of WSNs system are sensor node, relay node, actor node, cluster head, gateway and base station which are as follows [24].

1. Sensor Node: Capable of executing data processing, data gathering and communicating with additional associated nodes in the network.

2. Relay Node: It is a midway node used to communicate with the adjacent node. It is used to enhance network reliability. It is a special type of field device that does not have a process sensor or control equipment and does not interface with the process itself.

3. Actor Node: It is a high-end node used to perform and construct a decision

depending on the application requirements. Typically these nodes are resource-rich devices which are outfitted with high-quality processing capabilities, greater transmission powers and greater battery life.

4. Cluster Head: It is a high bandwidth sensing node used to perform data fusion and data aggregation functions in WSNs. Based on the system requirements and applications, there will be more than one cluster head inside the cluster.

5. Gateway: Gateway is an interface between sensor networks and outside networks. Compared with the sensor node and cluster head the gateway node is most powerful in terms of program and data memory, the processor used, transceiver range and the possibility of expansion through external memory.

6. Base Station: It is an extraordinary type of nodes having high computational energy and processing capability. All these sub-units need to be in a tiny, small size like a matchbox-sized module and may be smaller size [2] the required constraints on the size to ensure that it will be light enough to remain suspended in the air.

Table 2.1: WSNs Node Types.

Sensor Node	Executing data processing, gathering and communicating
Relay Node	It is used to enhance network reliability
Actor Node	It is a high-end node used to perform and construct a decision
Cluster Head	Performs data fusion and data aggregation functions in WSNs
Gateway	An interface between sensor networks and outside networks
Base Station	Have high computational energy and processing capability

2.3.2 Node Specification

Specification for the nodes are depending on the application and the node type but generally as follows [1]:

- Consume extremely low power.
- Operate in high volumetric densities.
- Have a low production cost.
- Operate unattended and they are autonomous..
- Adaptive to the environment.

2.4 Types of WSNs

WSNs can be deployed in different positions, and we can distinguish those types as follows to provide some details about them [2]:

1. Terrestrial WSNs:
They are deployed in a given area and must provide reliable communication in a dense environment. The data have to communicate data back to the base station in an effective way, it has limited battery power, and it is not rechargeable, we can back up the battery with a second source, like the solar cells. The terrestrial WSNs keep energy with the optional routing approach(multi-hop), the transmission range is short, data redundancy is avoided, delay minimization, use low duty cycle operations, in-network data aggregation.

2. Underground WSNs:
Underground WSNs nodes are entombed underground or in a cave or mine to monitor the underground conditions, there are additional sink nodes above ground to relay information from the sensor to the base station, underground sensor node are costly because of the convenient select for the equipment part, guarantee reliable communication through the soil and rock and other mineral contents, the challenges in wireless communication is the signal loose and high level of attenuation, underground WSNs must be energy conservative, so they must be planned carefully with cost and energy considerations.

3. Underwater Acoustic Sensor Networks(UASNs):
This technology provides new opportunities to explore the ocean and detect earthquakes and tsunami among many things. The acoustic signals attenuate less than the optical signals and can travel further distances than radio signals and optical, these nodes have to be self configure and adapt to the harsh ocean environment.

4. Multimedia WSNs:
Multimedia WSNs are proposed to enable monitoring and tracking of events in the form of multimedia, those sensors equipped with cameras and microphones, these sensor nodes interconnect with each other over a wireless connection to process, retrieval, correlate data and compression. They must be deployed in a preplanned manner to guarantee coverage, cross-layer interaction among protocol layers can improve the processing and deliver the data.

5. Mobile WSNs:
Mobile WSNs are held of a group of sensor nodes that can move on their own and they are reliable, energy efficient, have a feasible cost, react and adapt with the physical environment, and can adapt to isolated regions[3].

2.5 Routing Categories

Routing protocols are important for the communication process to transfer data between the nodes themselves and the nodes and the base station.
The protocols have categories as follow:

Figure 2.3 Route Determination.

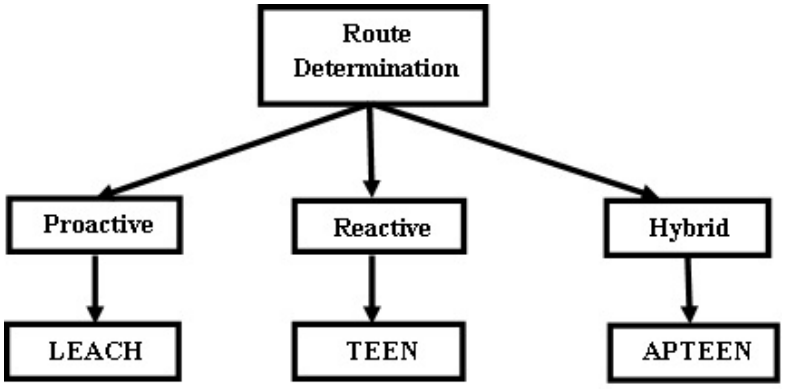
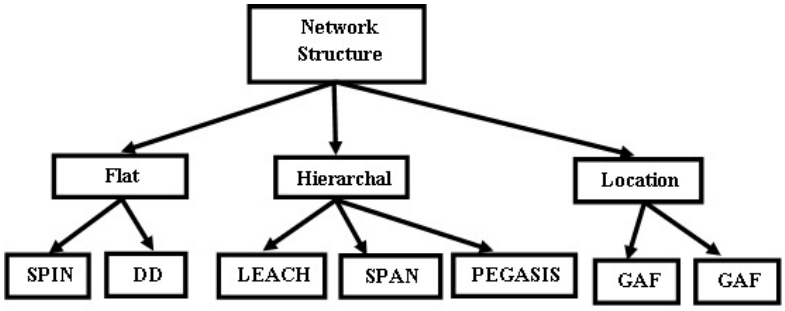


Figure 2.4 Network Structure.



2.5.1 Why LEACH and VRS

The reason behind choosing LEACH is the CH rotation which makes it dynamic by nature and that enable us to control the conditions of cluster formation to save the network energy more than any other hierarchical protocol.
VRS has the benefit of distributed data aggregation by using the location advantage so the path from the source to the destination is near optimal.

2.6 WSNs Structure

We can represent the network communication design by its structure, it is the specialized domain of the physical ingredients of the network. The configuration and functional organization, in addition to the operational basics and procedures plus the use of the data formats [29][30]. The internet network architecture is predominantly expressed by its use of the internet protocol suites in addition to a specific model for interconnecting networks or nodes in the network or the use of specific type of hardware links, although we can consider the network structure as a depicted physically and logically [32].
The position of the devices and the components construct the physical topology of the network. We can specify it by means of the access devices capabilities of the network, the control level, and fault tolerance is required with the association of the cost for the cabling and telecommunication circuits. Moreover, the logical topology clarifies how the flow of data within the network. And how the signals perform on the network media, the way that data take from one device to the next through the network with no consideration to the interconnection of physical devices [35][36].
WSNs structure involves various topologies for radio communication networks, and they are as follows:

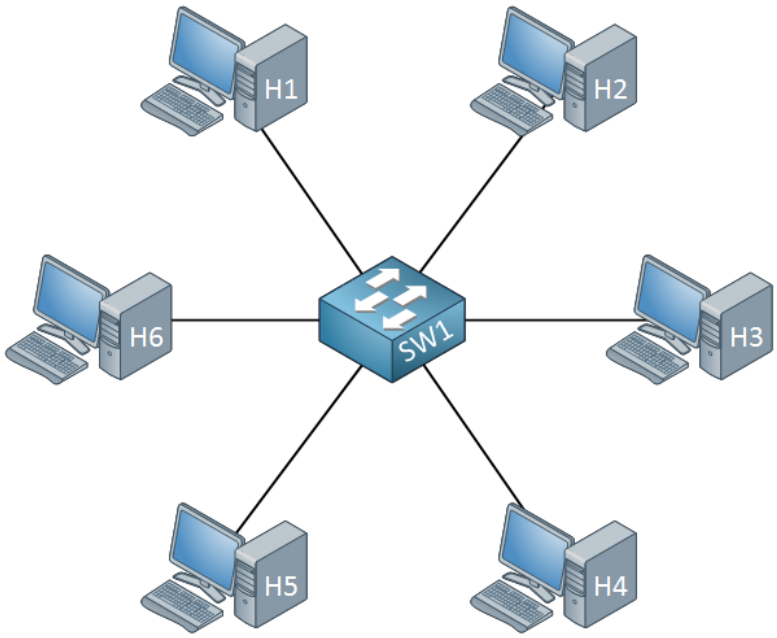
1. Star Network:

It is called a single point to multi-point. The topology structure of the star network communicates with a single base station that sends and receives the messages [31], it is a simple network that has the ability to remote nodes power consumption to the minimal rate which allows communication with low latency between the sink node and the base station [33][34]. The dependency on the single node to manage the network is one of the disadvantages of this topology also it has to be within the range of radio transition for all the nodes and it is not robust enough [39]. Which appears in Fig(2.5).

2. Mesh Network:

A mesh network allows transmitting data from one node to another node in the network that is within its radio transmission range. Which allows a multi-hop communication that is if a node wants to send a message to another node which is out of radio communications range it can use an intermediate node to forward the message to the desired node [31]. A mesh network allows the redundancy and scalability.
In this topology, a node failure does not affect the whole network, a remote node can communicate with any other node in its range which can forward the message to the desired location and we can extend the network range by adding more nodes

Figure 2.5 Star Topology[34].



[33].
The drawbacks of this topology that the nodes with the multi-hop communication are high power consumption compared to other nodes also the time to deliver the message to the destination increases according to the number of communication hops [34]. Which we can see it in Fig(2.6).

3. Tree Network:

A tree network joins multiple star topology into a bus topology in a hybrid approach to upgrade the network scalability [33]. The network is set up as a hierarchy with at least three levels. Only hub devices connect directly to the tree-bus and every hub function as the root of a tree of devices [34]. Which is shown in Fig(2.7).

4. Grid Topology:

The grid topology is modeled as a 2D network with n*n fixed nodes. Also, we can accept 3D hexahedral, tetrahedral pyramid and wedge cells to be used, the grid points are used to maintain contact between adjacent cells [34].
In grid network communications can only occur between nodes that are linked. Neighbors with a separation distance of d. The main idea is to divide the grids. Network area is partitioned into the non-overlapping square grid with the same size, so it has to be at least one node only in working state in each grid at any time [37].
The nodes in a grid should work in turn to prolong the network lifetime. In every

Figure 2.6 Mesh Topology[34].

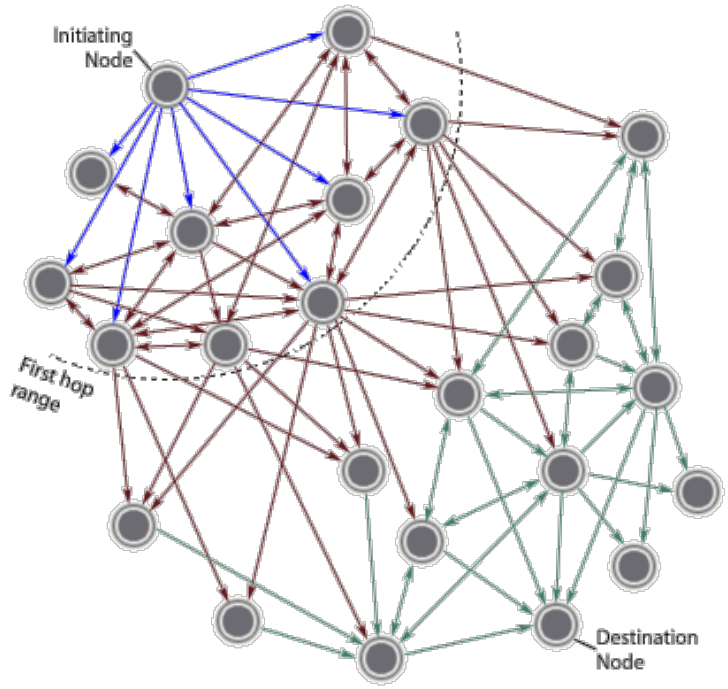
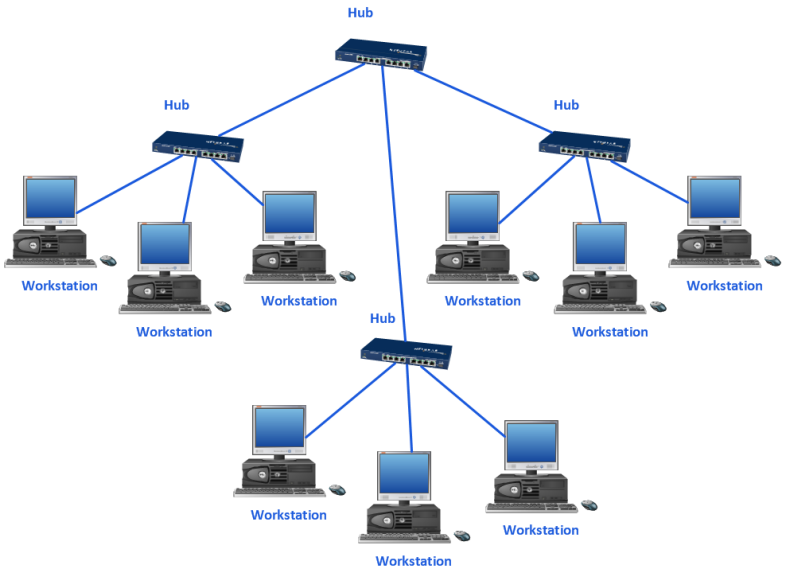
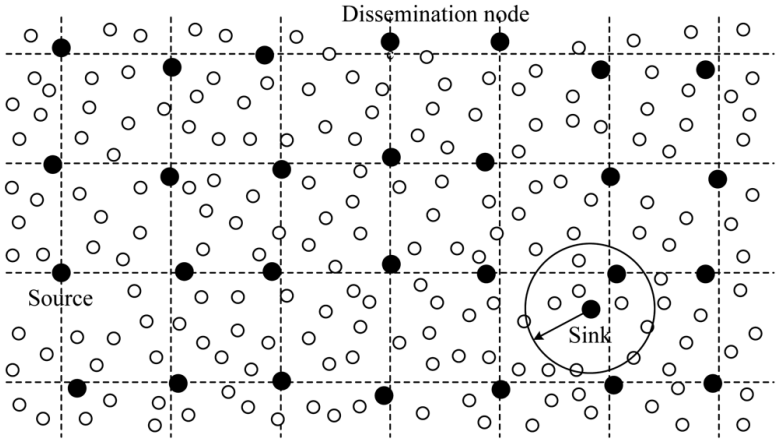


Figure 2.7 Tree Topology[34].



single grid, there is one node selected to be the grid head, which is responsible for forwarding routing information and transmitting data packets routing is performed in a grid by grid manner. The grid topology configuration plays an important role for damping transient frequency-power oscillations during fault events [41]. Which appears in Fig(2.8).

Figure 2.8 Grid Topology[37].



2.6.1 Why Grid Topology

The chosen topology is grid topology in order to take advantages of the location in the network model.
The grid is divided into equal squares so that there are common areas between each 2CHs so that the information in an area is accessed by using more than one CH in case of some node death. In addition, the selection of squares reduces the noise during data correspondence between nodes.

2.7 Characteristics of WSNs

specification for the nodes enable the WSNs to have unique characteristics to help it do its work in an appropriate way and those characteristics are[25]:

- Limited power, they can harvest or store.
- Ability to cope with node failures.
- Ability to sustain the harsh environmental conditions.
- Mobility of nodes.

- Dynamic network topology.
- Communication failure.
- Heterogeneity of nodes.
- The large scale of deployment.
- Unattended operation.
- Scalable Node capacity only limited by the bandwidth of gateway node.

2.8 WSNs Advantages

WSNs have many advantages as follows [25].

- WSNs arranging can be executed without fixed infrastructure.
- It reaches several places that are hard to reach like mountains, oceans, forests.
- Flexibility if there is a need for a new workstation.
- It is not expensive to execute.
- It does not need wires.
- There is a place for new devices.
- It can operate with central monitoring.

2.9 WSNs Challenges

Some of the challenges for these systems are[13][26]:

- Reliability.
- Power Consumption.
- Node Size.
- Mobility.
- Privacy and Security.

2.10 Summary

In this chapter we are discussing the WSNs what are those, and how they are working, discussing the applications they used in, types, routing protocols, advantages and challenges in WSNs.
This is the overview of the WSNs to move on to the next chapter to present the literature review.

Chapter 3

Literature Review of Routing Protocols

In this chapter, we are presenting the details of the routing protocols for the WSN according to their categories, and then we are discussing the detailed studies of LEACH and DD and VRS.

3.1 Existing Routing Protocols for WSN

Routing techniques are important for sending data between the node and the base station (sink node), for the communication, so there are different protocols proposed to classify routing protocols for the wireless sensor network there are different parameters we can classify the protocols according to them such as [3]:

1. Route Determination:

Proactive Protocol the nodes sense the environment and transmit the data to a base station, through predefined route, so the routes are determined as a prior then they are needed and updated the routes, when the changes in the network topology occur and it is not appropriate for ad-hoc networks, where the topology changes permanently like low energy adaptive clustering hierarchy protocol(LEACH).

