WIRELESS SENSOR NETWORK NODE LIFETIME ENHANCEMENT USING MOBILE SINK BASED ON HYBRID PROTOCOL

Dissertation submitted in partial fulfillment of the requirement for the degree of

MASTER OF TECHNOLOGY
IN
ELECTRONICS AND COMMUNICATION ENGINEERING

By

ANUJA ARMAN
Enrollment No – 132018

Under the supervision of

Dr. D. S. Saini

May – 2015

DEPARTMENT OF ELECTRONICS AND COMMUNICATION

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234, INDIA

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

CHAPTER 2 LITERATURE REVIEW

CHAPTER 3 MOBILITY IN WSN

CHAPTER 4 MULTI-CHAIN BASED HYBRID ROUTING PROTOCOL

CHAPTER 5 MOBILE SINK BASED MHRP

CHAPTER 6 CONCLUSION

DECLARATION

I, **ANUJA ARMAN**, hereby declare that thesis entitled "**WIRELESS SENSOR NETWORK NODE LIFETIME ENHANCEMENT USING MOBILE SINK BASED ON HYBRID PROTOCOL",** has been carried out by me under the supervision of **Dr. D.S. Saini**, Department of Electronics and Communication Engineering, Jaypee University of Information Technology, Waknaghat, Solan-173234, Himachal Pradesh, and has not been submitted for any degree or diploma to any other university. All assistance and help received during the course of the investigation has been duly acknowledged.

Date:

ANUJA ARMAN
Deptt. of ECE
JUIT

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY
(Established under Act 14 of Legislative Assembly of Himachal Pradesh)
Waknaghat, P.O. Domehar Bani, The. Kandaghat, Distt. Solan - 173234 (H.P.)
Phone: 01792-245367, 245368, 245369
Fax: 01792-245362

CERTIFICATE

This is to certify that the work titled "**WIRELESS SENSOR NETWORK NODE LIFETIME ENHANCEMENT USING MOBILE SINK BASED ON HYBRID PROTOCOL"** submitted by "**Anuja Arman**" in partial fulfillment for the award of degree of M.Tech at Jaypee University of Information Technology, Waknaghat has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

Dr. Davinder Singh Saini
(Associate Professor)
Department of Electronics and Communication Engineering
Jaypee University of Information Technology (JUIT)
Waknaghat, Solan-173234, India

ACKNOWLEDGEMENT

I would like to express my gratitude to my guide **Dr. D. S. Saini**, Associate Professor for final year project, for providing excellent guidance, encouragement and inspiration throughout the project work. Without his invaluable guidance, this work would never have been a successful one. I take this opportunity to thank **Mr. Tapan Jain**, Assistant Professor for helping me at different stages of project in building novel ideas and his patience which helped me completing my project fruitfully. I would like to express my profound regards to **Dr. S. V. Bhooshan (H.O.D)** for his valuable support and guidance at regular intervals.

Last but not least a special thanks to my parents and friends for their caring and encouragement.

Signature of the student …………………………..

Name of student …………………………..

Date …………………………..

ABSTRACT

Wireless sensor network (WSN) is a network made up of many micro-sensors. It is mainly used to accept and send different kinds of data to the base station. Sensor nodes deployed in network contains restrained battery power so the network lifetime is a paramount factor. Thus, energy efficient routing protocol should be adopted to increase the network life expectancy and it is not easy for a network with large number of nodes to exchange the battery. Thus, energy efficient routing protocol should be preferred to enhance the life expectancy of network. Hierarchical Routing Protocols are the best known protocols to minimize the energy diminution. PEGASIS is one of the best fundamental chain-based hierarchical routing protocols which can be hired to lessen the energy diminution in network. This thesis encloses the survey of different chain based routing protocols that have been developed from PEGASIS and also discuss some of the shortcomings and issues in PEGASIS which are overcomed by the descendants of PEGASIS.

This thesis describes a proposed Multi-chain based Hybrid Routing Protocol (MHRP) which adopts a joint strategy of multi-chain concept and Pre-Chain Leader (P-CL) selection procedure to realize the increased node lifetime in wireless sensor networks (WSN). The multi-chain concept aims to balance the network overhead due to less number of nodes in chains comparatively. It also minimizes data delivery delay in order to improve the network performance. The Pre-Chain Leader improves the greedy algorithm and aims to balance the workload of head node selected among the entire node by adopting another leader node in case when head node is far away from sink node.

Furthermore, the mobility of a sink in the proposed hybrid protocol is implemented in order to advance the network lifetime of Wireless Sensor Networks. Since the motorized movement of mobile sink is steered by current or petrol, there is need to confine this movement within boundaries and the trajectory of mobile sink should be fixed. Hence, the optimal trajectory of sink is being implemented in MHRP on which the mobile sink moves and stays for a sojourn time at sojourn location to guarantee complete data collection. Simulation analysis shows that we achieve better overall performance of the network by using these concepts in our hybrid protocol and can be used to attain delay-intolerant applications.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

MEMS	Micro-Electro-Mechanical System
WSN	Wireless Sensor Network
CSMA	Carrier Sense Multiple Access
MAC	Medium Access Control Protocol
MECN	Minimum Energy Communication Network
MSWSN	Mobile Sink WSN
LEACH	Low Energy Adaptive Clustering Hierarchy
PEGASIS	Power Efficient Gathering in Sensor Information System
CCS	Concentric Clustering Scheme
DERP	Distance-based Energy-efficient Routing Protocol
IEEPB	Improved Energy Efficient PEGASIS Based routing protocol
MULE	Mobile Ubiquitous LAN Extensions
MHRP	Multi-chain based Hybrid Routing Protocol

CHAPTER - 1

INTRODUCTION

Key Topics

- ✓ Wireless Sensor Network
- ✓ Routing Techniques
- ✓ Problem Description
- ✓ Motivation
- ✓ Objective
- ✓ Thesis Structure

INTRODUCTION

1.1. Wireless Sensor Networks

Recent advancement in Micro-Electro-Mechanical System (MEMS) based sensor technology has brought a revolution to the development of small size multifunctional sensor nodes. Meanwhile it draws attention of many researchers because of the enormous scope of its applications in numerous areas.

A wireless sensor network (WSN) consists of hundreds or thousands of sensor nodes organized in an ad-hoc manner to achieve a predefined goal. Nowadays it is intensively motivated by various industrial as well as consumer applications such as battle surveillance applications, region monitoring, medical applications and so on. [1] Categorizes these applications and gives typical examples for each category. Here we briefly summarize these applications.

Military Applications:

The rapid deployment, self-organization and fault tolerance characteristics of sensor networks make them appropriate for military purposes. Monitoring friendly forces, battlefield surveillance, reconnaissance of opposing forces, targeting, and nuclear and chemical attack detection are examples of military applications. They can be used in hostile environment where it is too dangerous for humans to operate.

Environmental Applications:

The most widely used sensor network application is environmental monitoring. Various types of sensors enable the nodes to sense the environment and perform given tasks continuously. This kind of application includes forest fire and flood detection, habitat monitoring, tracking the movement of targeted animals.

Health Applications:

Some of the health applications for sensor networks are integrated patient monitoring; diagnostics; drug administration in hospitals; monitoring the movements and internal processes of small animals; telemonitoring of human physiological data (heart rate, blood pressure detection, so on); and tracking and monitoring doctors and patients inside a hospital.

Home Applications:

Sensor nodes can be used for home automation to provide smart home environment in which all the appliances can interact with each other and be controlled remotely outside the home.

Commercial Applications:

This type includes managing and controlling inventory, detecting and tracking vehicles, and factory process control and automation.

It provides massive amount of benefits by inculcating remote sensing points without any cost of running wires which includes energy as well as material savings, labour savings which results in improvements in processing and productivity. Sensor nodes have limited processing power, storage space and limited communication bandwidth. Hence in network data management and information processing such as data aggregation and routing techniques need to be developed. Lifetime is the key characteristics to evaluate performance of a sensor network are determined by residual energy of the system. Energy efficiency can be introduced WSN by any of the following methods:

- Energy conservation mechanism
- Power consumption mechanism
- Energy harvesting mechanism
- Energy efficient routing mechanism

This new kind of network raises several questions and open issues that have to be addressed and answered by the research community in order to promote the use of WSNs from the research papers to our everyday life. In this thesis, one of the most challenging such open issues has been addressed namely enhancing the energy efficiency of WSNs. In order to better understand the importance of this topic and of the solutions, a short overview of the challenging world of wireless sensor networks has been discussed. Firstly the special features of the wireless sensor network model will be discussed and the way they cooperate to form a network.