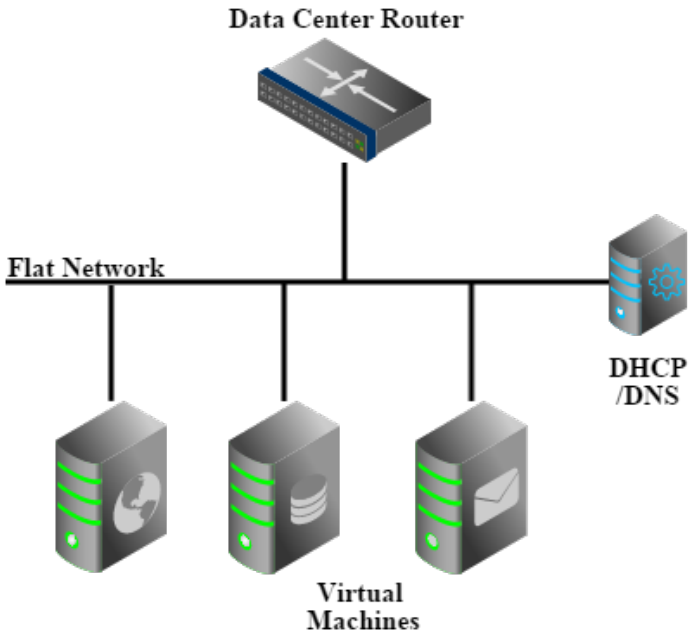
Reactive Protocol this protocol is used in time critical application due to the sudden changes in the sensed attribute beyond some predetermined threshold value, the node react immediately and this tells us that its only invoke a route discovery procedure on demand and its suitable for dynamic networks like Threshold sensitive Energy Efficient sensor Network(TEEN) [3].

Hybrid Protocols they incorporate the concepts of proactive and reactive protocol, at the first compute all routes, and they improve the routes at the time of routing, like adaptive periodic TEEN(APTEEN) [2].

2. Network Structure: and it has three sub-categories:

a. Flat Network: all the sensor nodes have the same level of functionality and responsibilities [10], each node plays the same role and sensor nodes collaborate together to perform the sensing task [13]. The information is distributed in the flat routing as needed to any reachable sensor node within the sensor cloud, and there is no effort is made to organize the networks, and traffic only discovering the best route hop by hop [1]. Which is seen in Fig(3.1)

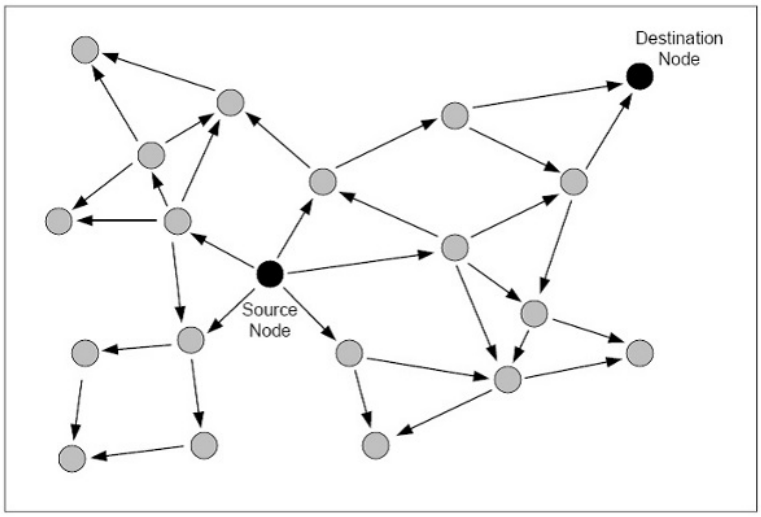
Figure 3.1 Flat Network[13].



In this protocol data, elimination and negotiation can be used to save energy in the network, and the route discovery process can be initiated by flooding or broadcasting data to all neighbor nodes without paying attention to the topology updates and it has three sub-categories:
Flooding protocol it is the most basic flat routing protocol, it can be easily implemented over WSN, without considering the topology or the structure of the networks, there is no need for any complex algorithm programming, it simply broadcasts data to all the neighbor nodes [4]. The data can be delivered to the destination node by repeating the same process of broadcasting, it has some critical problems, the first one is the generation of a duplicate message in large numbers by many nodes and the second one occurs when a certain node receives the same

data twice which is called implosion [1]. Which appears in Fig(3.2)
Sensor protocol for information via negotiation (SPIN) it is a modification of classic flooding. In classic flooding, the information is forwarded on every outgoing link of the node the drawbacks of flooding includes draining out the battery life of the sensor network to a great extent [19].

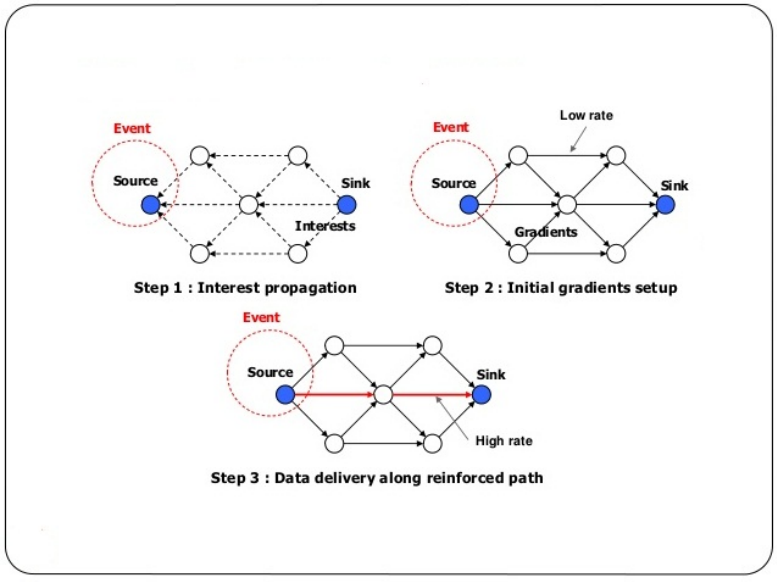
Figure 3.2 Flooding Protocol[4].



SPIN was developed to overcome the drawbacks. It is an adaptive routing protocol which transmits the information first by negotiating. It makes use of metadata of the actual data to be sent. Metadata is broadcast and will contain the description of the message that the node wants to send and the actual data will be transmitted only if the node wishes to receive it. It first asks for any node[12], which has interest in the data and send that data only to those nodes who are interested in the data, it deals with three types of packets data advertisement (ADV), a data request (REQ), and data (DATA) packets [6]. In this protocol, the energy may be drained quickly and its scalability is very small, the negotiation system reduces the produced redundant data to half. *Directed Diffusion Protocol(DD)* it is a data-centric routing protocol, initializing the process of collecting data is done by a base station or sink node in three steps [1][18].
Step 1:the sink node broadcasts an interest packet with a gradient value with attributes value and direction to all the neighbor node and the neighbor nodes will broadcast to the neighbors and so on until the interest message reaches the source node that has the same data required.
Step2:the source node will use the gradient on the interest message, to send the data packet to the sink node using multi-paths.
Step3: the best paths are reinforced by the sink node, the best path selection de-

pends on the application, some of them require the shortest path and some the lowest energy consuming path[6]. The communication in directed diffusion is neighbor to neighbor, so all the nodes have the ability to carry out data aggregation and caching, so it is not suitable for applications that need continuous data delivery [1]. DD consists of several elements:
1. Interests (a query or an interrogation which specifies what a user wants (named data)).
2. Data Messages (can be an event).
3. Gradients (it is created in each node that receives interest, and we can deal with it as a direction state)
4. Reinforcements (it is one or a small number of the network paths) Diffusion is data-centric and all communication is neighbor to neighbor, so every node is an end. Moreover, there are no routes in a sensor network. So each sensor node can interpret data and interest messages. Gossiping this protocol is proposed to address the problems of the flooding scheme instead of broadcasting, it sends the packet to a single neighbor chosen randomly from a random table, which avoids the implosion problem, but the overlap problem is not resolved, these protocols squander energy at a slow rate due to the slow information distribution [8][18]. Which is seen in Fig(3.3)

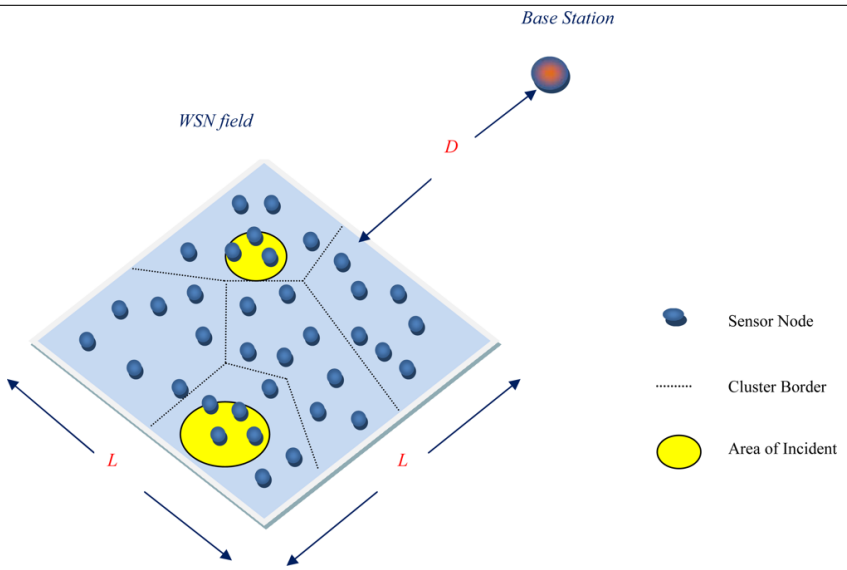
Figure 3.3 Directed Diffusion Protocol(DD)[18].



b. Location Based: these protocols take advantage of the location of the wireless sensor nodes, in data routing the node address is determined according to the

physical location which is determined through Global positioning system(GPS) or other positioning techniques, the distance between the neighbors node can be calculated according to the signal strength and it has three sub-categories [14][16].
Geographic Adaptive Fidelity(GAF): originally this protocol was proposed for

Figure 3.4 Location Based Network[16].



wireless ad hoc network but it is suitable for WSN, it is concerned with energy awareness in which it saves energy without affecting the routing dependability, the protocol main idea is to divide the sensors field into fixed virtual grid zones, it works in three stages the first one is discovering stage, in which each node can discover its neighbors [22].
The active stage is the second phase, in which the nodes participate in routing data and the sleep stage which holds the process of turning off the node's transmitter and setting the node to sleep mode is the last stage, which saves more power [1].
The protocol reliability on the GPS technique makes it not always available especially for indoor application, and it costs extra overhead on the memory unit. It's the goal to optimize the performance by identifying equivalent nodes by considering the forwarded packets.
Geographical and Energy-Aware Routing Protocol(GEAR) it is popular in data-centric WSN applications, it endeavors to hand over the data to all the nodes inside a target area, the main concept of (GEAR) is reducing the number of interests in direct diffusion by sending the interest packets to assured area or direction in the network, this protocol keeps two values [5][14][16]:
The first one is an estimated cost, which is the combination of distance to the target region and the remaining energy and the second one is the learned cost, which

is the change in the estimated cost caused by routing around network holes, these holes are created when the nodes do not have any other nearby nodes, the network is hole free when the estimated cost is equal to the learned cost [8].
The GEAR protocol has two phases the first one is to forward packets, which the target region, and the second one is disseminating the packets within the target region [6]. We can see it in Fig(3.4)

c. Hierarchical Based : it is used to perform energy efficient routing, originally it was proposed to route data in wired networks [8], but with enhancement related to network scalability and the efficiency of communication [8], it became suitable for routing data in wireless networks [5], it attempts to conserve energy by arranging the nodes into clusters to more than one level [4] the first one is responsible for selecting the cluster-heads and the second is related to routing decision [1][10]. Which appears in fig(3.5)
The high-level nodes is assigned to handle processing and transmitting data while the low-level nodes are assigned to sense events only [7][15][11].
low Energy Adaptive Clustering Hierarchy (LEACH): LEACH is a protocol which confers the guarantee about the distribution of energy in the sensor node. In this protocol, the cluster head gets the data from its member nodes of the cluster and aggregate the data before sending to the base station.
Cluster head nodes die earlier than other nodes because they are consuming more energy than a non-cluster head node. The whole network is divided to clusters and each one has a cluster head assigned to it, the data are delivered into the data sink or base station [1], the responsibility of data collection, processing and sending the data to the base station lies on the cluster head [11].
Cluster heads are randomly selected so it cannot guarantee the even distribution and does not consider the transmission distance and uses the single hop model to communicate with the base station [1], the random selection for the cluster head aims to spread the energy dissipation to all nodes due to the rotation select of cluster heads, LEACH uses a TDMA-code division multiple access(CDMA), inter-cluster and intra-cluster collisions are reduced by using MAC [1][23]. Which is seen in Fig(3.6)
Power-Efficient Gathering in Sensor Information System(PEGASIS) The main idea of PEGASIS that it assumes all nodes can communicate with base station by using multi-hop to reach the base station [9] through communicating with their close neighbors, in this scheme the location for all nodes is random and each node has to maintain a database for all locations, so each node has the ability to detect communicate fuse, and position data that assumes that the nodes have global knowledge of the network [10][21].
This determines to use greedy algorithm [1] to construct a chain, from the furthest

node from the sink, to enhance the robustness of the network nodes at random locations must die to reconstruct the chain since it depends on distance in this protocol [11]. The energy load evenly will be distributed among the sensor nodes in the network.
We initially place the nodes randomly in the, therefore, the i-th node is at a random location.
The nodes will be organized to form a chain which can be accomplished by the sensor nodes themselves using a greedy algorithm or the BS can compute this chain.
Switched Port Analyzer protocol(SPAN) the protocol goal is to make nodes more energy efficient [1], so the main idea of this protocol is to switch the radio off when the node is neither receiving or transmitting data, the sensors in SPAN works as coordinator [6].
SPAN is an efficient, high-performance traffic monitoring system. It duplicates network traffic to one or more monitor interfaces as it transverse the switch. It is used for troubleshooting connectivity issues and calculating network utilization and performance. It examines other ports or segments without taking the network out of service [20]. Which is seen in table(3.1)(3.2)(3.3).

Table 3.1: Flat Protocols Characteristics.

Protocol	SPIN	DD
classification	flat	flat
mobility	supported	limited
Power management	limited	limited
Network life time	Good	Good
scalability	limited	limited
Resource awareness	Yes	Yes
Query based	Yes	Yes
Data delivery model	Event driven	Demand driven

3.2 Improvements of LEACH Protocol

Many routing protocols have been proposed for WSNs, to explain and to do enhancements on them to conform to the surrounding environment and here is a list of the enhancements on LEACH protocol:

Table 3.2: Location Protocols Characteristics.

Protocol	GEAR	GAF
classification	location	location
mobility	limited	limited
Power management	limited	limited
Network life time	Good	Good
scalability	limited	limited
Resource awareness	Yes	Yes
Query based	No	No
Data delivery model	Demand driven	Virtual grid

Table 3.3: Average Cluster Protocols Characteristics.

Protocol	LEACH	PEGASIS	SPAN
classification	clustering	clustering	clustering
mobility	Fixed base station	Fixed base station	Fixed base station
Power management	maximum	maximum	limited
Network life time	Very good	Very good	good
scalability	Good	Good	limited
Resource awareness	Yes	Yes	Yes
Query based	No	No	No
Data delivery model	Cluster head	Chain based	continuously

1. Malik et al. in [1] Researchers examined the energy efficiency and performance of LEACH protocol using own set of parameters. the lifetime and data delivery characteristics are being compared with the help of analytic comparison and from the simulation results. From this work, they find that LEACH provides better results for the number of cluster heads as 3 and 4. This paper has covered the performance of LEACH protocol only.
2. Yadav et al. [2] The researchers proposed a new amended cluster algorithm of LEACH protocol which is supposed to balance the energy consumption of the whole network and extend the lifetime of the network the proposed clustered routing technique offers when compared to the non-clustered routing and they found that the improved algorithm is more energy efficient than the original.

Figure 3.5 Hierarchical Network[5].

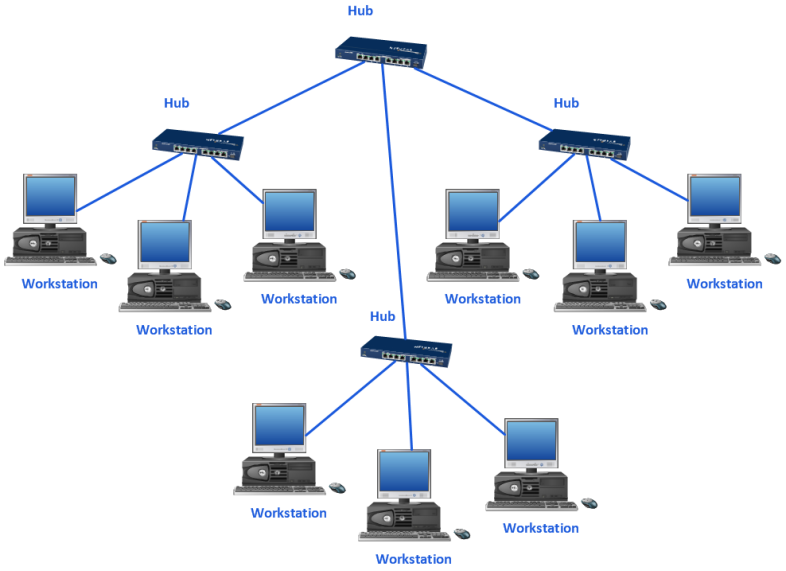
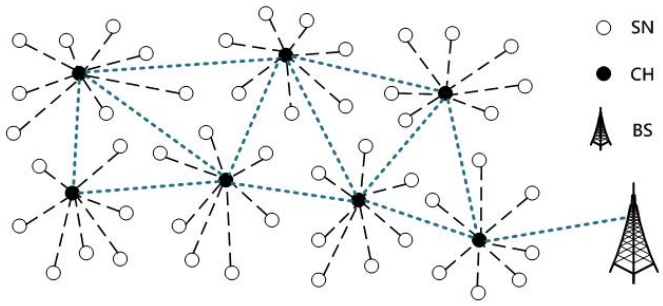


Figure 3.6 Low Energy Adaptive Clustering Hierarchy (LEACH)[11].



3. FU et al. [3] The paper submit a new amended algorithm of LEACH protocol (LEACH-TLCH) that is suggested to balance the energy consumption of the network entirely and to extend the network lifetime by using the concept of balancing the energy consumption of the cluster heads. That was elected in a random way for the LEACH which causes the energy stream of some cluster heads to be less or the distances from the base station are far, because of the heavy energy burden, these cluster heads will soon die.
4.Ebadi. [4] This paper submits a multi-hop clustering algorithm (MHC) to save the energy of the wireless sensor networks. The cluster heads in MHC are being selected according to two parameters the remaining energy and node degree. Also, cluster heads select their members according to the two parameters of the sensor the remaining energy and the distance to its cluster head.

5. MarhoonP et al. [5] Propose a new algorithm that enhances the LEACH algorithm to upgrade the network coverage. This algorithm is called Extended Area Coverage Enhancement (EACE) and the researchers find that the number of nodes that worked at each round in the new algorithm is increased compared to that in LEACH, this provide more covered areas and gather more information in parts of the network that could not send their data in LEACH since there is no near node that acts as cluster head and provides a gateway to communicate with the sink.
6. In Sharma et al. [6] a protocol is suggested, that is heterogeneous in energy. the researchers first analyze the basic distributed clustering routing protocol LEACH (Low Energy Adaptive Clustering Hierarchy), which is a homogeneous system, then the impact of heterogeneity in the energy of nodes was being studied to extend the lifetime of WSN. Shows that the proposed Leach-heterogeneous system significantly reduces energy consumption and increase the total lifetime of the wireless sensor network.
7. Salim et al. [7] They propose a clustering routing protocol named intra-balanced LEACH (IBLEACH), which extends the LEACH protocol by balancing the energy consumption in the network. Which shows that IBLEACH outperforms LEACH and the existing improvements of LEACH in terms of network lifetime and energy consumption minimization.
8. Zhao et al. [8] The researchers established a vice cluster head through the communication process for each cluster, that targets to minimize the energy consumed on the re-clustering process and to extend the time of being in a steady-state phase. the enhanced protocol performs better than the LEACH and the LEACH-C.
9. Xiangning et al. [9] LEACH protocol was improved by means of energy-LEACH and multihop-LEACH protocols. Energy-LEACH protocol enhances the method of choosing the cluster head, the nodes with more residual energy will be selected as cluster heads in turn. Multihop-LEACH protocol enhances the communication mode between cluster head and sink. So we can say that energy-LEACH and multihop-LEACH protocols perform better than LEACH protocols.
10. Yassein et al. [10] The researchers behold LEAH protocol that is the most serious protocol in a wireless sensor network that uses cluster based broadcasting technique. They proposed a new version of LEACH protocol called V-LEACH protocol. The number of messages formed by the V-LEACH is less than the messages created by the original LEACH, and the new version messages are less.Which means the remaining energy on the network using V-LEACH is more than the remaining energy on the network using the original LEACH.
11. Intanagonwiwat et al. [11] The researchers characterized the directed-diffusion model for the design of divided sensing algorithms. And we can see that directed diffusion has the potential for significant energy efficiency. Even with comparatively non-optimized path picking, it executes superior if it is idealized as a traditional data dissemination approach such as omniscient and multicast. The

diffusion techniques are constant with the considered range of network dynamics. To make full potential you have to take patronage of the sensor radio MAC layers design.
12. Mirnabibaboli et al. [12] The goal of the study are limiting the flood problem to increase the network lifetime. interests are classified based on their content, and the network is divided geographically. A counter is assigned to each Geographical location that will determine the use of Flooding for a potential existence of a source and to use Rumor for elsewhere. Using the above-mentioned recommendations, energy consumption would decrease due to the reduction in Flooding; and consequently, network lifetime would increase.

Table 3.4: Improvements of LEACH Protocol.

Yadav	Balance the energy consumption of the whole network
FU(LEACH-TLCH)	Balance the energy consumption of the CH
Ebadi	Multi-hop clustering algorithm (MHC) to save the energy of the WSNs
MarhoonP	Enhances the LEACH algorithm to upgrade the network coverage
Sharma	It is heterogeneous to extend the lifetime of WSN
Zhao	A vice cluster head through the communication process for each cluster
Yassein	It uses cluster based broadcasting technique
Intanagonwiwat	It executes superior if it is idealized as omniscient, multicast

3.3 Detailed Study of LEACH, DD, VRS

Routing protocols are formed from the smallest unit of processing that is used from the exchanged information from routing, then the exchanged information is used by a routing algorithm to determine the optimal path to the destination and the creation of a routing table [58]. Many algorithms exist and use different information to calculate the path from a source to a destination.
Intra-traditional network routing the data is considered to be a two-phase process [43]. The first one is the route discovering phase, it is established between all source-destination pairs, this phase can be proactive routing or on-demand routing (reactive routing) and the second one is the packet forwarding phase which forward the packets along the chosen path toward their destination [59].
And because of the topology changing frequently due to node movement and variations in channel strength, it causes a loss via distance attenuation shading by obstacles or interference from other node all of this will make finding a route will cost a high overhead and it must be paid often which will cost the network performance to decrease and affect the system, that makes the traditional two-phase

routing impractical and delivering the packets to their destination is hard [44][45]. So the solution is to use the alternative approach which is the one phase routing. The purpose of this alternative is to eliminate the explicit discovery of the routes so the algorithm can find a path in the changing network and the algorithm for that is volcano routing scheme (VRS) [42][59].

3.4 Energy-Efficient Routing Protocols

According to the networks, architecture routing protocols are generally classified as plane routing and level routing. Plane routing protocols such as DD, SAR, SPIN, Romer Routing, and the typical level routing protocols are LEACH, PA-GASIS, and TEEN. And in this thesis, we will focus on the LEACH and DD.
we will discuss the two protocols with details to merge them in one network dynamically [61].

3.4.1 LEACH Protocol

Among the numerous routing protocols in particular level routing. LEACH is one of the major improvement of conventional clustering approaches in WSN, many clustering algorithms are based on LEACHs ideology and architecture [53].
LEACH clustering strategy depends mainly on the randomly selected cluster heads(CHs). That will be done by forming clusters out of the sensor nodes and it depends on the strength of the received signal, and another goal is to use the local cluster head as their own routers to the sink node [50][62].
LEACH provides a conception of round and uses it as a unit, it runs with many rounds, each round contains two states:
1. Cluster Set Up State: This stage helps the nodes to decide whether to become a cluster head or not for the existing round [51][46]. The node will be in charge of being a cluster head or not by selecting a number between 0-1, which is connected with a threshold T(n) if it is less than the determined threshold it will become a cluster head thats what makes this stage significant is the cluster head selection [48].
The threshold is set as : p is the desired percentage of cluster heads, r is the current round and G is the set of nodes.
2.Cluster Steady State: In this phase we can store energy for the purpose of reducing unnecessary energy costs [52] and for that the time of the second state is usually longer than the time of the first state for saving the protocol payload [48].
Cluster head selection algorithm adopted by LEACH protocol avoids fast energy loss of cluster heads and its data aggregation effectively reduces the amount of communication, moreover, it is the first protocol that proposed the data fusion, it

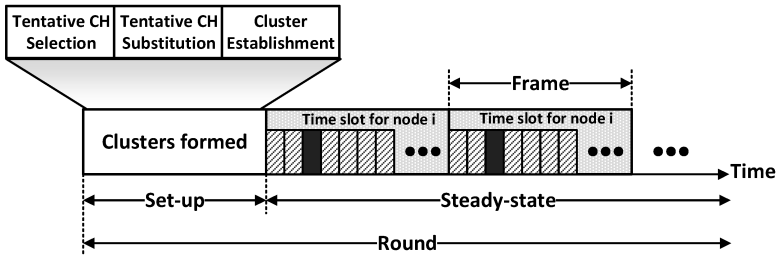
Figure 3.7 LEACH Equation.

$$T(n) = \frac{P}{1 - P \times \left(r \bmod \frac{1}{P} \right)} \qquad \forall n \in G$$

$$T(n) = 0 \qquad \forall n \notin G$$

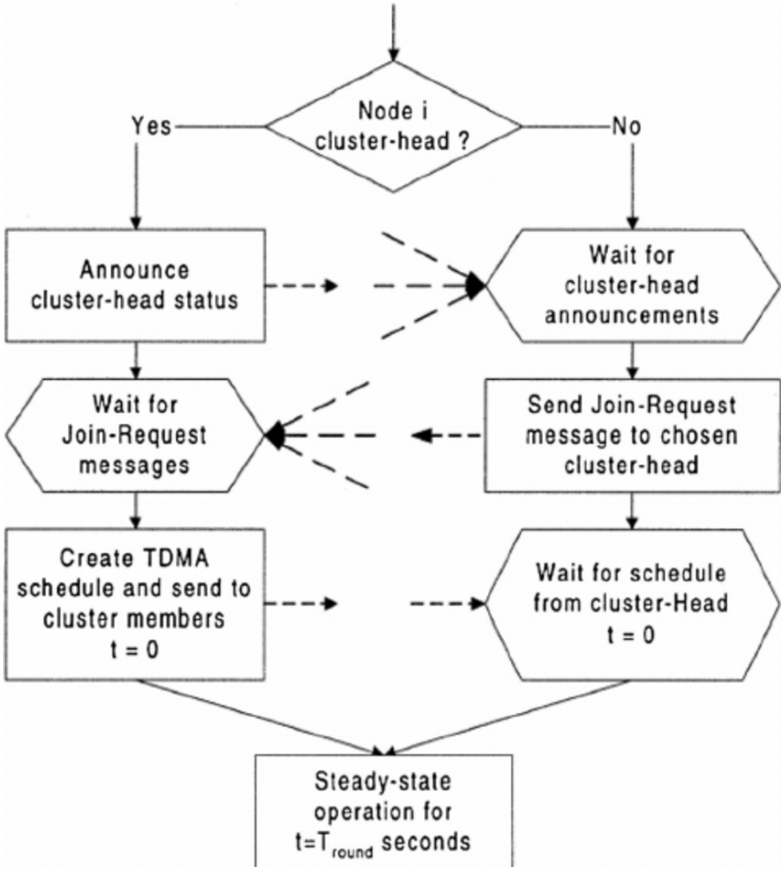
is the milestone significance in clustering routing protocol [49].
The main job of cluster head that it collects data from their surrounding nodes and pass it on to the base station, because of the cluster heads rotates we can consider LEACH as a dynamic protocol [46][48]. Which is seen in Fig(3.8)(3.9)(3.10)(3.11).

Figure 3.8 Time line Showing Operation of LEACH[48].



The fact that cluster heads can compress data arriving from member nodes and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station which reduces the inter and intra-cluster interface.
Hence, reduction in energy waste over a factor of 7x and 8x is achieved by LEACH compared with the direct communication and the transmission energy is reduced over a factor of 4x and 8x compared with the minimum energy transmitted [46].
The significant characteristics for the LEACH protocol can be concluded as [46]:
1. Balanced energy consumption can be achieved by rotating the cluster head randomized.
2. The start of a new cycle is known because we assume that we have synchronized sensors, so the location and distance information is not required for LEACH sensors.
By using the idea of dynamic clustering leads to extra overhead due to cluster head changes, advertisements, also the protocol assumes that all nodes are having the same amount of energy and that the cluster head consumes approximately the same amount of energy for each node. all these facts tell us that the LEACH protocol is not suitable for large networks and it is the most suitor for constant

Figure 3.9 Flow Chart for Cluster Head Formation[46].

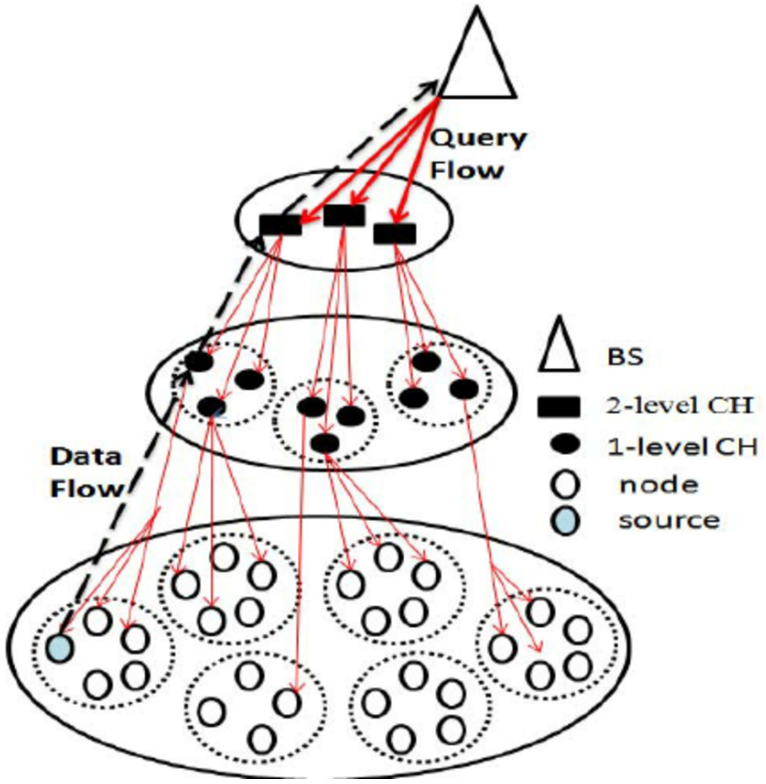


monitoring and diagnosis.
In this way, we can see that the LEACH protocol have three main techniques which are [47].
1. Adaptive Cluster Forming which ensures to share the energy dissipation fairly among all nodes and prolong the lifetime of the system.
2. Cluster Header Position Changing it does the same things as adaptive cluster forming.
3. Algorithms for Distributing Cluster Forming.

3.4.2 Directed Diffusion

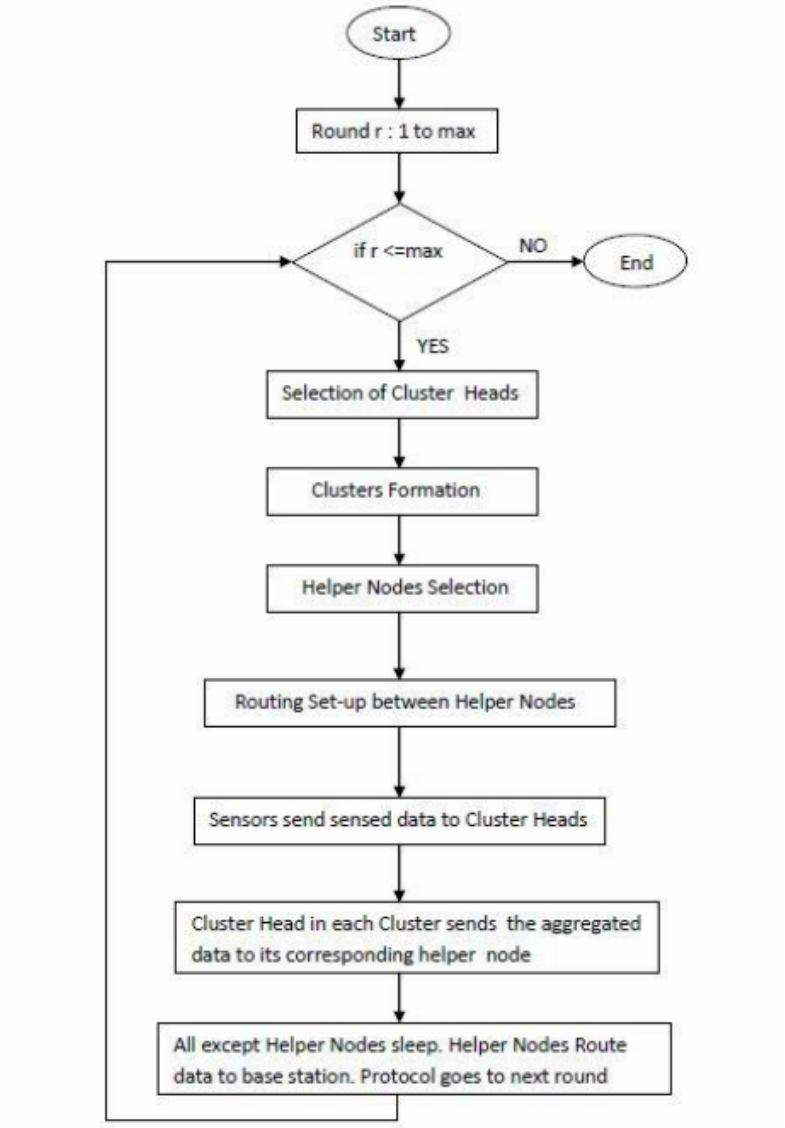
There are several elements for the directed diffusion: interest, data messages, gradients, and reinforcements. An interesting message is considered as a query or an interrogation that assigns what a user needs. Every interest holds a characterization of a sensing task, and it is confirmed by a sensor network for earning data

Figure 3.10 LEACH Process[49].