1.2. Wireless Sensor Network Model

In general, WSN has predominantly two types of nodes i.e. sink and sensor nodes. Sink is also known as base station. It is the node where data are gathered and interpreted. Generally, it is presumed that sink node has adequate amount of energy which cannot be depleted throughout the network operation. Each sensor node performs sensing, processing and communication in order to attain its task.

From the base station, users can access the data possibly through internet for further processing of the data and to extract useful information. Depending on the network size and network topology, there could be one or multiple sink nodes and the sink nodes can either be stationary at one position or patrolling in the network area. The sink node with base station functionality is usually supplied with large energy reserve and large computational power as it works as a pivot in the sensor network system.

Nowadays Micro-Electro-Mechanical System (MEMS) enables sensor nodes to be lower in production cost, smaller in size and multi-functional technically and economically feasible. Sensor nodes are electronic devices that are widely deployed throughout the network area to completely cover the environment and are equipped with sensing devices that can monitor a wide variety of ambient conditions. The workflow of sensor nodes includes generating data packages, which contains the information within the sensing area, and wirelessly transmitting them to the base station or other sensor nodes. Due to the limitation of maximum transmission range, data packages from a sensor node may not be able to reach the sink node directly. In this case, other sensor nodes are needed to forward the data to the destination. Thus, data transmission may involve multiple sensor nodes to receive the data package and route them back to the sink node.

1.2.1. Sensor Nodes

The task of a sensor node is to measure some kind of physical quantity i.e. temperature, humidity, seismic activity, light, acoustic sounds, etc. The node digitizes the analogue signal, processes it and sends it to a central node using its radio. The aim is to build sensors as tiny as possible (e.g., several cubic millimeters) and as cheap as possible (below 1 USD), typical sensor nodes are shown in Figure 1.1. Due to their small size, sensors have strong memory, processing and energy limitations. A typical sensor node has four main units: a sensing unit, a processing unit, a power unit and a transceiver as it is shown in Figure 1.2.

Figure 1.1: Typical sensor motes: MicaZ mote, Telos mote, Cricket mote and MITmot mote.

The sensing unit

The sensing unit operates the MEMS-based sensor (Micro Electro-Mechanical Systems) that measures some physical quantity from the surrounding environment. The unit can have one or more sensors making it possible to measure multiple quantities. The sensor generates an analogue signal that is digitized by the ADC (Analog-Digital Converter). Then the digital signal is forwarded to the processing unit for further analysis and processing. Since the advancements in sensing technologies are much slower than those of the semi-conductors, the sensing unit is typically the technology bottleneck.

The processing unit

The processing unit has an important role in managing the collaboration with other sensors in order to fulfill the given task. This element controls the sensors and executes the communication protocols. The processing unit can be a microcontroller, a microprocessor, or a Field Programmable Gate Array (FPGA). The latter one has the drawback that it consumes more energy and is not compatible with traditional programming methodologies. However, it also has the benefit of saving deployment costs by being programmable and reconfigurable. Usually the clock frequency is between 5- 8MHz.

The processing unit has a memory that is necessary for the storage of measured data, for the execution of different tasks and for reducing the amount of messages to transmit by local processing and data aggregation. Due to its low cost and high storage capacity, flash memory is widely used. The typical memory size is of a few hundred kilobytes. An important feature of the processing units is that they can operate in different energy saving modes. However, one has to take into account how long it takes and how much energy it costs to switch between these modes.

The need for efficient operation, the limited processing capability and the scarce memory resource raises contrary requirements in the design of the operating systems for sensors. On the one hand they should have minimal memory requirements and operation overhead. On the other hand they should be flexible enough to run complicated protocols.

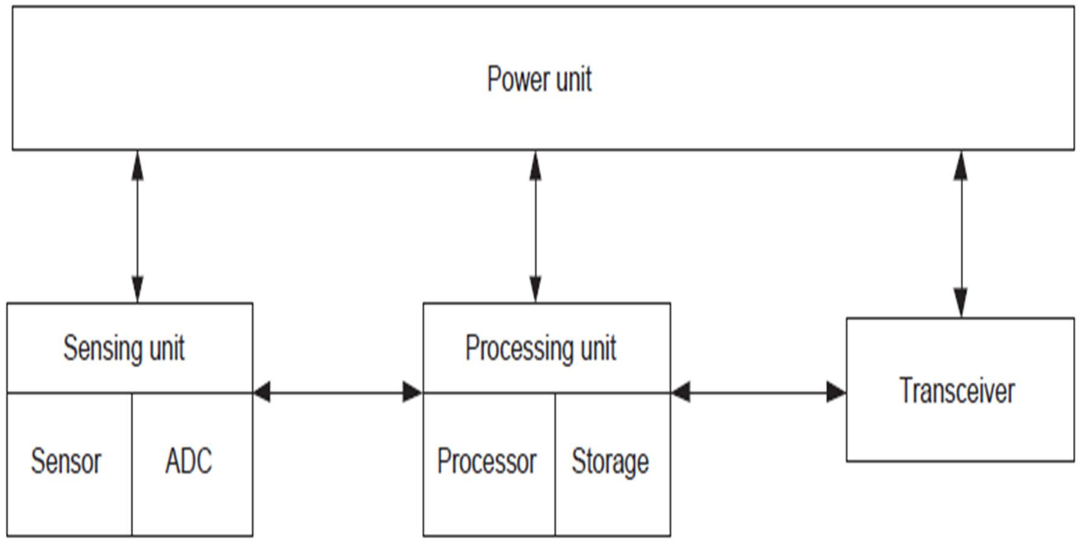

Figure 1.2: The units of a typical sensor.

The Transceiver

By means of the transceiver circuitry a sensor unit communicates with nearby units. Although early projects considered using optical transmissions (e.g. infrared) current sensor hardware relies on radio communication. Optical communication is cheaper, easier to construct and consumes less power than radio communication but requires visibility and directionality which are extremely hard to provide in a sensor network. Radio communication suffers a high path loss and requires complex hardware but is a more flexible technology. Currently available sensors employ one of two types of radios. Some sensors use a radio that supports Carrier Sense Multiple Access (CSMA) Medium Access Control (MAC) protocol. The typical bandwidth is 20 - 50kbps and it operates in a free band (433/916 MHz). The radios of the newer sensor models support the ZigBee (IEEE 802:15:4) protocol. They use the 2.4 GHz band and have a 200kbps communication bandwidth. The typical radio range is around 100m. However, this can be reduced by environmental effects.

The power unit

The power unit provides the energy for the operation of the sensors node. The size of the node is determined by this unit since it is the largest one among the four units. Therefore, it is of crucial importance to use small power sources. The batteries can be categorized as rechargeable and non-rechargeable. In some environments, it is not possible to replace or recharge the batteries. Therefore, it is very important to use long-lasting energy-sources, and to use the energy as efficiently as possible. Although many researchers aim to produce batteries that recharge themselves by deriving mechanical or solar energy from the surrounding environment. This cannot be an ultimate solution. In some applications sensors are deployed in dark places, in others the energy consumption of a heavily loaded sensor may significantly exceed the energy amount possibly charged by a solar cell, and there are also cases when the unreliability in the operation introduced by the dependency on the sunlight cannot be allowed. Most of today's typical sensors are powered by AA batteries.

In this scenario each sensor node can be assigned dual roles as both a data generator and a data router (sometimes referred to as a relay node). Sensor nodes which are closer to the sink are typically required to forward data packages from other sensor nodes that are far away from the sink in the network topology (as shown in Figure 1.3).

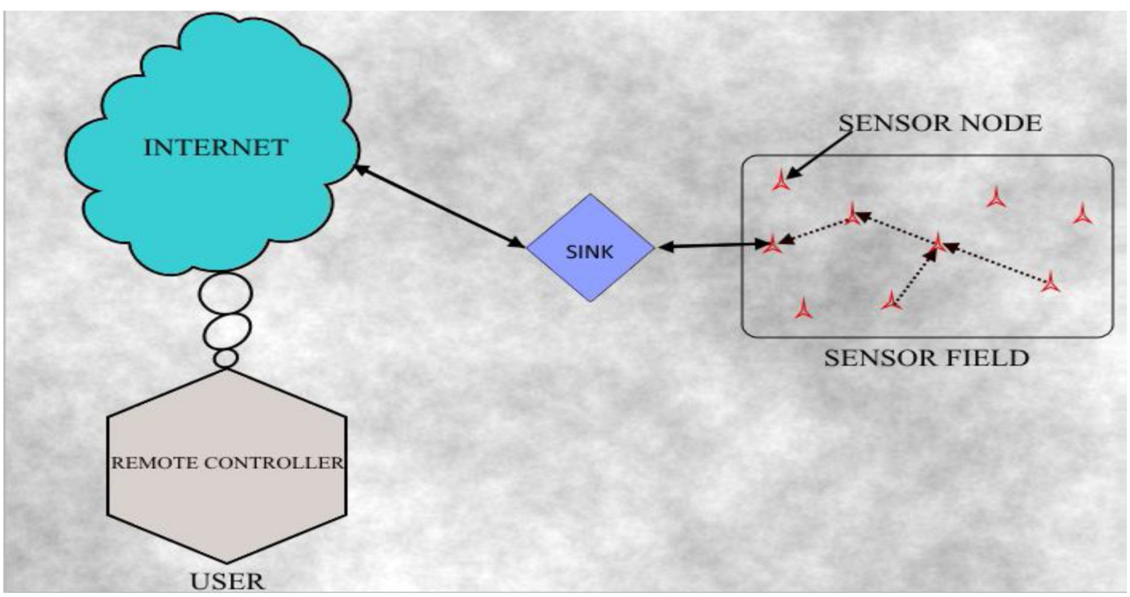

Figure 1.3: Illustration of Wireless Sensor Network

In a wireless sensor network (WSN), sensors are scattered in the field and communicate with each other wirelessly. However, sensor nodes are battery-powered with limited energy supply. Moreover, compared to the sink nodes, computational power of a sensor is also weaker. A sensor node consumes energy from the battery (usually <0.5 Ah, 1.2 V, according to [6]) and when a sensor node runs out of energy it cannot provide any service including sensing, data processing or data communication any more. When this occurs, sensor is considered to be “dead” and will be removed from the network topology. The lifetime of a sensor network is defined to be the time interval from its deployment to the time a “critical” number of sensor nodes die, rendering the network unusable. Hence the lifetime of a sensor node depends strongly on the battery power. A small portion of “dead” sensor nodes could directly affect the entire network lifetime and possibly lead to a huge loss in the network due to the routing path reallocation and failure of sensing and reporting events in the environment. Therefore, in order to prolong network lifetime and guarantee the robustness of the sensor network, efficient energy consumption and energy conservation are of great importance in wireless sensor networks when designing and deploying networks for practical use.

Another important issue is the performance of the network. In some environments, sensor network systems are required to be highly sensitive to the change in some ambient conditions (for example, the temperature of the reactor in a nuclear power plant) and require rapid response to the events or phenomenon within the environment. Therefore the assurance of successful data delivery and quickness of data processing and data transmission plays a crucial part in providing reliable sensing services. Usually researchers take the transmission delay as a measurement to assess the performance and quality of service of a sensor network system and hence, to minimize the transmission delay and maximize the output in an energy-efficient way is also a primary concern in the research works.

Although WSN networks can be considered as a kind of ad-hoc network, the protocols and architectures proposed for traditional ad-hoc networks are not directly applicable in WSNs because of some major differences:

- WSNs might be several orders of magnitude larger in number of nodes than traditional ad-hoc Networks.
- Sensors have strong limitations (processing, memory, energy supply). Thus, efficient resource management is needed.
- Common failure of sensors makes the topology change frequently.

- Sensors are usually static, while ad-hoc networks have mainly mobile nodes.
- The application has great influence on the desired properties (latency, bandwidth, etc.) of the WSN (e.g. military vs. civil applications).
- In ad-hoc networks communication is done point-to-point, while WSNs typically use multipoint-to-point or point-to-multipoint communication between the sensors and the sink.
- Location awareness is important in WSNs.

There are two main communication paradigms in WSNs: single-hop and multi-hop communication. In case of smaller networks where every sensor is inside the communication range of the sink, single-hop communication is used i.e. the sensors send the data directly to the sink. In wide-area networks this is not possible for every sensor; thus, multi-hop communication has to be used. This means that data packets of remote sensors are forwarded by their neighbors towards the sink. Based on the requirements of the application, there are three main operation modes for the collection of the measured data:

In *time-driven networks* every sensor reports to the sink in periodic time-intervals. This operation architecture satisfies the requirements of applications where the measured values are needed periodically. For example, this scenario has to be used in case of environmental observation and forecasting.

There are applications where there is no need for a sensor to report until an event happens within its vicinity. In *event-driven networks* only those sensors are communicating with the sink that is sensing an event. This scenario fits for example to the intrusion detection application. Only those sensors are reporting which are close to the intruder. The others spare their energy supplies by avoiding unnecessary communication.

Finally, in *query-driven networks* the sensor sends packets to the sink only upon receiving a query. The query may address all the sensors (e.g. “send all the temperature measurements") or only a subset of them (e.g., “what is the temperature in the north-western sector?"). This operation mode may be used for example for wildlife habitat monitoring, where the user does not want to know the location of the animals all the time, but only at given moments.

1.3. Overview of routing techniques

Challenges encountered as a result of constrained energy supply and bandwidth in WSN when managing the network necessitates the need for development of energy awareness protocol at all levels of networking protocol stack. To offer efficient power management in WSN, researches have been focus on areas such as system-level power awareness like radio communication hardware, low duty cycle issues and energy aware MAC protocols [7]. Also, it was observed that the network layer offers a better means through which reliable relaying of data and energy-efficient route setup within a network can help to maximize the network lifetime.

It should be noted that routing in WSN has much distinguishable features compare to contemporary communication and ad hoc networks [7].

These features are as follows:

I. WSN cannot be built with global addressing (internet protocol address) scheme due to the enormous number of sensor nodes.

II. There is significant redundancy in generated data because several sensors may gather the same data within a particular field. These redundancy needs to be removed to increase the bandwidth utilization and also reduce energy consumption in the network.

III. Transmission power, processing capacity and storage are constraint factors to be considered when managing a WSN.

Due to these differences, new protocols are being researched and fashioned to eliminate the problem faced in WSN. These routing protocols have been fashion on sensor nodes characteristics alongside its application and architectural requirement. The various protocols can be classified as

- ❖ Location-based protocol
- ❖ Data-centric protocol
- ❖ Hierarchical routing protocol

1.3.1. Location-Based Protocol

Most routing technique for WSN depends on location information of sensor nodes for estimation of distance between two specific nodes to deduce energy consumption. For example, to sense a known region through the use of location sensor, a specified query can be sent to that known region and this will significantly reduce transmitted data compare to a broadcast request being sent to the entire network. In other words, the location-based protocol utilizes the position information [8] to relay the data to the desired regions rather than the whole network.

An example of a protocol that uses this technology is MECN (Minimum Energy Communication Network). MECN sets up and also maintains a low energy in a WSN by using low power global power positioning system (GPS).

1.3.2. Data-Centric Protocol

Since assigning global identifiers to every sensor nodes in a WSN may appear not visible in some randomly deployed application. Data transmitted by every sensor node within a particular region has significant redundancy with it. To reduce this redundancy, data centric protocols were developed to select a set of sensor nodes and also utilize data aggregation during relaying of data.

An example of data centric is a sensor protocol for information via negotiation (SPIN). SPIN's data are named using metal-data that highly describes the characteristics of the data which is the key feature of SPIN. Flooding is another type of routing protocol in which each sensor node receives data and then sends them to the neighbors by broadcasting unless a maximum number of hops for the packet are reached or the destination of packet is achieved.

The advantage of SPIN is that the topological changes are localized since each of the sensor nodes needs to know only its single-hop neighbors [9]. However, it has a disadvantage of scalability (not scalable) and also the nodes around the base station could deplete their energy if the BS is interested in too many events. Moreover, SPIN's data advertisement mechanism cannot guarantee the delivery of data. For instance, if the sensor nodes which are interested in the data are far away from the source node and the nodes between source and destination are not interested in that data, such a data will not be transmitted to the destination at all.

1.3.3. Hierarchical routing protocol

Hierarchical routing in WSN involves the arrangement of clusters in form of hierarchy when sending information from the sensor nodes to the base station. Hierarchical routing efficiently reduces energy consumption by employing multi-hop communication for a specific cluster and thus performing aggregation of data and fusion in a way that decreases the number of data carried across the network to the sink. Cluster formation is based on residual energy in the sensor nodes and election of a CH. A very good example of hierarchical routing protocol is low-energy adaptive clustering hierarchy (LEACH). The LEACH approach involves formation of clusters of sensor nodes centered on the received signal quality and the use of a local CH as a router to the BS. Reduction in energy consumption in data transmission is achieved since the CH is involved in transmission to the BS rather than individual sensor nodes. The disadvantage about LEACH is its inabilities to be deployed in large network.

The Table I shows the comparison of the different routing protocols in terms of scalability, lifetime, data diffusion and power required in WSN. From table 2.1, we understand that hierarchical technique offers an approach to energy minimization and scalability features in a WSN.