[55].
Usually, sensor network collects the data or process the information of a phenomenon that matches a requested interest from a user. We can call the requested data an event which expresses a short characterization of the sensed phenomenon [59]. Directed Diffusion uses reinforcement mechanisms to choose a high-quality rout among the several access routes to transmit the data. But one of the main problems of this protocol is the implementation of flooding diffusion used to forward interest and discover the routing map that reduces network lifetime through high energy consumption.
However we can solve this problem by data-centric protocols which are query based and dependent on proper data naming [57]. In directed diffusion data is named using attribute-value pairs. Which appears in Fig(3.12)
The distribution of a sensing task throughout the WSN is considered as an interest in the named data [54], the distribution helps to set up gradients during the styling of the network to draw events. Particularly the gradient shows the creation of the direction state in each node which receives an interest. The neighboring node that receives the interest represents the gradient direction. Event start flowing toward the originators of interests along multiple gradient paths. The sensor network re-

Figure 3.11 Flow Chart for LEACH Operation[67].

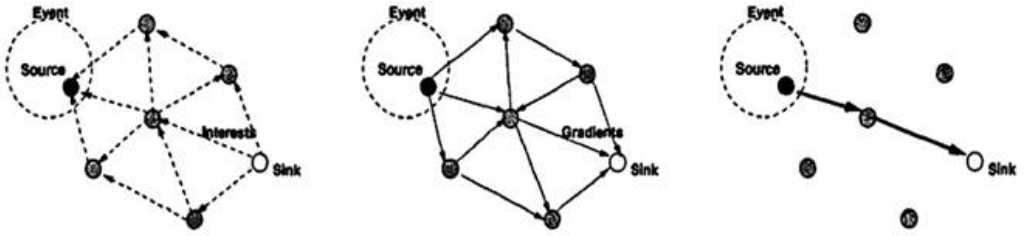


inforces one or some of these paths [54].

1. Naming In directed diffusion, tasks are described or named using attribute-value pairs. The characterization of interest in the data (matching the attributes) [56] the diffusion performance and the task expressivity can be affected by the naming approach and its arrangement.

A hierarchical arrangement of attribute-value pairs could narrow down the search

Figure 3.12 Simplified Schematic for Directed Diffusion[57].



(a) Interest propagation (b) Initial gradients set up (c) Data delivery along reinforced path

space during name resolution and simplify name specifiers for better understanding [54].

2. Interests and Gradients The named task description is usually injected into the network at some node (the sink). The sink node creates a task state which will be erased after the time indicated by the duration attribute [54].

For every active task, the sink broadcasts an interest to all its neighbors. The initial interest also contains the attributes which intended to determine if there are any sensor nodes that detect the phenomenon. The initial exploratory interest specifies a low data rate [56].

, In general, there are several choices for neighbors to resend the interest the simplest one is to rebroadcast the interest to all neighbors which are equivalent to flooding the interest. But there is a reasonable alternative in the absence of information about the sensor nodes that can satisfy the interest [56] after the interest was flooded all node establish gradients and each pair of neighboring nodes establishes a gradient toward each other as a result of a local interactions and it contains a value and a direction in which to send events.

3. Data Aggregation After a node in the specified region receives an interest the node tasks its local sensor to collect samples, to save power. All sensors are off until the node is tasked [54] a source generates data once certain conditions are satisfied. Data can be classified into two types exploratory and non-exploratory.

An event is marked as exploratory if the source has no data gradient or the source has generated no exploratory events within a window of time. Exploratory events are sent along all outgoing gradients whereas non-exploratory events are sent along only data gradients the node that receives an event from its neighbors searches it interests cache for a matching interest entry if no match exists the event is dropped.

If a match exists the node searches the data cache for a matching data entry to detect and to prevent a data loop. If a received event matches a data entry, the event is dropped otherwise, the received event is added to the data cache and resents to

the node's neighbors [56].
4. Reinforcement for Path Establishment and Pruning The sink initially and repeatedly diffuses an interest, when sensors detect a matching target they send exploratory events toward the sink after receiving the exploratory events. The sink reinforces at least one particular neighbor to draw down real data[56].

3.4.3 Volcano Routing Scheme (VRS)

It is a fast and simple method in the highly dynamic network which does not require geographic information VRS locally balancing the load between adjacent pairs of nodes. It has no explicit route discovery phase and can tolerate rapid changes in the network topology. And this can guarantee the system stability [42].
The VRS does not need to follow a standard routing algorithm, its internal operation is hidden from the rest of the world which makes it pick and chose how to run on its subnets [60]. Regardless of the topology variants. In VRS each node must have a complete view of its adjacent neighbors at any time t any node a knows any node b such that (a,b) E(t).
The time is divided into discrete time slots, all nodes start at the same time and work synchronously, in any time slot each link can transfer one packet and each packet belongs to one of the k flows in the network. The i-th flow(1ik) is identified by a tuple(Si, Di, Fi) where S the source node and D is the destination node of the flow and F is the maximum number of packets which flow i to be generated in any time slot [42]. The main idea of VRS is the potential-based routing which is used to defined k scalar fields on the network, one for each destination node.
VRS uses the potential function in a different way and its based on the number of packets buffered at each node of the network and not on the connectivity of the network.VRS works in this scenario at a given node "a", and for a given flow I the potential function pia equals the number of packets of flow I that reside at node a VRS forwards packets from nodes that have more buffered packets to nodes which have fewer buffered packets [42].
The advantages of using VRS that the overhead of running VRS is low compared to other routing algorithms, it is completely distributed, the amount of control traffic exchange between nodes is low, VRS guarantee to deliver packets to their destination no matter how often the topology of the network changes and no matter what the movement model of the nodes is, if the topology of the network is fixed the length of the path taken by each packet is close to the shortest path from the source to the destination [42].

3.4.4 VRS Demonstration

At the start of every slot packets are generated at the source. Throughout the slot every link transfers one from source to destination. At the end of the slot packets that attain destination are removed.
VRS Utilization and Features

- Local leveling of load .
- No specific route discovery.
- Reordering layers dose not disrupt the flow.
- Completely distributed.
- Low complexity.
- Minimal quantity of management traffic.
- Suitable for extremely dynamic atmosphere.
- Stable system.
- Near best path.
- Fixed topology.

3.5 LEACH and VRS Features

VRS is a very dynamic algorithm to use with the DD because it has a hidden operation from the rest of the world. In this way, it is picking and choosing how to run the network. The other beneficial side of VRS is that takes the nodes locations in consideration, hence if one node is not active or dead, the data is sent to the location requested the data, then the neighbor node is accepting the data. Hence I am avoiding the packet loss in this way.
For the LEACH advantages are the hierarchical structure and the ability to control the clustering strategy in the most energy efficient, and its flexibility with handling the data, it has a better lifetime system and utilization. Also, the low latency is provided by the algorithm to extend the network coverage.
DD is the best protocol to collect the data in a centric way to be energy efficient using the attribute value pairs to name the data. For all of that, I have chosen the VRS, LEACH, and DD for their benefits over the other restricted protocols used in WSN.

3.6 Summary

This chapter has discussed the details of LEACH, DD, and VRS. The features and advantages of each one and how to avoid the disadvantages to have the best optimal way to discover the route, and to deliver the packets to their destination. Which is the reason why I have chosen these protocols instead of the other routing protocols used in the WSN? From what I am going to the next chapter to present the basic model of the new network.

Chapter 4

Proposed Protocol

This technology is increasingly dominating every aspect of our lives the technology and communication part are used to ease our lives; Hence, we are going to solve the problem of the WSNs energy. Which is demonstrating and will have a very powerful future in the next few years.

4.1 Methodology

We have done a survey to start, that describes the LEACH and VRS which we are using for the new proposed protocol. We described every detail that helps to reproduce a new routing protocol that involves two different kinds of protocol with two different structures. We are using two protocols for the dynamic routing with two algorithms VRS protocol and optimization algorithm for the LEACH protocol and that is making the network topology energy efficient without a high cost for the whole network, doing that will prolong the network lifetime.
The simulation is used to measure the performance of the WSNs after proposing the dynamic protocol. Which gives the network the option to choose the protocol to operate according to the residual energy of the network and the nodes.

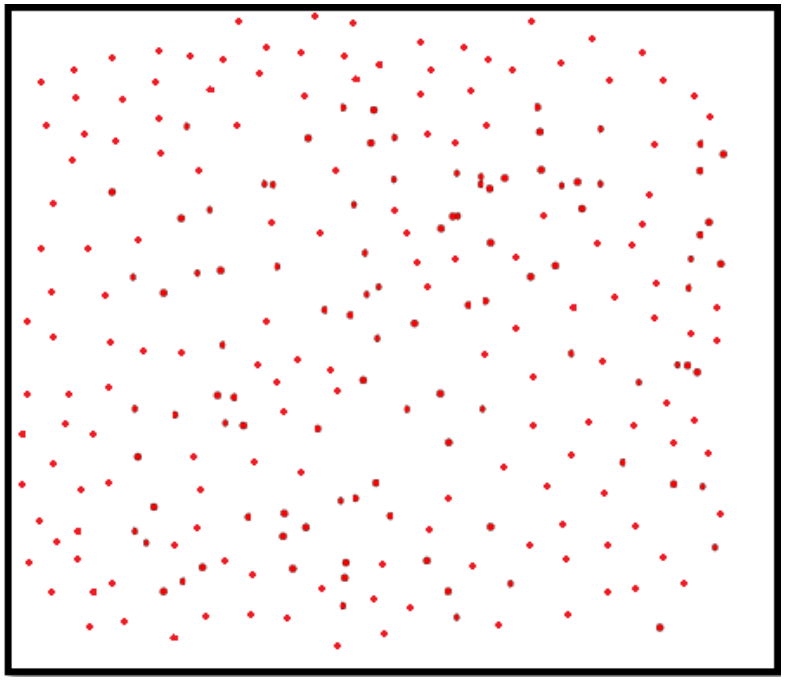
The network is preserving the energy by operating the VRS protocol on the lookup tables, so the nodes are on sleep mode until they are needed to operate a new task of harvesting information.
The lookup table saves the location of the nodes with (X, Y) pairs and a number as a name for the node to distinguish it from other nodes. Also, it saves the initial

energy(REC) for the network which we start with and the energy after every execution. Additionally, the efficient data aggregation (AGG) which makes use of the distance and position of nodes to send data in the most efficient way.
Those two parameters show the efficient utilization of energy for our newly proposed protocol which prolongs the WSNs lifetime since the power source is the most precious one for the WSNs.
Our dynamic protocol alternate using the LEACH protocol and VRS protocol dynamically. The BS has the choice of what to operate at a specific moment.

4.1.1 WSN Creation

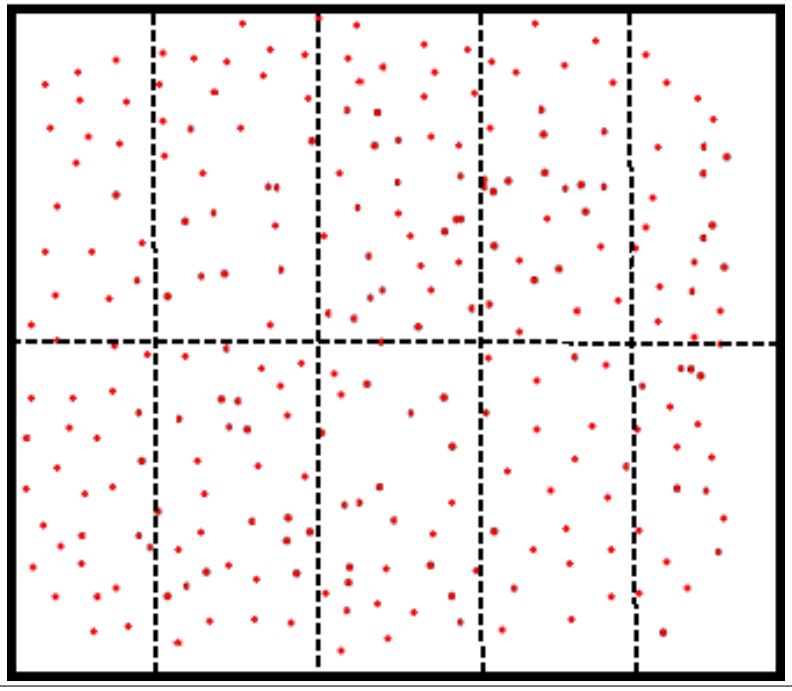
The sensor nodes are located in a two-dimensional area of X*X meter, N of sensor nodes are distributed in a random way with no mobility.
Each node knows its location and the distance to the BS and sink node and the neighbors' location. Which is seen in Fig (4.1).

Figure 4.1 Initial Nodes Position



The network is divided into grids and every node belongs to a known location. The nodes took their position in the grids and memorized their location and the neighbors' location inside the grid they belong to and their assigned sink node that will communicate and send the data to the BS. Which is seen in Fig (4.2).
The elected sink nodes gather the collected data from the normal nodes in order

Figure 4.2 Network Divided into Grids



to pass it through the data mining algorithm to build the data pattern to be saved. Which is seen in Fig (4.3).

4.1.2 WSN Route

The nodes choose the shortest path to send the data to the sink node, so it can send the collected data to the BS. Which is seen in Fig (4.4). The sink nodes communicate and send their locations with each other, so they know which one is the closest to the BS.
The closer one is elected to communicate with the BS on behalf of the whole network. Which is seen in Fig (4.5).

Figure 4.3 Elected Sink Nodes

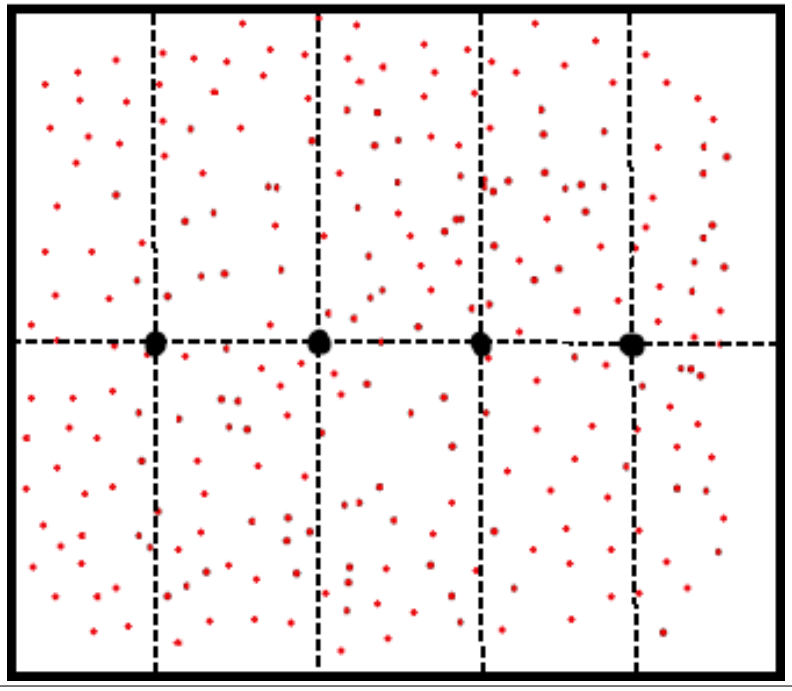


Figure 4.4 Data Path to Sink From Nodes

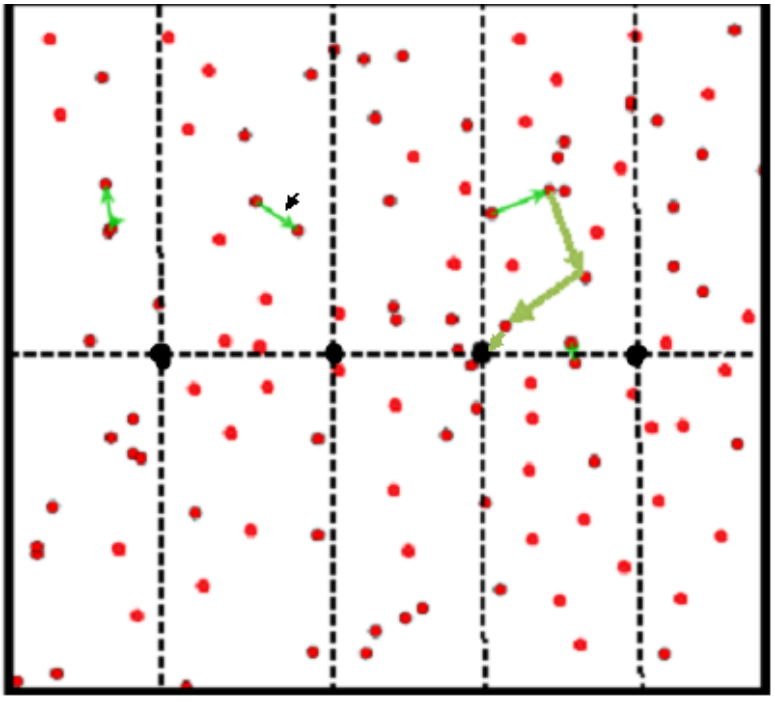
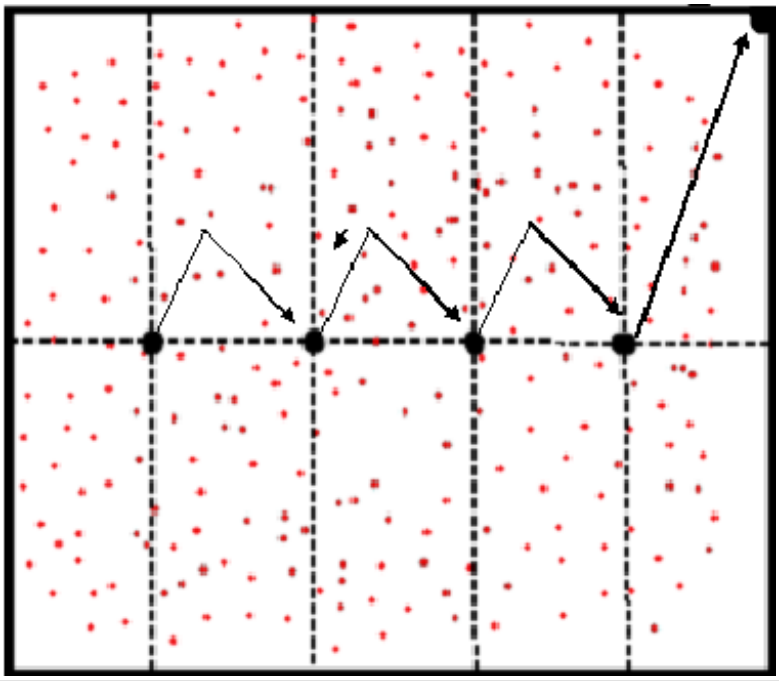