	Data-centric Technique	**Hierarchical Technique**	**Location-based Technique**
Scalability	Limited	Good	No
Lifetime	Long	Long	Long
Data Diffusion	No	Yes	No
Power Required	Limited	High	Limited

Table I: Comparison of routing technique

1.4. Problem Description

As the sink nodes are usually supplied with larger energy support and computational power, the energy conservation research works are mostly conducted to minimize the power consumption among the sensor and/or relay nodes. According to the functions of sensor nodes, in general, power consumption can be divided into three domains: sensing, communication and data processing. Of the three domains, a sensor node expends maximum energy in data communication that leads to the research preference in the networking area to mainly focus on minimizing communication costs in data transmission to achieve the optimal power efficiency.

1.4.1. Hotspot Problem

The main task of most wireless sensor networks is to collect data and send it in a multi-hop fashion to a base station. While forwarding data in a multi-hop fashion to the base station is often more energy-efficient than transmitting the data directly from the sensing node to the base station, a potential disadvantage of the multi-hop strategy is that the nodes close to the base station must forward much more packets than nodes further away from the base station. Therefore, these nodes "typically die at an early stage". This is sometimes called the "Hot Spot problem" and an example of this situation is shown in Figure 1.4.

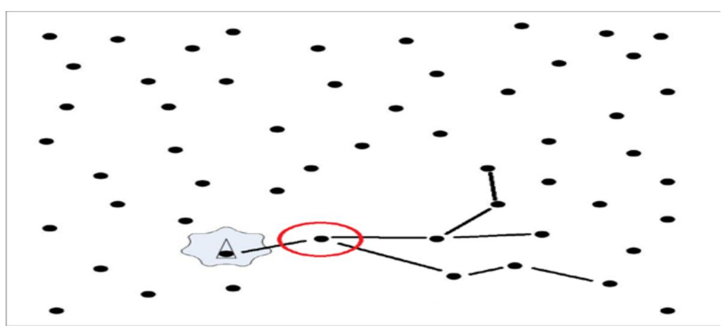

Figure 1.4: Demonstration of "Hotspot Problem"

In Figure 1.4, it can be seen that the sensor node A in the circle is noted as heavily loaded node. According to the data transmission paths, which are denoted as lines in the Figure 1.4, sensor A is responsible to forward data from other sensors and therefore the energy dissipation is concentrate on that particular sensor.

1.4.2. Redundant data transmission

The hierarchical based protocol such as PEGASIS may have few limitations as follows:

- There is no consideration about the energy of nodes and the location of sink during selection of head node.
- Bottleneck may occur due to single head node.
- Some delay may occur during chain formation due to implementation of greedy algorithm [2-3].

These limitations may cause the redundant transmission along the reverse flow from the sink when sensor nodes collect the data and deliver them to the head node in the chain as shown in Figure 1.5.

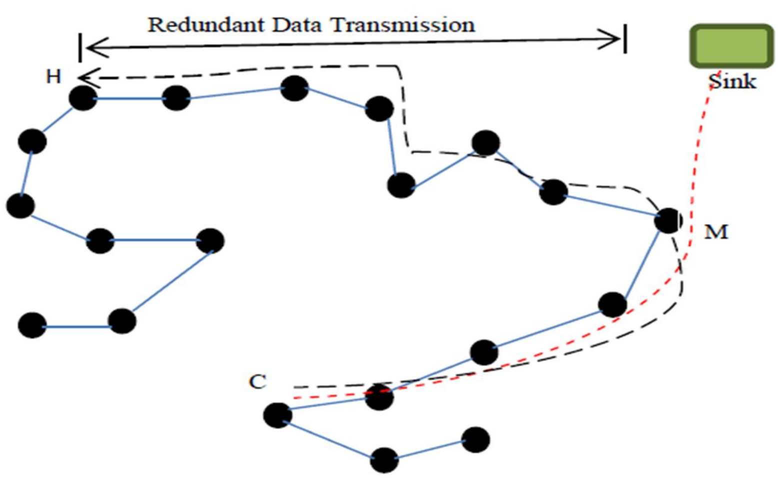

Figure 1.5: Redundant data transmission in chain based protocol

In the Figure 1.5, node H is considered as head node which will pass the token to all sensor nodes in order to collect sensing data. Each node located in the chain aggregates the data and sends it to its neighbor node. Node C does the same and delivers the data along the chain from own to node H. However, the optimized path for the data transmission from C to the sink should pass through node M. Hence, it is required to modify the greedy algorithm in order to reduce the redundant data transmission and to minimize the data delivery delay.

1.5. Motivation

In WSN, energy expenditure of a sensor node is due to either “serviceable” or “unserviceable” operations. The serviceable operations include receiving or transmitting data messages and handling requests. The unserviceable expenditure is due to the process of improvisation routing path, overhearing, retransmitting because of coarse environment, idle listening and dealing with redundant broadcast overhead messages.

Wireless sensor networks are battery operated. The sensor nodes of Wireless Sensor Network have limited source of energy when it is deployed in real time environment. The entire network rely on this energy to detect an event, collect information from environment, data aggregation and communicate with base station or sink to deliver the collected information.

The main challenges are how to maximize the network lifetime using minimum energy resource. Research has shown that hotspot problem leads to a premature disconnection of the network. In recent approaches, to reduce energy consumption, researchers focus on shifting the burden from the sensors to the sink node. In contrast to a traditional WSN model where the sink nodes remain stationary somewhere in the network and passively receive data from the sensor nodes and in Mobile Sink WSN (MSWSN) the sink node is mobile and traverse the network field actively to look for the sensors which are sending data and move closer to them. The issues of maximum network lifetime with a sink mobility approach include how to control the movement of the sink to achieve most efficient data gathering both to guarantee the quality of service and to reduce energy consumption. For example,

Depending on the system requirements, mobility approaches can decide

i) When to move the sink to respond to any event or change in the network.

ii) The actual position of a sink node and the routing paths to the sink.

iii) The trajectory of the mobile sink.

The idea behind this sink mobility is to shift the burden of data processing and energy consumption from the sensors to the sink node in order to extend the network lifetime as sink nodes are generally much more fertile in computational power and energy supply. Transmission range is an important parameter to determine energy consumption in data communication. Active movements of sink nodes closer to active sensors result in reduced transmission distances and fewer intermediate nodes to relay data. Therefore, the energy consumption tends to be more evenly distributed in the network and the "Hotspot" problem is alleviated and the performance of network can be improved in terms of lifetime better coverage and quick response time.

In this thesis, the multi-chain concept and P-CL scheme is used which aims to balance the network overhead due to less number of nodes comparatively in chains. It also minimizes data delivery delay in order to improve the network performance.

Sink mobility in the network is also implemented to solve the Hotspot problem encountered in the static sink network. Therefore, an optimized mobile sink strategy is used which helps to reduce energy conservation and prolongs network life time.

1.6. Objective

This thesis describes a Multi-chain based Hybrid Routing Protocol (MHRP) which adopts a joint strategy of multi-chain concept and pre-chain leader (P-CL) selection procedure in order to realize the increased node lifetime in wireless sensor networks (WSN).

The multi-chain concept aims to balance the network overhead due to less number of nodes comparatively in chains. It also minimizes data delivery delay in order to improve the network performance. The pre-chain leader modifies the greedy algorithm and aims to balance the workload of head node selected among the entire node by adopting another leader node in case when head node is far away from sink node.

An optimized mobile sink strategy is also introduced in the proposed hybrid routing protocol in order to get maximum coverage to every node in the sensory field and to alleviate the hotspot situation. The goal of the proposed hybrid approach is to evenly distribute the energy consumption among the sensors and further improve the network performance in terms of lifetime.

1.7. Thesis Structure

The rest of the thesis is organized as follows:

CHAPTER 2: This chapter gives a comparative study of different Chain based hierarchical routing protocol. The first order radio model and the need for improved routing protocol and its advantages are also discussed here.

CHAPTER 3: In this chapter an idea of necessity of mobility in WSN is explained. A survey of different types of mobility that occurs in WSN and existing mobility strategies are briefly discussed here.

CHAPTER 4: It describes about the proposed hybrid routing protocol named MHRP. Simulation of this protocol in MatLab is also described in this chapter.

CHAPTER 5: Implementation of the optimal trajectory of mobile sink in the proposed protocol is illustrated in this chapter. It also explains about the performance of different routing protocols on the basis of MatLab simulation.

CHAPTER 6: Finally, Chapter 6 draws the conclusion of the thesis and discusses the limitations and scopes of future work of the thesis.

CHAPTER - 2

Literature review

Key Topics

- ✓ First order radio model
- ✓ LEACH
- ✓ PEGASIS
- ✓ CCS
- ✓ DERP
- ✓ IEEPB

LITERATURE REVIEW

2.1. First order radio model

A sensor node is typically small in size and capabilities in terms of processing power, memory, communications and energy provisioning are limited. A sensor node typically consists of a sensing circuit, a digital signal processor, and a radio transceiver. The communication parts in a sensor are responsible for the majority of energy consumption [11]. To compute the energy dissipation in wireless transmission, this work uses radio energy dissipation model present in and as shown in Figure 2.1.