Figure 4.5 Sink Nodes Communication



The central server request specific data from the BS then it searches for the data on the lookup tables using VRS algorithm to look for the patterns constructed using the data mining algorithm with the decimal normalization.
If the data is founded in the lookup tables the data is sent to the BS to the final destination (central server) without searching the whole network, if not the BS is sending the request to the sink node to operate LEACH protocol to sense and collect new data needed for the central server.
The BS determines which sink node to send the data to using the location that the BS knows the data is in it.
In the network we have 4 sink nodes which send the data sensed from the normal nodes; Hence, the sensed data is remarked with their location.
So every node takes readings which are put in the lookup tables and the readings are arranged using data mining algorithm with decimal normalization to produce patterns of the data coming from the sink node to be sent and saved to the BS. After being divided into ranges so we can search the area(X, Y) which has the readings using the specific range and location.
location and energy are the main content in the lookup tables. The network grid structure has no influence on the constructed patterns from the data mining algorithm.
The tables are divided into groups according to the data source location.

LEACH protocol is used when we need to know the whole state of the network, and we need to collect data from all the node in a specific area belonging to one grid or many grids.
Starting with the clustering our protocol using the clustering characteristics and the distance between nodes by solving the optimization problem for the network. Hence, our protocol initializing a small world of sensors which are arranged randomly and the adjacency matrix is constructed by using the distance formula [65].

$$D = \sqrt{[(X2 - X1)^2 + (Y2 - Y1)^2]} \tag{4.1}$$

The distance formula is used to determine the optimal number of nodes that will be chosen as sink nodes by using the clustering analysis to share the resemblance of the centric communication function. Hence, to implement it, the hierarchical clustering analysis is used to build a series of sensor nodes from the lowest level to the highest with the consideration of the nodes communication distance. The cluster analysis needs the appropriate number of sink nodes to be identified and it is scaled through the lifetime of the network. Sink node cost and the premier energy for the network. To achieve that we need a median node called key nodes linked directly to the sink and those key nodes deliver the data from the sensor to sink and this data has to pass from(N-K)/K sensors.
Where (N) is the total number of the network nodes, while (K) demonstrating the number of key nodes that link with the BS.
To put a limit for the increasing number of sink nodes we define the network cost as C=N.Cn+n.Cs and the appropriate number of sinks will be computed by[65].

$$n = N\sqrt{[\frac{Cn * (Et + Er)}{Cs * K(E0 - Er)}]} \tag{4.2}$$

Where (Cn) is the sensor node cost, while (Cs) is the BS cost, (Et) is the transmitted energy for communication per node pairs, (Er) is the received energy for communication per node pairs, (E0) energy consumption while there is no communication between nodes.
According to that if we had two grids having the needed data the nearest to the BS will communicate.
In DD, The VRS is used to send the data to the location that needed the data not the nodes that requested it and with that, we will handle the flooding problem that causes overlapping and duplication of the messages. The computation for which protocol to chose is done on the BS also the grid division the BS will save a look-up table for the network behavior so it doesn't have to do the computation all over again every time when there is a need for information from the nodes.

The BS of the network is the node with full energy, which is dividing the network into ten equal grids every sensor in these grids is collecting data in it until it is needed.
Every node knows its location and distance to the BS in LEACH protocol we have sink nodes that connect the normal nodes with the BS. Sink nodes communicate directly with the BS. The packet is sent from the node to the sink node towards the BS in the same path back and forth. The path with the LEACH protocol is determined by the optimization algorithm.
The BS requires the needed data and before that no data is sent. BS sends the request to the specific location that knows it can find the data required in, and not for the whole network and that save the energy for the unrelated nodes from recollecting and computation.

Table 4.1: Nodes Communication Model.

Nodes	Nodes Task
Normal Node	Collect and sense data and send it to the sink
Sink Node	Communication between normal nodes and BS
BS	Request data and communicate with central server

The VRS has a great advantage, that it doesn't have a restricted route discovery phase and a high tolerance for the rapid changes. So if one node dies the neighbors of this node are going to handle the data request and communicate according to the time slots.
The advantage of not having a restricted route path for the VRS is helping with operating the optimization algorithm used in LEACH to handle the DD as well. So when the network energy is suitable and the amount of data is big(harvested from each sensor) and has a known location, we can use the LEACH protocol and use the optimization algorithm.
If the amount of data is small(in the lookup tables) we can use DD. The nodes collect the data and save it until it is needed, the BS is going to send a request according to the location and distance to a specific node and that is going to be the reply path for the data to go back to BS.
The optimization algorithm is used to measure the distance and the location for each node and VRS collects the data from nodes and save them till needed.
Transforming data between the nodes and BS for the DD and LEACH the BS will take the location information for every node into consideration and the packet will be delivered to the location which needs the information and it will be requested based on the location of the nodes and that will give us so many advantages about energy conservation because the nodes have not to store the information tables for the routes and the data packet arrival is based on the location and the distance of

the nodes using LEACH. Data collection from all the cluster heads will be done by CH and it will check the redundancy of the data to recognize the occurred pattern, which is beneficial for the sensor readings[63][64].
This is focusing on energy conservation on WSN and with this way we make just the cluster head communicates with the BS.

S=$U1, U2, ..Un$

$Computes\ the\ distance\ dj\ from\ Ui$

if $If\ (N(ui))\ and\ distance\ dj\ from\ Ui$ **then**
Ci=$Ui0, Ui1, ..Uin$

Do

$Compute\ E(OiI)\ where\ I = 0\ to\ n$

$CHi\ is\ the\ cluster\ head\ of\ Ci\ if\ E(OiI)\ is\ high\ unisenses\ the\ information\ and\ passes\ the\ messages\ to\ CHi$

$while(E(uiI)) \gg (E(uij))$

$CHi\ passes\ the\ information\ and\ aggregates\ it\ to\ the\ BS$
end if

The previous algorithm indicates to the distance computation process for the sensor nodes S and that helps the nodes to follow the nearest CH then it computes the energy to decide which sensor is chosen to be the CH to communicate with the BS and aggregate the data.
The packets content are the node location and distance between the node and the BS, the residual energy and the path is going to take it.

Table 4.2: Transmitted Packets Contents.

Data Packet	Request Packet	Reply Packet	Error Packet
Packet Number	Packet Number	Packet Number	Packet Number
Source Location	Source Location	Source Location	Source Location
Destination Location	Destination Location	Destination Location	Destination Location
Residual Energy	—	—	—
Protocol	Route Path	Route Path	Route Path
Data	Request	Reply	Error

For the maintenance, if the BS sent a request and that node is dead and has no energy the network sends an error message and the closest neighbor node that has almost the same location is going to handle the request after sending the error message and for the new request or accepting the reply that is sent from the neighbor.
A network with (100) sensors have been built and those sensors are going to collect data from their environment according to their location in a distributed way so it is distributing the workload in a resilient way that can prolong the network lifetime.
Hence, the distributed way will control the amount of communication between nodes and forbid heavy traffic from happening in the limited bandwidth of the wireless channels and that is a source preserving because in that way we control the power used in computation and communication process and to avoid any effects or unusual values in our information some normalization is going to be done on the data and decimal scaling is the used technique by moving the decimal points.
To do so distributed data algorithm is used in order to cope with the nodes limitations (power, computation, memory). The distributed algorithm is going to process the data locally then the results are aggregated in this way the energy for the communication process is reduced and at the same time, the number of messages during the process of data transfer to the central data is reduced.
The option of distributed data mining algorithm helps the WSNs to live longer and controls the huge data flow that can cause bottleneck and wastage of communication bandwidth because its collecting a huge data to analyze.

$Initialize\ network$

$Stand\ by\ until\ receive\ request\ from\ server$

if $If\ data\ in\ BS$ **then**
$search\ using\ DD\ in\ look\ up\ tables$

$else$

$Nodes\ take\ their\ positions$

$Compute\ cluster\ heads\ number$

$Compute\ the\ distance\ between\ nodes$

$Find\ the\ best\ route\ based\ on\ distance$

Transmit data between nodes and the BS

Make patterns using data mining algorithm

Save in BS using look up tables

End if

Sending required data to serverr

Go to step 2

end if

end if

4.2 Summary

Chapter four is the most important one, because it is describing the basic proposed protocol and how to use the two protocols to gather. And that is preparing us to see the end results of the proposed protocol and how it is working and how efficient it is.

Figure 4.6 Network Initialization using LEACH.

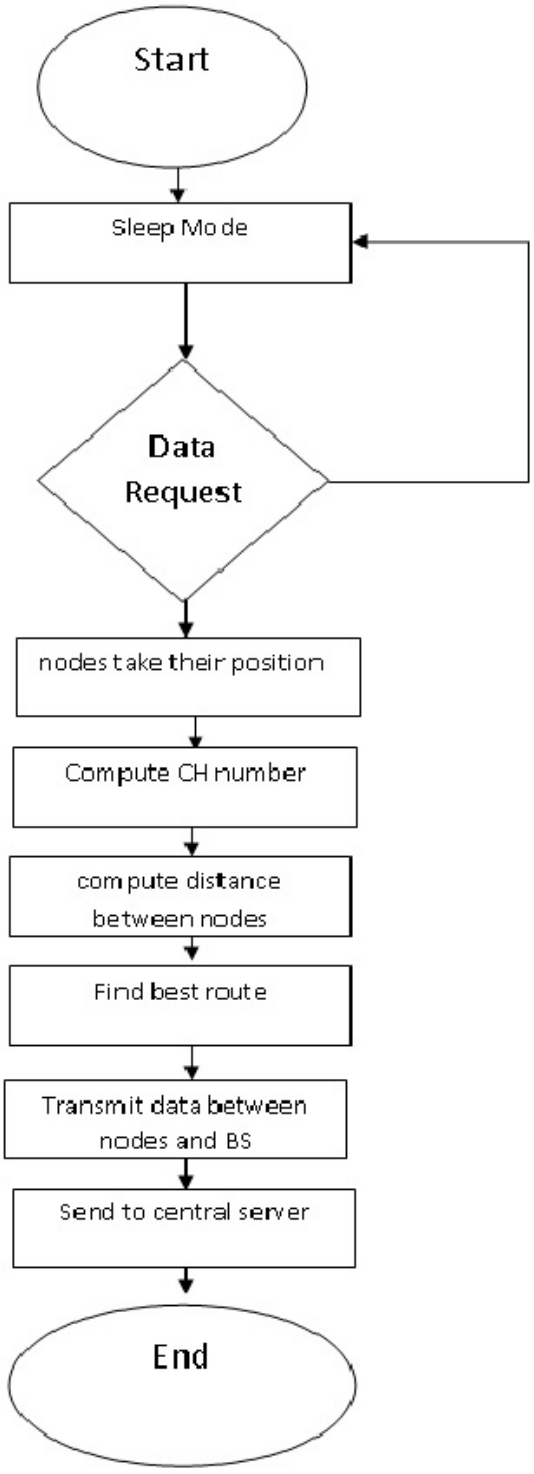
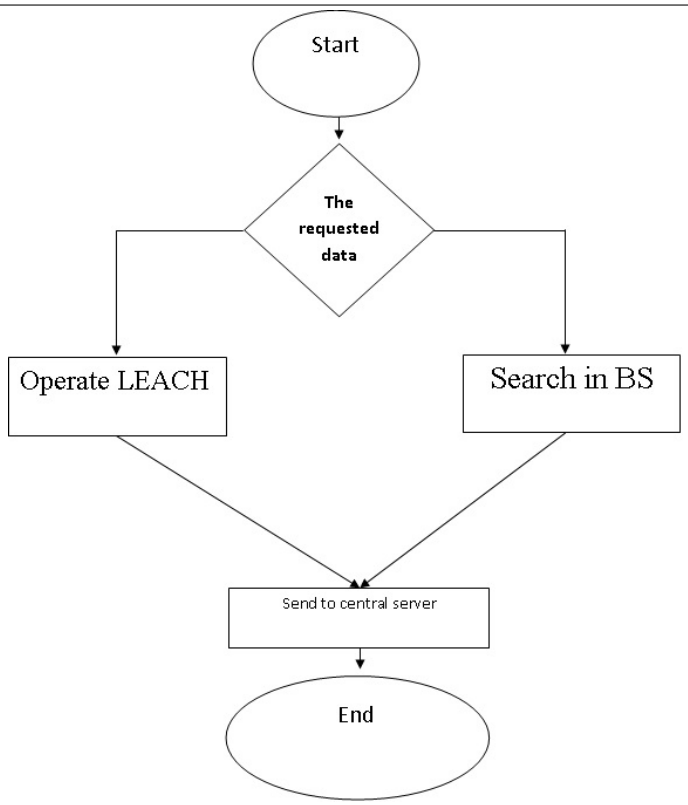


Figure 4.7 Network Flowchart.



Chapter 5

Experiments Results and Analysis

In this chapter, the proposed protocol is coming to life with the simulation results. The network initializing all the way through to the results of the proposed protocol.

5.1 Assumptions

For this proposed protocol, we make some assumptions as follows:

- The BS is located at point(100,100) far from the sensors and it is fixed to be as close as possible to the central server and to the normal nodes.
- The nodes are homogeneous and energy constrained.
- There is no mobility for sensor nodes.
- The nodes can use power control to vary the amount of power transmitted to reach the BS.

Our main concern is measuring the performance of WSN in terms of energy sufficiency we are using metrics that have an influence on energy consumption. In WSN, the matrices are used to evaluate the performance of a WSN as a whole. These metrics are:[51][46][48][57]

- End-to-End Delay: it represents the time needed for a packet to be transmitted from source to destination.
- Packet Delivery Rate: help us to know the ratio of the delivered packets to their destination with the packets sent from the source.

- Efficiency(Residual Energy): the energy of an isolated node is constant and independent of any changes occur within the system.
- Network Throughput: the quantity of data computed in any given period of time.
- Packet Routing Load: It represents the total number of routing packets transmitted in the process of successful data transmission.

Moreover the individual sensor node in WSN can be:

- Robustness: It is the ability to cope with errors during execution.
- Computation: It is the necessary calculation to be done by the node.
- Communication:It is exchanging information and data..

In this proposed protocol, we will take advantages of the location of the nodes and implement the LEACH and DD on a grid topology to save the network energy and it will be a homogeneous network.
All the available wireless sensor nodes are possessing an equal amount of initial energy E0=0.6 J the nodes will be distributed in 100*100 meters area.[51][46][48][57]. BS will be located at the point(100,100) with full energy

5.2 Simulation Environment of The Experiment

5.2.1 Simulation Options

Simulation tools are divided into two categories commercial and open source simulators.
NS2 implementation needs a script language OTCL to describe the network topology with the C++ which is the core of the simulation, and that was because the C++ takes a lot of time with the hardware used back at the time they first implement it.
OPNET simulator has a defined set of protocols and devices; Hence, we can not modify or create a new model using OPNET [68][69][70][71].

5.2.2 Why NS3 ?

Our proposed protocol simulation is done by using NS3 simulator due to its advanced benefits over doing the real physical experiment in the real world. Using simulation to see the relationship between the parameters and seeing the interactions inside the network and how it deals with the obstacles and the normal

Table 5.1: Simulators Advantages and Disadvantages.