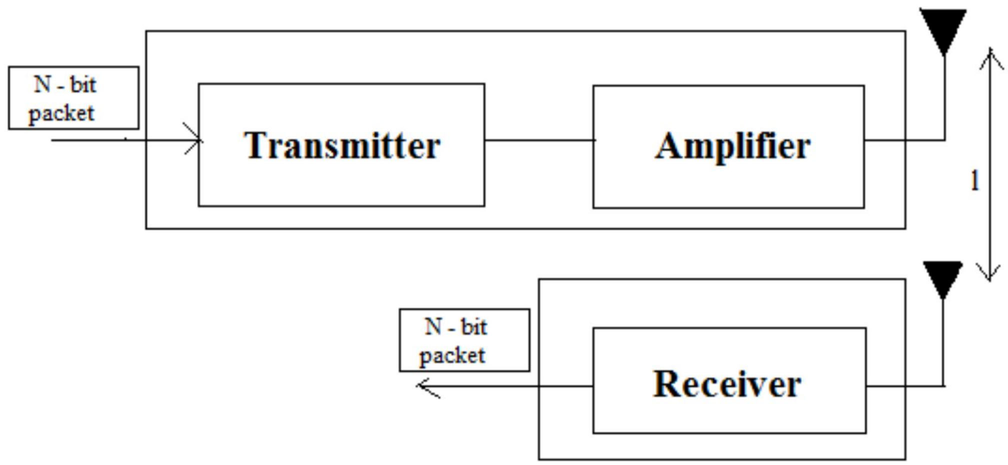

Figure 2.1: Radio energy dissipation model

In this model, energy is used by the transmitting/receiving circuitry and power amplifier.

Energy Dissipation at
Transmitter (E_{Tx}): 50nJ/bit
Receiver (E_{Rx}): 50nJ/bit
Amplifier (E_{amp}): 100pJ/bit/ m^2
Let, (E_{Tx} = E_{Rx} = E) and
Energy loss due to channel transmission: l^2
If we transmit N-bit message a distance l using this model, it gives:
To Transmit,

$$E_{Tx}(N, l) = E_{Tx}(N) + E_{amp}(N, l) \quad (1)$$

$$E_{Tx}(N, l) = E * N + E_{amp} * N * l^2$$

To Receive,

$$E_{Rx}(N) = E * N \quad (2)$$

2.2. Detailed study of Hierarchical based routing protocol

Hierarchical based routing protocol is more efficient because in this routing technique all the routing sensors in the network are clustered and a cluster head collects and aggregates the data and checks for redundancy of the data that is collected before it is sent to the sink [14]. Some of the routing protocols are described below:

2.2.1. LEACH

The current interest in wireless sensor networks has led to the emergence of many application oriented protocols of which LEACH is the most aspiring and widely used protocol [10,21]. LEACH can be described as a combination of a cluster-based architecture and multi-hop routing. The term cluster-based can be explained by the fact that sensors using the LEACH protocol functions are based on cluster heads and cluster members. Multi-hop routing is used for inter-cluster communication with cluster heads and base stations. Simulation results shown in [15] that multi-hop routing consumes less energy when compared to direct transmission. It has already been stated that wireless sensors sense the data, aggregate them and then send data to the base station from a remote area using the radio transmission scheme as communication medium.

Data which is collected by the sensors is sent to the base station. During this process a lot of problematic issues occur such as data collision and the data aggregation. LEACH is well suited to reduce the data aggregation issues using a local data fusion which performs a compression of the amount of data that is collected by the cluster head before it sends it to the base station. All sensors form a self-organized network by sharing the role of a cluster head at least once. Cluster head is majorly responsible for sending the data that is collected by the sensors to the base station. It tries to balance the energy dissipation within the network and enhances the network’s life time by improving the life time of the sensors [16]. The operations that are carried out in the LEACH protocol are divided into two stages: the setup phase and the steady-state phase.

Set-up Phase

In the set up phase, all the sensors within a network group themselves into some cluster regions by communicating with each other through short messages. At a point of time one sensor in the network acts as a cluster head and sends short messages within the network to all the other remaining sensors. The sensors choose to join those groups or regions that are formed by the cluster heads, depending upon the signal strength of the messages sent by the cluster heads. Sensors interested in joining a particular cluster head or region respond back to the cluster heads by sending a response signal indicating their acceptance to join. Thus the set-up phase completes [17]. The cluster head can decide the optimal number of cluster members it can handle or requires. Before it enters the steady-state phase, certain parameters are considered, such as the network topology and the relative costs of computation versus the communication. A TDMA Schedule is applied to all the members of the cluster group to send messages to the cluster head, and then to the cluster head towards the base station. Figure 2.2 below shows two phases of a sensor in a LEACH protocol. All the sensors form as cluster members to the cluster heads and in the second phase cluster heads perform the transmission of data to the sink in a multi-hop structure.

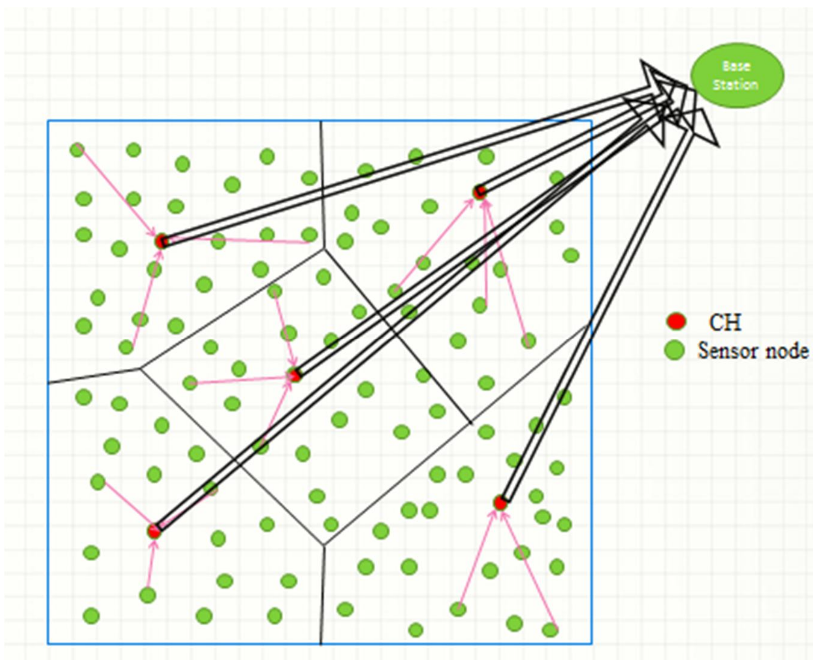

Figure 2.2: Data Transmission in LEACH

Steady State Phase

As soon as a cluster head is selected for a region, all the cluster members of that region send the collected or sensed data in their allotted TDMA slots to the cluster head. The cluster head transmits this collected data in a compressed format to the base station which completes the second phase, called the *Steady State Phase*. Once the steady-state finishes the data transmission to the sink, the whole process comes to an end and a new search for the forming of cluster heads for a region and new cluster-member formation begins. In short, it can be said that a new set-up phase and steady state starts with the end of data transmission done to the sink. This alternative selection of cluster heads within the region, which is carried among the sensors in a self-organized way helps in reducing or lowering the energy that is utilized.

There is a possibility that all the sensors might not be too close to the cluster head so the amount of energy that is utilized by the farther sensor is not equal to the amount of energy utilized by the nearest node. In order to minimize this, cluster heads formation or the role of luster head is performed by a rotation among all the nodes in the group. LEACH minimizes global energy usage by distributing the load of the network to all the nodes or cluster members at different intervals [21].

All the cluster heads send the data which is collected towards the base station in a compressed format. All the cluster heads may not be close to the base station so they send the compressed data to the neighboring cluster heads, and in this way, a multi-hop routing network is formed. LEACH plays a randomized rotation of the cluster head in order to save the high energy that is dissipated while transmitting data to the base station. This rotation is observed within all the sensors so as not to drain the energy or battery of a single sensor.

2.2.2. PEGASIS

PEGASIS stands for Power Efficient Gathering in Sensor Information Systems. Wireless sensor nodes sense data and send it directly to the base station or they perform a clustering procedure as in LEACH. LEACH is known for cluster formation which contains cluster members sensing the data and the cluster head which gathers the data collected in a fused manner (all the data is sent as a single packet) to the base station. This procedure has gained in conserving a lot of energy that would otherwise be wasted. PEGASIS is an extension to LEACH. It has better ways of conserving energy which last even more than using cluster mechanism in LEACH.