Simulators	OPNET	NS2	NS3
Cons	Definite Protocols and Devices	Script Language	—
Pros	Access to Other Editors	Event Driven	Scalable
Language	C++/java	C++/OTCL	C++/python
License	Commercial	Open Source	Open Source
Time Taken To Learn	Long	Long	Short
Data	Request	Reply	Error
Hardware	—	free disk 5GB	free disk 5GB
RAM	—	minimum(256)	minimum(256)

operation in the communication process between the channels.
In the simulation, we had a dynamic environment to control our experiment and to create the network using mathematical equations and algorithm, which we have to adjust them if there is a necessity to do so. Using dynamic environment like simulators helping to construct efficient implementation to the network model. Dealing with that is going to help us understand the experiment and analysis easily. With the benefit of the low-cost experiment.
The platforms used in the simulators give us the graphs and the results needed to deduce the new fact and helping to prove our proposed protocol. The simulator helps you to verify and validate your proposed protocol using its techniques.
In WSN we need to use simulation to enhance the proposed protocol. So the simulator is constructing our proposed protocol with accurate results. Network simulator version 3 is the tool that we are using to implement the thesis which is an open source, discrete event network simulator. It helped to model the actions of the dynamic compound system to give a series of defined proceedings.

NS3 is executed using C++; Hence, the memory management functions are obtainable and they are free, It is de-allocating the nodes by pursuing the number of pointers which can be helpful with dealing with the packets.
NS3 is scalable, controlled and provides a cost-efficient substitute for running the system without putting it in real experiments.
There are several simulators to use but the most suitable simulator is NS3 for its advantages[69][68]:
1. Scales to thousands of nodes
2. It holds the complete system
3. It is Fidel and holds all the interactions in the network sequentially.
4. Allows driving, monitor, debug simulation.

5. The simplicity of the NS3 does not prevent its power
6. It works with two languages C++ and Python for pindings. But it is can be implemented entirely with C++.
There are other options like NS2, but it is not scalable as much as NS3 with large networks, and there is no graphical user interface. Also, it needs a lot of command writing and scripting language knowledge.

5.3 The Environment

The parameters for the simulation have been used as follows[51][46][48][57]:
1. The required energy for sending and receiving 1 bit is Eelec=50nJ/bit.
2. Each node has a restricted amount of data K=200bit.
3. The energy for every sensor starts with E=.6J but BS have a full energy.
4. Node number is n=100.
5. The radio idle power .0375mw.
6. The radio transmission power .660mw.
7. The radio reception power .395mw.
8. Packet size 100 bytes.
9. Data rate 1Mbps.
10. Radio range 90 meter.
11. Sensing range13-48 meter.

5.4 Conducted Experiments

For the empirical side of the thesis, We created a grid network topology, that contain 100 sensor nodes and only one BS. The BS which has the highest energy of all nodes is performing the clustering process and the cluster head selection, the location, and the energy are computed by the BS and known to the nodes themselves.
The sensed data are collected and delivered to the destination from the source through the route selected using LEACH protocol.
In Fig(5.1) the network startup and the nodes locations and distribution, the cluster's creation are done at the first stage. The nodes are distributed through 4 grids, and that donates that the suitable number of cluster head is 4 according to the cluster head equation calculations which in Fig(4.7) in page 35.
After the network creation and the nodes settle in their position, the hierarchical process of LEACH starts. Grouping the nodes according to their location on the grid and based on their location.
The next stage is to know how many clusters head the network is having using the

Figure 5.1 Network Creation Stage 1

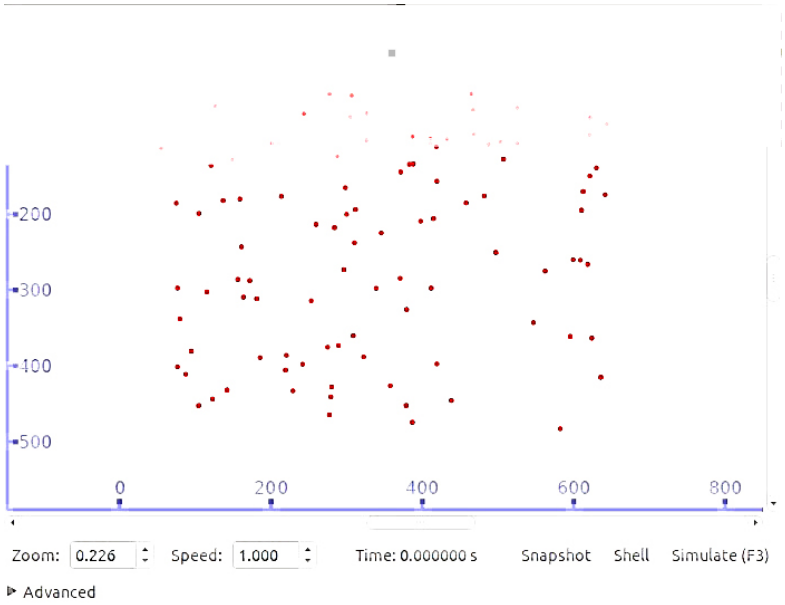
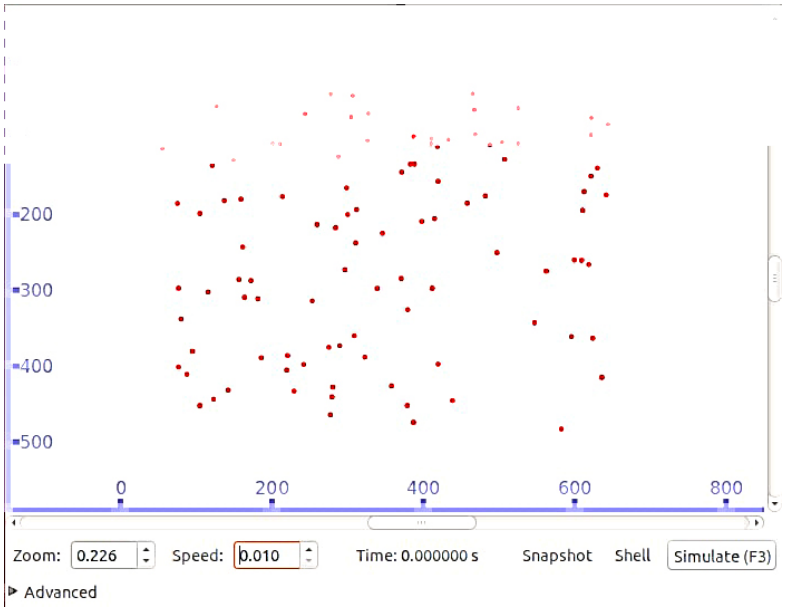


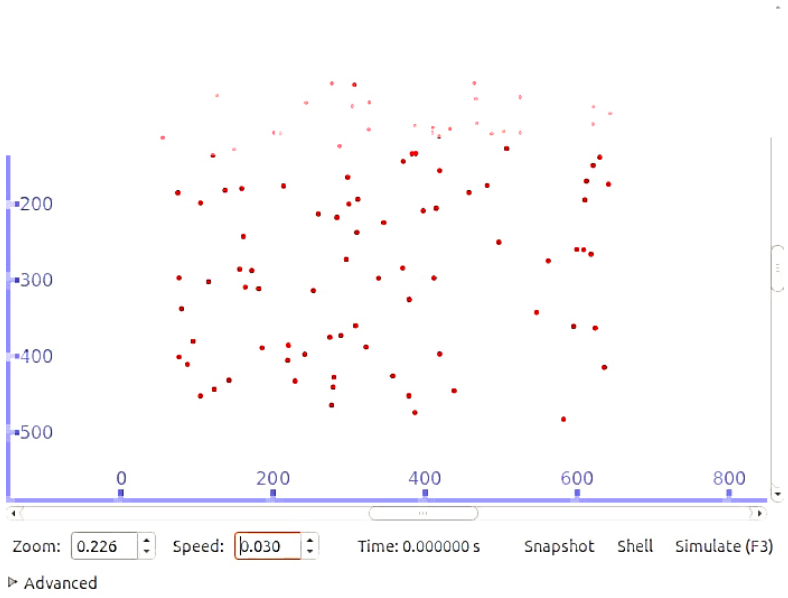
Figure 5.2 Network Creation Stage 2



equation (Fig 4.7 the sink node formula, in page 35), the best number of cluster heads are 4 because the cluster heads are energy consuming due to the communication and the transition with the BS[65]; Hence, less of cluster heads are better. The network is communicating with the BS without exhausting the network en-

ergy and shortening the lifetime, which is seen in Fig(5.3).

Figure 5.3 Cluster Head Selection



The source selection and the destination selection in our WSN and assigning the nodes to the nearest cluster head without losing energy from the nodes themselves. The nodes were divided into 4 large clusters to communicate with the BS; So, the sensors nodes collect the sensed data and send it to the destination through the route in Fig (5.4).

Finding the best route between the source and destination according to the optimization algorithm that is used with the LEACH protocol to select the shortest best path to save the energy by visiting the lowest number of nodes to save their energy while harvesting the data from the environment.
Being in the sleep mood is saving a lot for each node to prolong the network lifetime in Fig(5.5).

Data transmission (packet delivery) between nodes to the destination nodes to the BS. Each packet sent is going the same path as the request, and each packet is containing its location and the data needed. Moreover, the location where it is directed in Fig (5.6).

The data for each node is saved in the lookup tables, these lookup tables are built using decentralized mining algorithm using decimal normalization to save the needed information about the environment they are planted in.
When the central server is requesting any information from the BS the first step is to search using the DD protocol in the lookup tables for the data. The data is delivered to the central server from the look-up tables if not the WSN is going to

Figure 5.4 Source and Destination Selection.

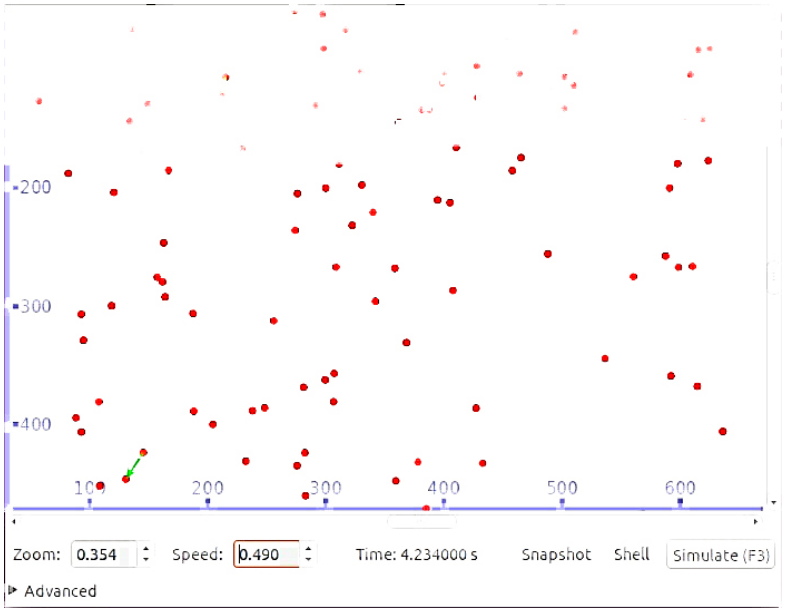
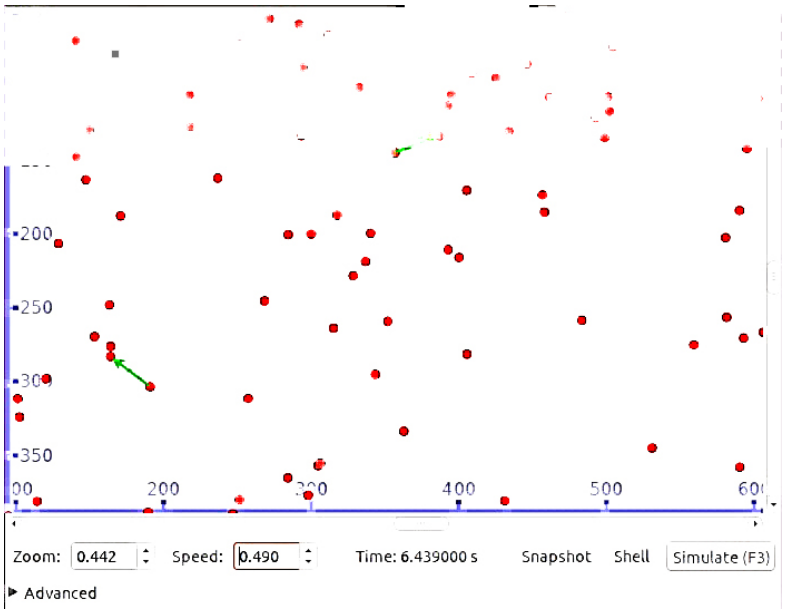
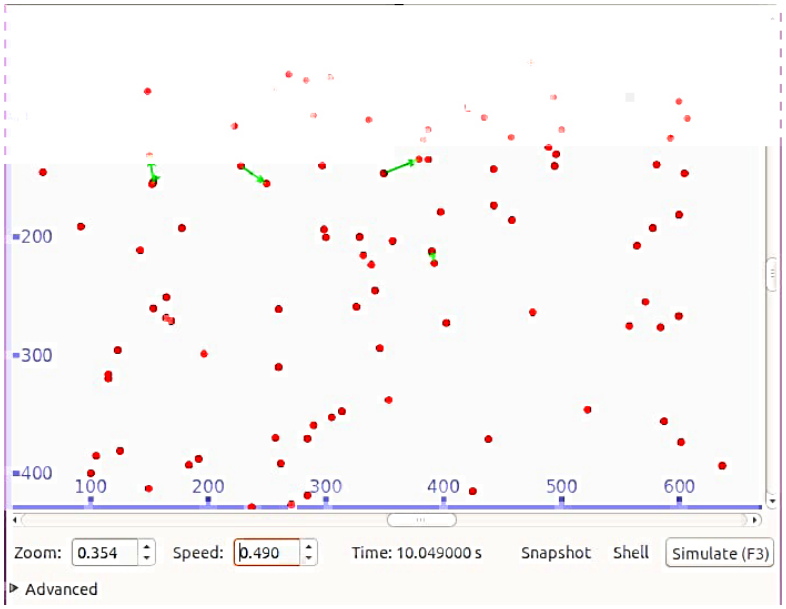


Figure 5.5 Best Route Determination



start the clustering process with the LEACH protocol to sense new data.
In this table, we can see the startup energy (REC) for the BS and the computation for the nodes as well. The presented proposed protocol shows an efficient data forwarding (AGG) in the network due to the region based energy aware cluster

Figure 5.6 Data Transition Between Nodes.



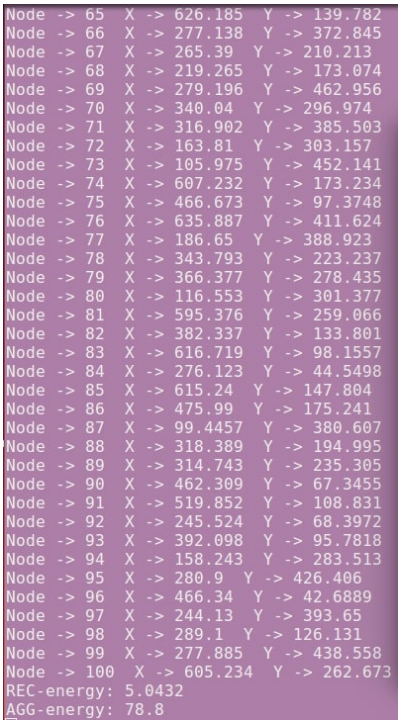
which equals 5.0432 as initial energy for the whole network.
In additional to the efficient data aggregation, which is processing the data aggregation in an efficient way during the clustering orderly to prolong the WSN lifetime, so it saves the energy for the nodes and the cluster heads in addition to the BS by preventing the excessive data from being processed and sent. Hence, the most energy consumed during the sensing and transmission process which saves the ultimate energy for the whole WSN as seen in Fig (5.7).

The data from the iterations and the computations are saved in the lookup tables and searched for using DD with the VRS algorithm when needed. If the needed data is not in the lookup tables the BS is going to search and harvest new data from the sensors using the LEACH with his optimization algorithm to build new lookup tables for the requested data. So I am presenting the performance of end to end delay, energy consumption, the packet delivery rate and finally throughput for the new energy efficient proposed protocol, which is in Fig (5.8).

5.5 Proposed Protocol Evaluation

The proposed protocol has been tested to measure the metrics influence on the energy. To help the network save energy and prolong the lifetime. In the following experiments, the nodes density has been fixed to 100 sensors and assumed there is no mobility in the network.

Figure 5.7 Energy Computation at the First Execution.



The experiment is performed to present a new proposed protocol for routing using two different protocols to preserve the energy for the WSN in order to prolong the network lifetime because of the power limitations that occur with the WSN.

1.The End-to-End Delay Versus The Node Number

End-to-End delay means the packet arrival time to their destination. Which include the route discovery operation delay and the packets transmission queue. The packets that are counted only that have successfully reached the destination. We run the simulation to calculate the average delay for 100 (samples) nodes. So when the packet arrives to the destination we record the arrival time to calculate the current delay. The same operation is done with every packet and we increment the samples one by one then we can get the total delay for the whole network.

Fig (5.9) presents the rate of the data arriving at their destination, it increases by the number of nodes participating in sending the required information. However, the increase is due to the new route discovery which is done by the nodes trying to compete to reach the wireless channel and not to be dropped or lost.
Fig (5.9) represents that the end-to-end delay for the proposed protocol gradually starts in a smooth way from 0.6 second for the 1 node of the transmission process. Which means that always the network has routes to the destination and available all the time.

Figure 5.8 Energy Computation at the Second Execution.