If we have nodes in the network which are at some distance from the base station, the easiest and the simplest way of transmitting the sensed data to the base station is to transmit it directly, which may lead to quicker depletion of energy in all the nodes. The nodes at a large distance away from the base station are depleted quicker than the nodes which are closer to the base station as they need some extra energy to reach the farthest base station. Another approach where energy is consumed in low amounts is by forming cluster heads and cluster members using the sensor nodes in the network. Cluster members perform the sensing and computing the data (Data Fusion) and the cluster heads transmit the fused data to the base station. All the nodes in the network take their chance to act as cluster heads to send the fused data to the base station; again the farthest cluster head needs some extra energy to send the data to the base station. The key idea in using PEGASIS is that it uses all the nodes to transmit or receive with its closest neighbor nodes. This is achieved by the formation of a chain as shown in the Figure 2.3 below. All the nodes which collect the data fuse it with the data received by the neighbor node and transmit it to the next-nearest neighbor.

In this way all the nodes receive and fuse their data, and pass it to the next neighbor in a chain format till they all reach the base station. Every node in the network takes turns as a leader of the chain and the one responsible to transmit the whole fused data collected by the chain of nodes to the base station.

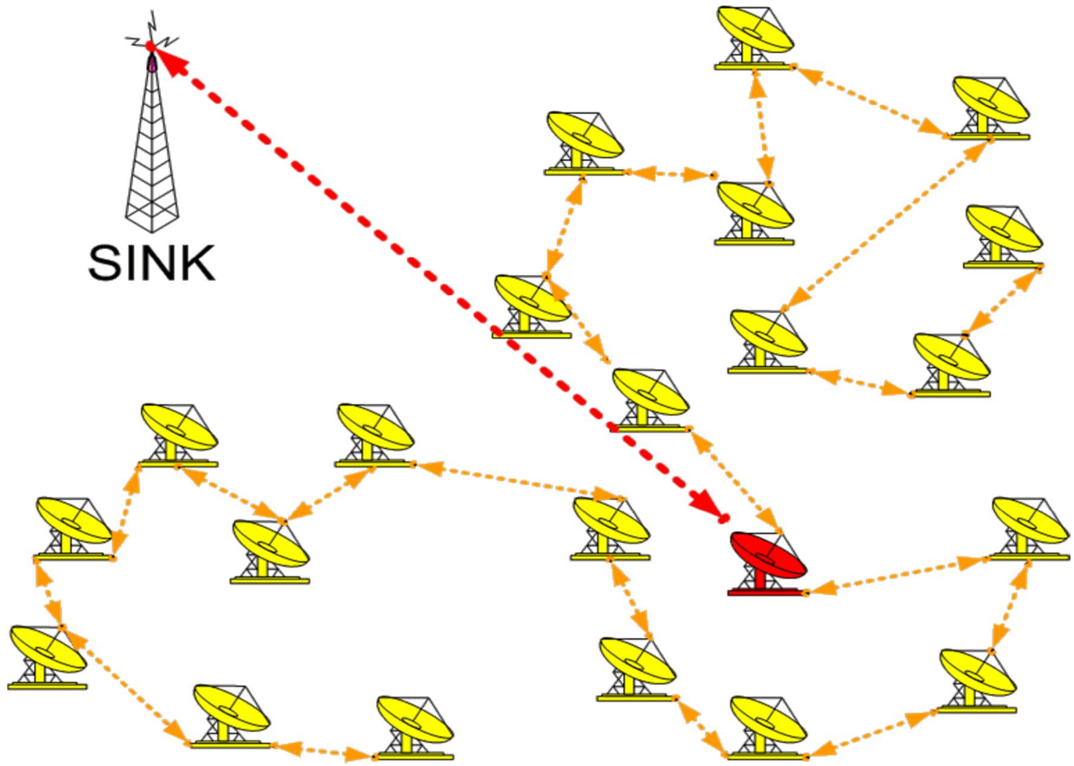

Figure 2.3: Formation of chain using nodes in PEGASIS

In this way the average amount of energy spent by each node is reduced. Greedy algorithms are used to see that all nodes are used during the chain formation. PEGASIS assumes that all the nodes with varying or low energy levels can be compensated in order to calculate the energy cost of the transmissions with the remaining energy they are left with [19]. It is not necessary that all the nodes need to know its neighboring nodes, the base station can determine the path or form the chain for all nodes, or all the nodes can determine their neighboring nodes by sending a signal. Depending upon the signal strength, the nodes adjust their signal such that they hear only the nearest neighbors in the network.

From Figure 2.4 below, the operation of PEGASIS is clearly understood. A greedy algorithm is applied to form a chain among all the best nodes that are at a one-hop distance from each other and to the base station. If the farthest node is selected, it starts transmitting the data. For example, if node 4 start the chain formation process and it sends the signal to the nodes in the network to find the nearest neighbor, node 3 is the nearest, so it transmits the sensed data. Upon receiving the data from node 4 node 3 starts finding the nearest neighbor by sending signals and when it finds that node 2 is the nearest, it fuses its own data with the data received from node 4 and transmits all this data to node 2. Node 2 finds node 1 as the nearest and transmits the sensed data with the fused data (the whole data is formatted a single packet). Now node 1 is the nearest node to the base station, so it acts as a leader and transmits all the data. Only the first node in the chain have nothing to fuse except the data it has during the chain formation, the remaining nodes all have some data to append with the received data from other nodes.

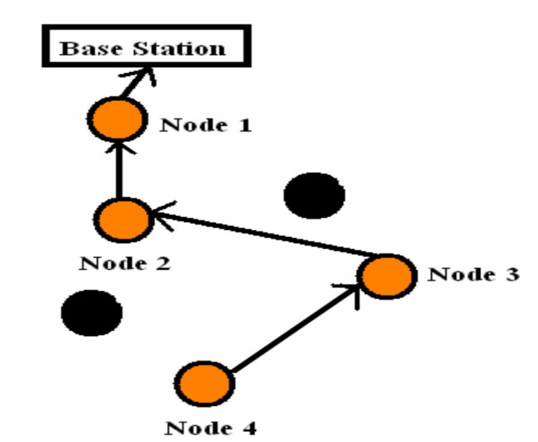

Figure 2.4: Flow of Data in PEGASIS forming Chain to reach BS

This approach will distribute the energy load evenly among the sensor nodes in the network as it uses all the nodes of the network to form the chain and perform simple data forwarding operations. If any node dies in the chain, a new chain is formed, eliminating the dead nodes. From the simulation reported in [9], it is clear that PEGASIS improves on LEACH by saving energy at different stages, such as for example cluster-member forming and cluster heads. Here all the nodes have an equal chance of becoming the leader once and transmit data to the base station in one round. An energy balance is estimated on the nodes in the network which conserves lot of energy. The amount of nodes that die during the chain process is reduced when compared to LEACH for all types of network sizes and topologies. The network lifetime is increased, as all the nodes actively participate and deplete the equal amount of energy on the whole.

A simulation analysis of PEGASIS is reported in [9], comparing it with the LEACH protocol using different network topologies. Many experimental results proved that PEGASIS is supporting longer network lifetime, more balanced energy dissipation and higher performance.

Problems with PEGASIS Protocol

The problems related to current PEGASIS protocol are as follows:

- Each sensor node in the wireless sensor network is required to have extra local information about the neighboring nodes.
- There is no energy consideration while selecting the head node.
- Selection of the head node does not depend on the location of the base station.

In thesis work, the greedy algorithm has been implemented in MatLab. The simulation result is shown below:

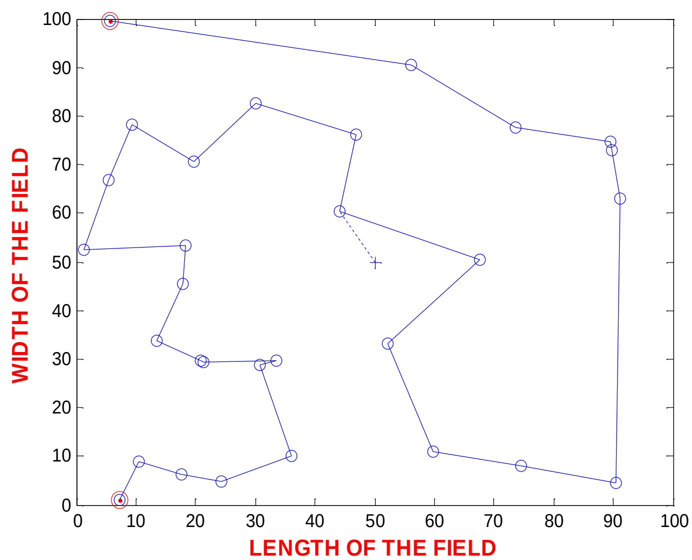

Figure 2.5: Illustration of Greedy algorithm

2.2.3. CCS

CCS stands for Concentric Clustering Scheme. Concentric Clustering means that the shape of a cluster is concentric circles when the sensor networks are divided into several clusters. This scheme is implemented in order to avoid the data transmission as well as excess energy consumption in the basic PEGASIS. The Concentric Clustering Scheme consists of four steps. These are:

Concentric circle level assignment

The concentric circles are formed around the base station using the strength of signal. Each concentric circle is assigned its own level. The number of concentric circles is depending on the different parameters such as the number of nodes, the sensor network density or the base station location. The concentric circle level assignment is shown in Figure 2.6.

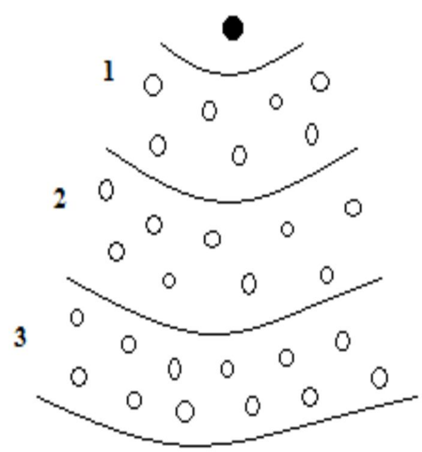

Figure 2.6: Concentric circle level assignment

Chain construction in each level

In each level area, the chain construction takes places between the nodes present in that particular area. Using greedy algorithm, the chain construction takes place from the farthest node to the base station. This process is same with the current PEGASIS protocol. The more the distance of the node from the base station, the high is its level. It can be seen in Figure 2.7.

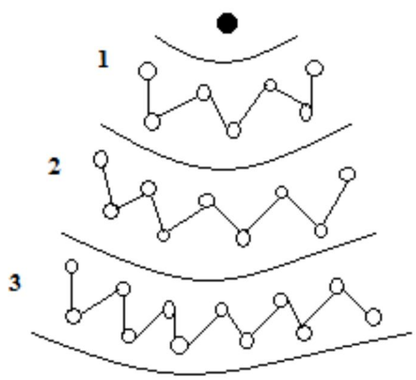

Figure 2.7: Chain construction in each level

Chain leader construction

At each level area, one of the nodes is selected as the chain leader. After the selection of the chain leader, each chain leader informs its own location information to the upper and lower level chain leaders in one grade. During the data transmission process, a chain leader is received the data from all nodes in the same level and the chain leader in the upper level. The collected data is then transmitted to the chain leader in lower level by one grade as shown in Figure 2.8.

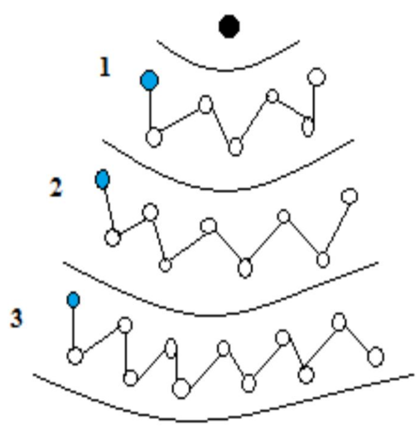

Figure 2.8: Chain leader construction

Data Transmission

The process of data transmission is based on the current PEGASIS protocol. All the nodes in each level receive the data along the chain from their nearest node. The node then fuses the received data and its own data before transmitting it to the next node. The chain leader receives the data from the node in same level and the chain leader in the upper level. Also, the chain leader in each level is responsible for transmitting the aggregated data to the chain leader of the lower level by one grade. Therefore, the lifetime of wireless sensor networks can be improved in the concentric clustering scheme by avoiding redundant data transmission.

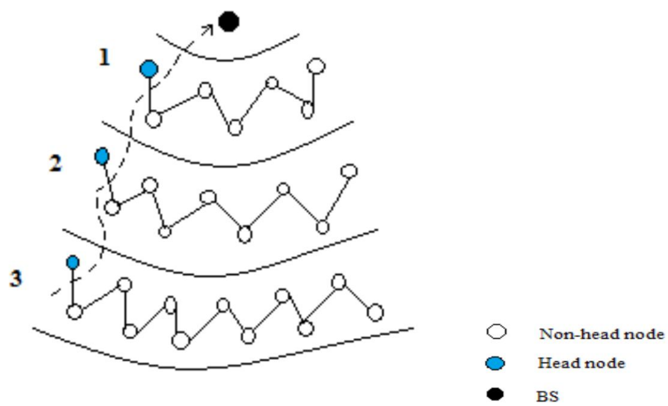

Figure 2.9: Data transmission

In sum, sensor nodes are divided into several levels like a concentric circle and the chain is constructed in each level. Next, the head node in each level is selected and performs routing to protect a redundant data transmission. This scheme may have two or more levels and head nodes. In addition, the size or number of levels may be dependent on various requirements of applications.

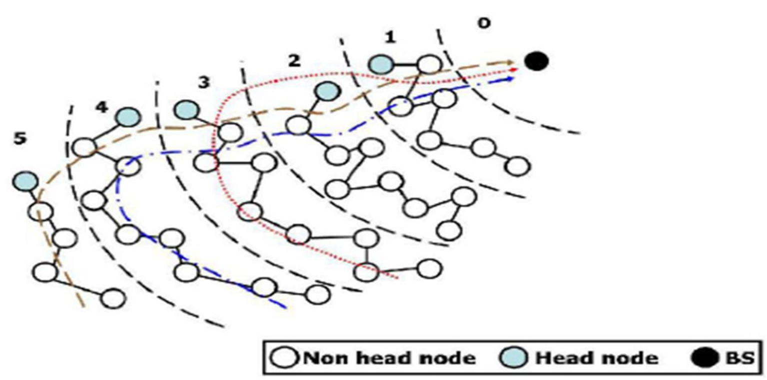

Figure 2.10: Data transmission in each level

Figure 2.10 shows us the data transmissions from the head node in 3, 4, and 5 level to the base station. In Figure 2.10, we divide the sensor network into five levels considering the location of the base station. All data flow is headed for the base station and it is clear that the concentric clustering scheme makes the sensor networks to avoid a redundant data transmission. Therefore, we can save the energy to transmit from each node to the base station and we can prolong the life time of the wireless sensor networks.

2.2.4. DERP

Distance based Energy efficient Routing Protocol (DERP) is a proposed protocol to overcome the problem faced by current PEGASIS protocol in transferring the data from the far away node which acts as a head to the sink. It improves the greedy algorithm by considering the distance between chain leader and the sink. DERP selects a pre-chain leader (P-CL) to distribute the even energy between sensor nodes. Apart from this, DERP extends to a multi-hop clustering protocol by using relay node depends on the distance between the P-CL and Sink. To address the problems of energy consumption, a novel chain based DERP protocol is introduced, which considers distance between chain leader and the sink. The energy efficiency can be improved by extending the single hop communication schemes in LEACH and PEGASIS to multi hop communication.

Assumptions made by DERP are:

- Sensor nodes are immobile and energy inhibited.
- Communication is direct between sensor node and sink.
- Single hop communication is used.
- Distance between sensor nodes is measured by received signal strength.
- The location of sink node is constant with infinite energy.

Chain Formation in single hop DERP:

The farthest node from the sink is selected and a chain is formed using the greedy algorithm. After the chain formation, sink broadcasts a message. The node which responds first is then selected as the P-CL node. Whenever any event occurs, the data is transmitted. The data is delivered from the source node to the sink via P-CL. When the data reached to the P-CL node, which is present in data delivery path, the transmission of data stopped. The received data on the P-CL node is then forwarded to the sink. The selection of the new P-CL node depends on the energy content of that particular node. Therefore, P-CL concept is adopted to evenly distribute energy among the sensor nodes.

Chain formations in multi hop DERP:

In a single hop communication, the energy consumption is only reduced when the two nodes are in close proximity to each other. The energy dissipation depends on the distance between two nodes. The multi hop communication takes place only when the distance between two nodes is greater than the addition of distance between two hops. If the single hop communication scheme is better than it is chosen over the multi hop scheme.