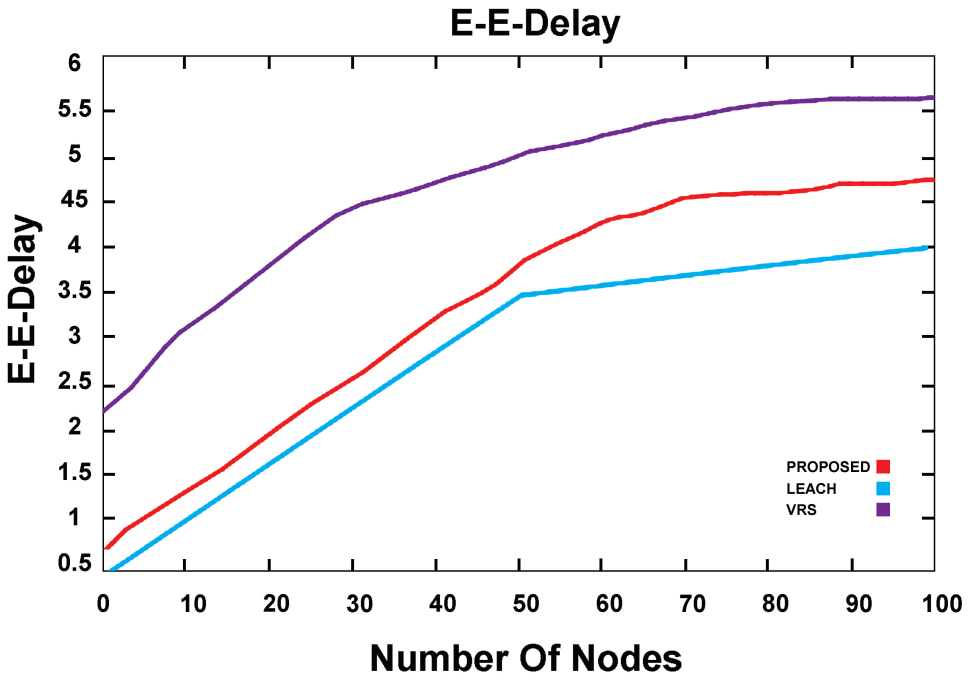
```
Node -> 69  X -> 282.869  Y -> 460.251
Node -> 70  X -> 341.922  Y -> 295.961
Node -> 71  X -> 306.222  Y -> 380.633
Node -> 72  X -> 163.976  Y -> 291.777
Node -> 73  X -> 108.463  Y -> 451.986
Node -> 74  X -> 597.503  Y -> 179.449
Node -> 75  X -> 463.624  Y -> 103.17
Node -> 76  X -> 636.022  Y -> 405.764
Node -> 77  X -> 188.299  Y -> 388.641
Node -> 78  X -> 339.805  Y -> 220.664
Node -> 79  X -> 358.194  Y -> 267.56
Node -> 80  X -> 118.681  Y -> 299.515
Node -> 81  X -> 587.521  Y -> 257.628
Node -> 82  X -> 381.211  Y -> 133.787
Node -> 83  X -> 608.759  Y -> 104.01
Node -> 84  X -> 273.566  Y -> 50.1713
Node -> 85  X -> 603.918  Y -> 144.748
Node -> 86  X -> 465.055  Y -> 174.446
Node -> 87  X -> 107.852  Y -> 380.808
Node -> 88  X -> 330.814  Y -> 197.596
Node -> 89  X -> 322.547  Y -> 231.415
Node -> 90  X -> 453.14  Y -> 77.4008
Node -> 91  X -> 509.798  Y -> 113.636
Node -> 92  X -> 248.987  Y -> 70.3565
Node -> 93  X -> 401.524  Y -> 93.2733
Node -> 94  X -> 161.601  Y -> 279.358
Node -> 95  X -> 282.026  Y -> 423.964
Node -> 96  X -> 468.898  Y -> 45.6514
Node -> 97  X -> 248.337  Y -> 385.874
Node -> 98  X -> 291.581  Y -> 130.336
Node -> 99  X -> 275.47  Y -> 434.635
Node -> 100  X -> 598.279  Y -> 267.16
REC-energy: 4.8384
AGG-energy: 75.6
REC-energy: 4.5824
AGG-energy: 71.6
REC-energy: 4.3264
AGG-energy: 67.6
```

Then the proposed protocol starts stabilizing at node no. 70 tell the last node participating in the network.
Due to the new route discovery operated by LEACH the delayed packets are increased to 1.3 second for node no.1 comparing with the same node in the proposed protocol and starts stabilizing at node no. 50.
For the VRS it starts from 2.3 second for node no. 1 and increases steadily then stabilize at node no 80.

2.Energy Consumption Versus The Number Of Nodes

Energy consumption means how much energy the WSN consumes while operating. The main concern is the efficiency of the WSN. Hence, presenting the energy consumption with the number of nodes. In order to the high energy consumption of the cluster head formation.
The energy consumption in each sensor is the sum of the transmission energy consumption and the received energy consumption multiplied with the time. Ec=(Et+Er)*t
.
Where Ec is the consumed energy, Et transmission energy consumption, Er received energy consumption, t is the time.
Fig (5.10) presents energy consumed by the activated nodes through the network while harvesting data to find the required information which increases with the

Figure 5.9 End-to-End Delay.

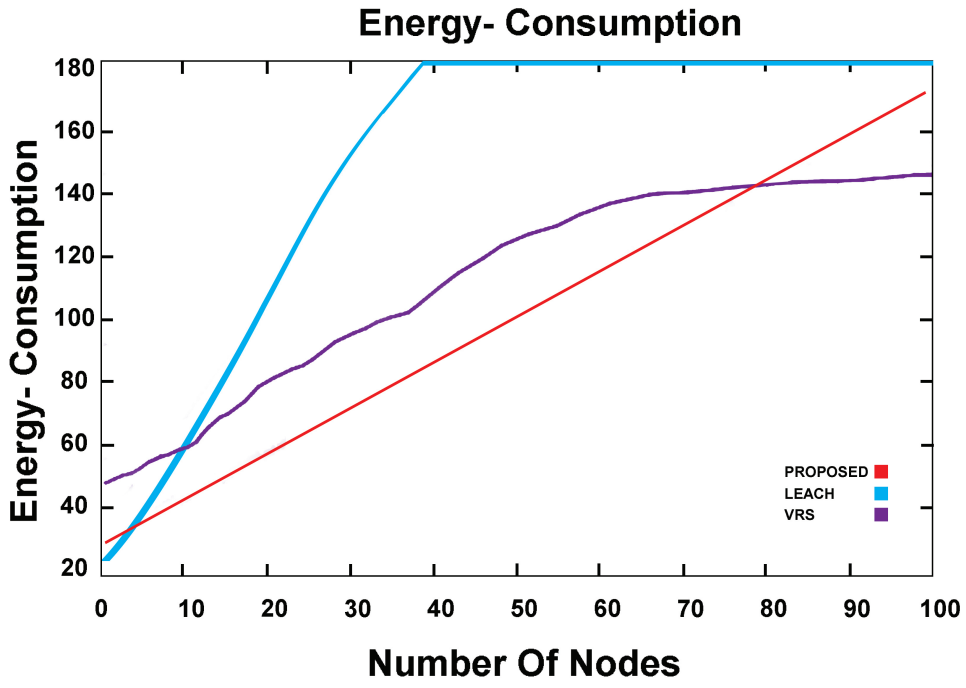


increase of the nodes number participating in the process.
Fig (5.10) shows that the energy consumption for the proposed protocol gradually starts with 20 for 10 nodes and reaches the maximum energy consumption 180 when using every node in the WSN. However,the LEACH reaches the maximum when using 40 nodes only which clearly shows that the proposed protocol is energy efficient more than LEACH. The proposed protocol is consuming the energy economically and dose not reach the maximum until all the sensors are participating in the process.
For the VRS starts gradually from 30 for one node the stabilize starting from node no.60.

3.The Packet Delivery Rate Versus Time

Packet delivery rate means the ratio of sent packets to the number of received packets at the destination. We can compute it by dividing the successfully received packets to the total sent packets. Packet delivery=successfully received packets/ total packets.
Fig (5.11) presents that it increases with time which indicates a good performance for the WSN. Due to the successfully delivered packets to their destination without errors or being lost.
Fig (5.11) indicates that the packet delivery ratio for the proposed protocol is bet-

Figure 5.10 Energy Consumption.



ter than the packet delivery for the LEACH on its own. The packet delivery ratio for the proposed protocol gradually starts from 15 at the 1 second of the transmission process then stabilize at second 7. However, the LEACH start from 11 at the 1 second, which indicates that the proposed protocol is delivering the packet to the destination effectively.

For the VRS starts from 36 at the 1 second the decreases gradually then stabilize at second 6.The protocols indicates that every packet sent arrives to the destination and the best one is VRS because it depends on the location.

4.The Throughput Versus The Number Of Nodes

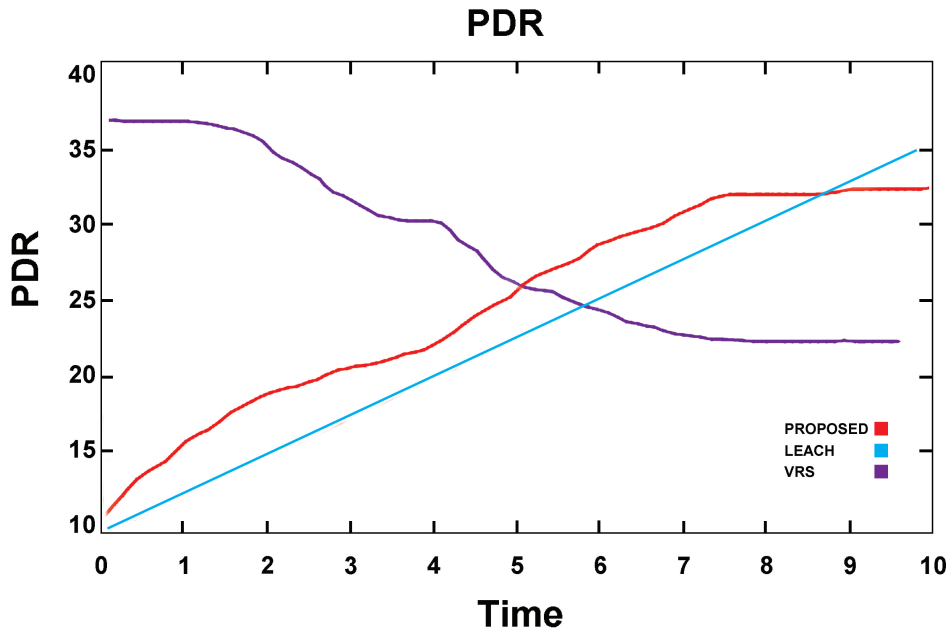
Throughput is the maximum infallible packets delivered to the destination during the communication process, and how fast sending the packet through the communication channel is without having congestion.

Fig (5.12) presents that more nodes are delivering more packets. Which indicates a good performance for the WSN.

Throughput for the proposed protocol starts gradually from 23 Mbps for the first node then starts stabilizing when node no.60 is activated.

LEACH throughput depicts that it might have some energy lost dealing with the congestion problem. Furthermore the packets are delivered effectively to their destination through the communication process.

Figure 5.11 Packet Delivery Rate.



For VRS it decreases from 48 Mbps the stabilizes at the node no. 70.

5.The Packet Routing Load vs Simulation Time

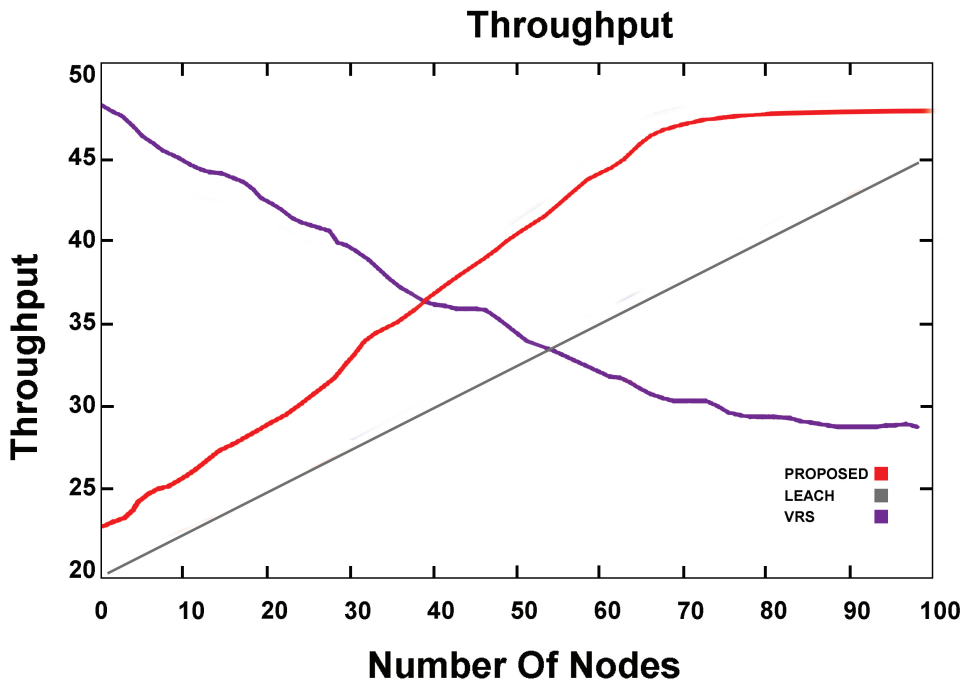
The packet routing load expresses the total number of transmitted packets over the successful transmission. In which the router chooses the best low-cost route to the destination, and in this case with low energy consumption.

Fig (5.13) shows that that more packets are sent to their destinations at the first few minutes and after that, it stabilizes, which means that the proposed protocol saves the energy for the nodes that transmit data. Because it delivers 160 packets in less than 15 seconds then stabilize at this range of packet delivery

Fig (5.13) represents LEACH routing load gradually increases which depicts that the increasing packet routing load with time consumes more energy from the nodes which reduce the network performance.

However, VRS starts from 50 packets then stabilizes at node no. 50 with 90 packet delivered.

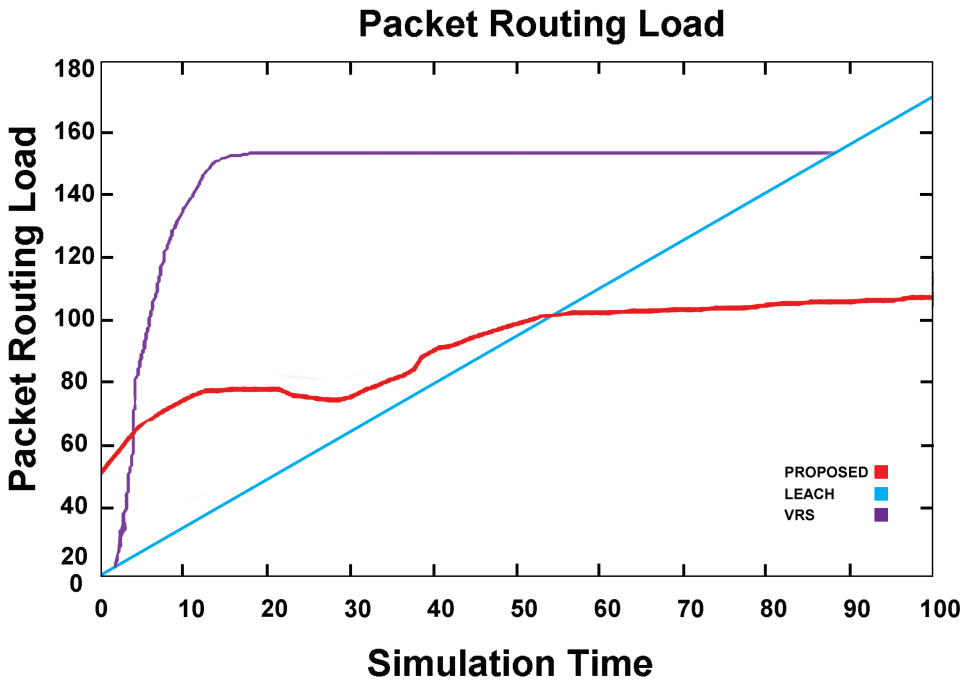
Figure 5.12 Throughput.



5.6 Summary

This chapter shows the results of the newly proposed protocol how it operates and the WSN behavior during the communication process. How they deliver the packets. Moreover, the best route and the computation inside the network.
What makes the new proposed protocol better than using one protocol at a time that I am making benefit of the advantages of the two protocols, to prolong the network lifetime.
The newly proposed protocol proved that it can prolong the network lifetime by improving the 5 metrics that we measured.

Figure 5.13 Packet Routing Load.



Chapter 6

Conclusion and Future Work

6.1 Conclusion

The whole idea is about creating a new way of dealing with WSN to overcome the power limitations, and to prolong the network lifetime. This is done by using two energy efficient protocols which are the LEACH and DD. We are using the clustering process and the hierarchical structure of the LEACH and making use of the cluster heads to do the communication process with the BS. Which saves the energy for the nodes and consumes the energy from the limited number of cluster heads. As for the benefits of the DD, the protocol is the location because the DD deals with the VRS algorithm it makes use of the location of each node. So, it helps to know the position for each node; Hence, if there any problem reaching the specific node.
The proposed protocol is sending the packets to the location and the nearest node is handling and processing the request and the data. From that, we deduced that adopting a new thought in dealing with the WSN is going to make a breakthrough in the networks industry. In this way, the network industry is avoiding a lot of limitations starting with the power consumption to all other areas that need development or override.
, Of course, using two protocols or even more. It is helping to have more benefits and avoid the problems for each one when it is standing alone. It has its problem, but we are avoiding these by using the right calculations and algorithms.
The creative way of thinking by using more than one protocol is not going to overhead the network if we used the right protocols together. In addition to doing the needed adjustment on each protocol to cope with the requirement and to overcome the obstacles and limitation.
At the first we thought it is easy to make the network dynamic from a to z but in reality, it is not. The first phase we had to put some specific commands to operate

like sensing, the normal nodes are sensing the data and sending it to the sink node which organizes the sensed information by their location and where they come from which node and the energy status of the specific node to send them to the BS. The BS is doing the computation and assign a pointer to the information. So it is easy to trace them later when the data is needed.
The data pointer is saved in the lookup tables which are organized according to the residual energy computed by BS and the pointer(packet number). All this is done by using data mining algorithm; So it can create and save lookup tables, remarked with the source location and the amount of energy at each node; Moreover, observing the network behavior and making patterns of the most important parameters and features to save them. So it is easy to take the data from the tables without operating the network.
All of that needs a normalization process using the decimal technique. In order to avoid the up normal value because we depend on location.
When the central server communicates the BS for some data. BS is operating the DD on the lookup tables saved in it and searching the patterns collected using the mining data. If the data is found it is going to be sent to the central server without operating LEACH on the whole network. If not the network is operating LEACH to harvest new data as requested. finally, the last phase is the dynamic selection of the protocols, choosing which one to operate based on its presence or absence on the lookup tables.
Using the newly proposed protocol in WSN are better in the network lifetime matter, it improved the network lifetime by enhancing the performance of the nodes through the communication process and in the way of using the energy in each node and it was measured to show how well it did in the energy consumption matter.

6.2 Limitation

The following section introduces the limitations of this study:
1. The first one is how to deal with two protocols with two different structures. That coming with finding the right algorithm to avoid their cons and to be energy efficient as well as the protocol.
2. The scalability problem that occurs when the nodes number increase; Hence, it is beneficial to use a scalable simulator or adjust the scalability by adjusting the protocol if needed.

6.3 Future Work

In the future there is so many enhancement we can do to evolve the WSN performance and it is as follow:
1. Testing the network with increased node number more than 200.
2. Defining more parameters concerned with network security because it is vulnerable to attacks.
3. It would be beneficial to send an error message to the BS as a warning if the nodes are about to die.
4. Overcoming the distraction problem when there are other devices around.

Bibliography

[1] Shuang-Hua Yang. *Wireless Sensor Networks Principles, Design and Application*. Springer CH(1-2).

[2] *Wireless Sensor Networks Concepts, Application, Experimentation and Analysis*. Springer Ch(2). Hossam Mahmod Ahmad Fahmy.

[3] *Wireless Sensor Networks: A Survey on Recent Developments and Potential Synergies*. Journal of Supercomputing,10.1007/s11227-013-1021-9springer,Verlag,2013. Priyanka Rawat, Kamal Deep Singh, Hakima chaouchi, Jean Marie Bonnin.

[4] *Wireless Sensor Networks*. SPIE, Vol 6357,6357-1, 2006. Chris Guy. `https://www.spiedigitallibrary.org/conference proceedings of spie`

[5] *Energy-Efficient Hierarchical Routing for Wireless Sensor Networks: A Swarm Intelligence Approach*. Wireless Personal Communications, 2017, Vol92, No 2, Page 785, Springer 2016. Palivinder Singh Mann, Satvir Singh.

[6] *Wireless Sensor Networks: A Survey*. Computer Networks 38 (2002) 393422, Elsevier, 20 December 2001. I.F.Akyildiz, W.Su.y.Sankara Subramaniam,E.Cayirci.

[7] *Classification and Comparison of Routing Protocols in Wireless Sensor Networks*. Ubiquitous Computing and Communication Journal(Ubicc) -Vol4. Rajashree.V.Biradar,V.C.Patil, Dr.S.R.Sawant, Dr.S.R.R Mudnolkar.

[8] *A Survey of Wireless Sensor Network*. International Journal of Emerging Technology and Advanced Engineering, Vol 3, No 3, March 2013. Shabbir Hasan, Md. Zair Hussain, R. K. Singh.

[9] *A Generalized Framework for Energy Conservation in Wireless Sensor Network*. IJCSI, Vol 8, No 1, January 2011. V.S.Anita Sofia, Dr.s.Arockiasang.

[10] *A Comparative Study of Wireless Sensor Networks and Their Routing Protocols*. Sensors, 2010, 10(12), 10506-10523; https://doi.org/10.3390/s101210506. Debnath Bhattacharyya, Tai-hoon Kim,Subhajitpal.

[11] *An Energy Efficient Cluster Based Routing Algorithms for Wireless Sensor Network*. International Journal of Engineering Science and Computing (IJESC), Vol 6, No 7, July 2016. Suman Bara, Silki Baghlal.

[12] *Multihop Routing in Self-Organizing Wireless Sensor Networks*. International Journal of Engineering Science and Computing (IJCSI), Vol 8 No 1, january 2011. Rajashree.V.Biradar,Dr.S.R Sawaut, Dr.R.R Mudholkar, Dr.V.C.Patial.

[13] *Routing Protocols in Wireless Sensor*. Sensors 2009, 9(11), 8399-8421; https://doi.org/10.3390/s91108399. Luis Javier Garcia villalba.

[14] *Survey on Positioning Based Energy Efficient Wireless Sensor Networks*. Sensor, 2016. Robin Chadha.

[15] *A Survey on Clustering Routing Protocols in Wireless Sensor Networks*. Sensors 2012, 12(8), 11113-11153; https://doi.org/10.3390/s120811113. Xuxun Lin.
`http://www.mdpi.com/journal/sensors`. accessed in 2018

[16] *Geographical and Energy Aware Routing are Cursive Data Dissemination Protocols for Wireless Sensor Network*. 2001. Yan Yu, Remesh Govindon.
`http://graphics.stanford.edu/courses/cs428-05-spring`

[17] *Wireless Network Security*.Hindawi publishing corporation, EURASIP Journal on Advances in Signal Processing (EURASiP), December 2009. Yang-Xiao Hnichen,Shuhui Yang, Yi-Bing Liu and Ding-Zhu Du.

[18] *Directed Diffusion for Wireless Sensor Networking*.IEEE/ACM TRANSACTIONS ON NETWORKING, Vol 11,No.1, February2003. Chalermek Intanagonwiwat, Ramesh Govindan, Deborah Estrin, John Heidemann.

[19] *SPIN Protocol for Wireless Sensor Network*.International Journal of Advance Research in Engineering, Science Technology (IJAREST),Vol 2, No 5,May 2015. Kunal.M.Pattani,Palak.J.Chauhan.

[20] *Lan Switching First-Step,CH1, Swich Port Analyzer*. http://etutorials.org

[21] *PEGASIS:Power-Efficient GAthering in Sensor Information System*.Computer System Research Department, pdfs.semanticscholar.org. Stephanie Lindsey, Cauligi S.Raghavendra.

[22] *Geographic Adaptive Fidelity and Geographic Energy Aware Routing in AD Hoc Routing*.International Journal of Computer Communication (IJCCT), Vol 1, No 2,3,4;August 2010. Sinchan Roychowdhury, Chiranjib Patra.

[23] *LEACH Protocol in Wireless Sensor Network: A Survey*. International Journal of Computer Science and Information Technologies (IJCSIT),Vol 7,April 2016. Reshma I.Tandel.

[24] http://shodhganga.inflibnet.ac.in/bitstream/10603/ $[07_chapter_01.pdf]accessedin2018$

[25] https://www.elprocus.com/architecture of WSN and applications

[26] *Wireless Sensor Network-Technology and Protocols*.September6,2012, CH1, page1-4, ISBN978-953-51-0735-4. Mohammad A. Matin and M.M. Islam.

[27] *Wireless Sensors in Heterogeneous Networked Systems, Computer Communications and Networks*.Springer 2014, DOI 10.1007/978-3-319-09280-5-2, CH2, page5-7. J. Ceclio, P. Furtado.

[28] *Component-Based Wireless Sensor Networks .A Dynamic Paradigm for Synergetic and Resilient Architectures*.38th Annual IEEE Conference on Local Computer Networks, 978-1-4799-0537-9/13//31.00 2013. Sharief M.A. Oteafy and Hossam S. Hassanein.

[29] *Network Study Gide*.Fourth edition,2005,ISBN0-7821-4406-3. David Gorth, Toby Skaudier.

[30] *Networking Computer*.Third edition, 2002, INC.S, San Francisco, Sybel.

[31] *Wireless Sensor Networking- Technology and Protocols*. ISBN: 978-0-470-11275-5 April 2007 CH1, P5-9. Kazem Sohraby, Daniel Minoli, Taieb Znati.

[32] *An Energy-Efficient Topology Control Mechanism for Wireless Sensor Network Based on Transmit Power Adjustment*.Springer Science+Business Media New York 2015, DOI. 10.1007/s11277-015-2363-9. Jarad Akbari Torkestani.

[33] *Network Structure or Topology*.India International [Journal of Advanced research In Computer Science and Management Studies] Vol 1, No 2, July 2013, ISSN 2321-7782. Kartik Pandya, (S.M.V).

[34] *Network Topologies In Wireless Sensor Network: A Review*.The International Journal of Electronics Communication Technology (IJECT), Vol 4,No SPL 3, Aprile-June 2013, ISSN 2230-9543. Divya Sharma, Sandeep Verma, Kanika Sharma.

[35] *Energy Efficient Topology for Wireless Sensor Networks*.IJECT,International Journal of Distributed and Parallel systems (IJDPS), Vol 3, No.5, September 2012,DOI 10.5121/IJDPS.2012.3516. Gurwinder Kaur Rachit Mohan Garg.

[36] *Routing Topology Inference for Wireless Sensor Network*.ACM SIGCOMM computer communication Review Vol 43, No.2, April 2013. Yaoliang Rui Liu.

[37] *Analyzing Rotational Intertia, Grid Topoligy and their Role for Power System Stability*.Elsevier, https://doi.org/10.1016/j.ifacol.2015.12.436,IFAC 2405-8963, 2015. Andreas Vlibig, Theodors Borsch, Goran Andersson.

[38] *Computer Network Development to Achieve Resource Sharing*. Spring Joint Computer Conference,1970, New Yourk 543-549. Berry Dwessler, Lawrence. G Roberts.

[39] *Teach-ICT OCRGCSE computing- computer network topologies*. https://www.ocr.org.uk/Images/231758networks delivery guide.pdf.

[40] *Introduction to computer network topology about.com*. https://www.studytonight.com/computer-networks/ [network-topology-types]. January 18, 2016.

[41] *Energy Efficient Routing for Wireless Sensor Networks with Grid Topology*. International Conference, EUC 2006, Seoul, Korea, August 1-4, 2006. Proceedings. Hoch Guan, Goh, Mou LimSim, Houg Tat Ewe.

[42] *Routing In a Highly Dynamic Topology*.Second Annual IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks, 2005. IEEE SECON 2005. Yashar Ganjali, Nick McKeown.

[43] Dynamic Routing,CH4. (http://www.ics.uci.edu/ magda/ics$_x$33/$ch4.pdf$)$accessedin2018$

[44] *Effective Local Dynamic Routing Strategy for Air Route networks*. Chinese Journal of Aeronautics, 21 July 2015, 28(6):1709-1717. Wu Wenjun, Zhao Lingxi.

[45] *Dynamic Routing*.
`http://WWW.techopedia.com`accessed in 2018

[46] *Energy Efficient LEACH Protocol for Wireless Sensor Network*.International Journal of Information and Network Security (IJINS), Vol 2, No 4, August 2013, ISSN: 2089-3299. Nishi Sharma, Vandna Verma.

[47] *Improvement on LEACH protocol of Wireless Sensor Network*. International conference on Sensor Technologies and Application, DOI 10.1109,2007 . Fan Xianguing, Song Yulin.

[48] *Low Energy Adaptive Clustering Hierarch in Wireless Sensor Network (LEACH)*.
International Journal of Computer Science and Information Technologies (IJCSIT), Vol 5, No3, 2014, ISSN:0975-9646 . Lalita Yadav, Ch.Sunitha.

[49] *LEACH Protocol In Wireless Sensor Network: A Survey*.
International Journal of Computer Science and Information Technologies (IJCSIT), Vol 7(4), P 1894-1896, 2016, ISSN 0975-9646 . Reshma I.Tandel.

[50] *IBLEACH: Intra-balanced LEACH Protocol for Wireless Sensors Networks*. Springer 2014, 20:1515-1525, DOI 10.1007/s11276-014-0691-4 . Ahmad Salim, Walid Osamy, Amed M.Khedr.

[51] *LEACH-B: An Improved LEACH protocol for wireless sensor network*. IEEE, 2010, 978-1-4244-3709-2. Mu-Tong, Minghao Tang.

[52] *Improvement on LEACH Protocol of Wireless Sensor Network(V-LEACH)*. January 2009, Research Gate, DOI: 10.1109. M.Baniyassein, A.AlZoubi, Y.Khamayseh, W.Mardini.

[53] *Protocols and Architectures for Wireless Sensor Network*. WILEY.com. Holger Kaurl, Andreas Willig.

[54] *Directed Diffusion for Wireless Sensor Networking*. IEEE/ACM Transactions on networking, Vol 11(1), February 2003, 1663-6692. Chakrmek Intanagonwiwat, Ramesh Govindam, Deborah Estrin, John Heidemanm.

[55] *Network Structure and Topology Based Routing Techniques in Wireless Sensor Network A Survay*. International Journal of Computer Application(0975-8887), Vol 74(12), July 2013. Rajendra Singh Bisht, Shailendra Mishra.

[56] *Directed Diffusion: An Application-Specific and Data-Centric Communication Paradigm for Wireless Sensor Network*. University of Southern California, Doctor thesis, December 2002. Chalermek Intanagonwiwat.

[57] *Improving the Directed Diffusion In order to Reduce the Average of Energy Consumption in Wireless Sensor Network*. The fifth International Conference on Sensor Technologies and Application,IARIA, 2011, ISBN 9781-1-61208-144-1. Miresmacil Mirnabibaboli, Mehdi Mirfattahi, Mher Markosyan.

[58] Ruoting, `http://WWW.en.WiKipedia.org/wiki/routing`accessed in 2018

[59] Exchange Server 2003 Message Routing June 2007, `http://WWW.technet.microsoft.com`accessed in 2018

[60] Exchange Server 2003 Message Routing June 2007, `http://WWW.desktop.arcgis.com` accessed in 2018

[61] *Survey on Single Path and Multi Path Energy Efficient Routing Protocols for Wireless Sensor Networks*. Journal of Computer and Communicatins, 2017, 5, 1-11, ISSN 2327-5227. Nimrah Saeed, Maryam Murad, Mehmood Nawaz, Misbah Irum.

[62] *A Survey on Clustering Techniques for Wireless Sensor Network*. International Journal of Research in Computer Science, Vol 2(4), P 51-57, 2012, ISSN 2249-8265. Rudranath Mitra, Diya Nandy.

[63] *Generalized Framework for Energy Conservation in Wireless Sensor Network*. International Journal of Computer Science Issues (IJCSI), Vol 8, No 1, january2011, ISSN 1694-0814. V.S.Anita Sofia, Dr.S.Arockiasamy.

[64] *Multipath Routing Techniques in Wireless Sensor Networks: A Survey*. springer, 30 june 2012, DOI 10.1007/511277-0120723-2. Kewei sha, jeguesh gehlot, Robert greve.

[65] *Energy Effective Wireless Sensor Network Modeling Based on Complex Networks*. Journal of sensors, vol 2016, article ID 3831810, hindawi publishing corporation. lin xiao, fahui wu, digcheng yang, tiankui zhang, xiaoy zhn.

[66] *Data mining techniques for wireless sensor network: a survey*. International Journal of Distributed Sensor Networks, https:doi.org 0.1155 2013 406316, July 21,2013. Azhar Mahmood, Keshi, Shaheen Khatoon, Mi Xiao.

[67] *Assisted-Leach (A-Leach) Energy Efficient Routing Protocol for Wireless Sensor Networks*. International Journal of Computer and Communication Engineering. 420-424. 10.7763/IJCCE.2013.V2.218, 2013. Inodh Kumar, Sunkara Pal, Ajit.

[68] *A Survey of Network Simulation Tools: Current Status and Future Developments*.
`http://www.cse.wustl.edu/ jain/cse567-08/index.html`.
accessed in 2018 Jianli Pan.

[69] *A study of comparison of Network Simulator -3 and Network Simulator - 2*. International Journal of Computer Science and Information Technologies, Vol. 3 (1) , 2012, 3085 - 3092. Rachna Chaudhary, Shweta Sethi, Rita Keshari, Sakshi Goel,Rachna Chaudhary et al.

[70] *Analysis and comparison of different network simulators*. International Journal of Application or Innovation in Engineering Management (IJAIEM),ISSN 2319 - 4847. Vinita Mishra, Smita Jangale.

[71] Repairing Network Connectivity, Arc map,
`http://opnetprojects.com/opnet-network-simulator` accessed in 2018