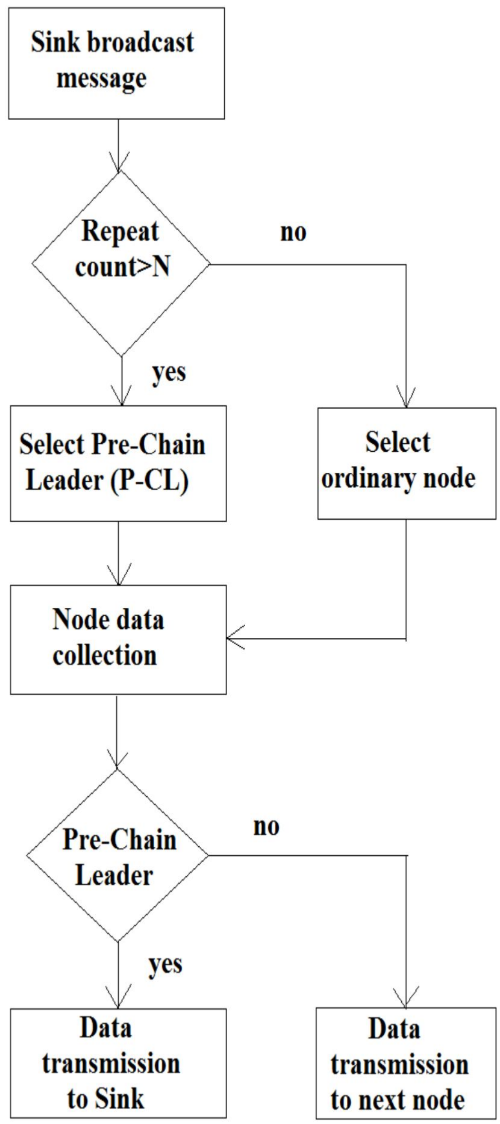

Figure 2.11: DERP Flowchart

2.2.4. IEEPB

IEEPB stands for Improved Energy Efficient PEGASIS Based routing protocol. EEPB overcomes some shortcomings over PEGASIS but has still some limitations as following: The chain formation in EEPB has uncertain and complex threshold adoption. EEPB ignores the appropriate proportion of sensor node energy and also the distance between base station and node during selection of leader node. Thus, IEEPB (Improved Energy Efficient PEGASIS Based routing protocol) resolves several issues over EEPB. It has mainly three steps to implement the round operation such as

Chain formation

It starts with initialization of the network parameters and after determining the node number, initial energy and the location information of base station. Base station sends a message to all nodes to know their information and position. Then, the farthest node is being assigned to start to form a chain with its neighbor. Each node gets the distance information between itself and neighbor nodes. It continues to form a chain till all nodes has connected.

Selection of head node

It selects the head node using weight method by considering both the distance between node to the base station and the residual energy of nodes. The steps involved are:

I. The distance parameter is estimated as (consider multipath model)

$D = D_{BS}^4 / D_{AVG}^4$ where,

D_{AVG} = average distance (node to base station).

II. D_{BS} = Estimated distance via received signal strength between (nodes to BS). The energy parameter is estimated as

$E_p = E_{in} / E_r$ where,

E_r = node residual energy.

E_{in} = Node initial energy.

III. The weight parameter is estimated as

$W = w_1 E_p + w_2 D$ where, w_1 and w_2 are the weight factors coefficient and must satisfy

$w_1 + w_2 = 1$

Now, comparison of the weights each node occur which lead to the selection of head node (i.e. node having minimum weight) of this round.

Communication phase

After implementing two phases which has been already discussed, the head node sends a token to start the transmission from the farthest node (end node). IEEPB contain many end nodes. Every node sends the sensing data to neighbor node in given time slot (TDMA mechanism). Then, data fusion occurs between the received data and its own data and the same process continues till one round finished. One round will finish until base station accept the data from the head node. The chain formation in IEEPB is shown in Figure 2.12. In MIEEPB [12-13], A multi-chain model is implemented to attain proficient energy utilization of sensor nodes. An algorithm is being proposed for trajectory of movable sink [13] where the sink moves along its trajectory and in order to achieve complete data gathering, the mobile sink stays at sojourn location for a sojourn time. As a result, it gives better performance in comparison to IEEPB [14] in terms of network lifetime.

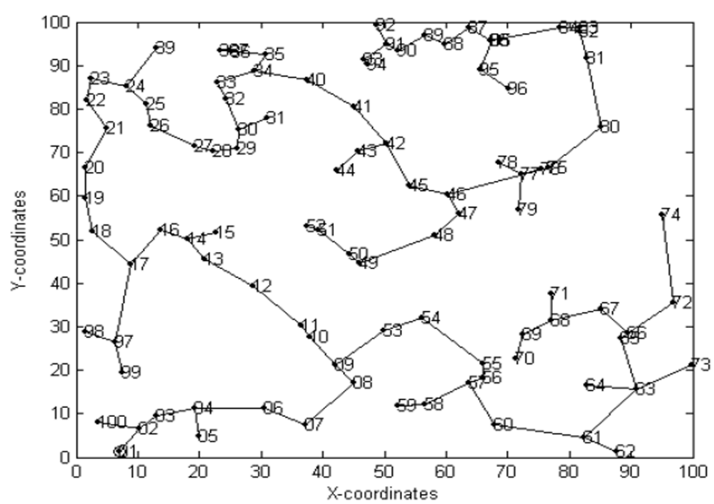

Figure 2.12: Chain formation in IEEPB

CHAPTER - 3

MOBILITY IN WSN

Key Topics

- ✓ Need of mobility
- ✓ Mobility Model
- ✓ Node Mobility
- ✓ Event Mobility
- ✓ Sink Mobility

Mobility in WSn

3.1. Need of mobility in WSN

Sometimes, in a sparse WSN sensor nodes are far enough from each other. It is also true in WSN that energy consumption during communication is proportional to square root of distance between the sensor nodes. So, more energy is consumed when nodes are far away from the sink node. Multi-hop data propagation also consumes significant amounts of energy especially in the area near sink where the sensor nodes need to relay data from other nodes that are far away from sink node. Due to this uneven energy consumption, nodes near sink node deplete faster and die very soon. This is sometimes called the Hotspot problem. When a sensor node runs out of energy it will no longer provide sensing and data processing. Thus, it can lead to a huge loss in the network due to the routing path re-allocation and failure of sensing and reporting events in the environment. Hence energy conservation has been receiving increased attention in WSN research works. The concept of mobile sink has been recently introduced for WSNs in order to improve the overall performance of WSNs as it shifts the burden of energy consumption from the sensor nodes to sink nodes, which are typically considered to have unconstrained energy supply and larger computational power.

In Mobile Sink Wireless Sensor Network sensor nodes are statically deployed in the sensory field to sense the environment and the sink node traverse the network actively to look for the sensors which are ready to send data and move closer to them. There may be one or more mobile sinks in a sensor network. Mobile sink traverse randomly or predefined way to collect the sensor data. It may collect with one hop or multi-hop fashion. The general idea for this sink mobility approach is to shift the burden of data processing and energy consumption from the sensors to the sink in order to extend the network lifetime as sink nodes are generally much more fertile in computational power and energy supply. Since distance is the important parameter in determining energy consumption in data communication, active movements of sink nodes closer to the sensors result in reduced transmission distances, and fewer intermediate nodes to relay data. Therefore, the energy consumption tends to be more evenly distributed in the network and the “Hotspot” problem is alleviated so that the performance of network can be improved in terms of lifetime and quality of service.

Mobility allows better load balance energy consumption among the node in sparse WSN, enhance sensing coverage and network lifetime elongation. Implementing mobility better routes for packet delivery from sensor node to sink can be found as well as data reliability can be enhanced if sensor nodes move closer to the events. Mobile WSNs need

- Advanced topology management capabilities i.e. the ability to specify simultaneously the speed and direction of each individual node.
- The ability to track and localize nodes.
- A reliable source of energy to avoid unnecessary pauses or abrupt stops.
- Speed of the mobile device etc.

However, despite the advantages that mobility offers to sensor networks, there is one critical constraint that cannot be avoided. Sensors are severely energy constrained and available energy has to be shared for sensing, data processing, transmission, etc. Since mobility also consumes energy, it is very likely that there is a limit on the overall movement distance capability of the sensors. And delay is an important factor to be considered. Mobility can only be implemented on delay tolerant applications.

There are three types of mobility in WSN.

I. Node Mobility

II. Event Mobility

II. Sink Mobility

3.2. Mobility Model

Several researches have approached the problem of deploying mobile node or nodes in WSNs in order to prolong the network lifetime and improve its performance. Consequently, some of the proposed models depend on using a single mobile node to collect information from static sensor nodes. On the other hand, there is another category of mobility models that use more than one mobile node in the network. Worth mentioning, the number of mobile nodes used in the models proposed in the second category ranges from two mobile nodes to a sensor network consisting of mobile sensor nodes that move in order to get the best possible coverage and connectivity for the area of deployment. Accordingly, mobility models for WSNs can be mainly classified into two categories Homogenous and Heterogeneous models.

The homogenous mobility models depend on having a group of mobile nodes that use the same mobility model to move within the network. However, the heterogeneous models are based on having a single mobile node that moves according to a specified mobility model within the network. Note that the above mentioned categories can be further classified into subcategories as can be seen in Figure 3.1.

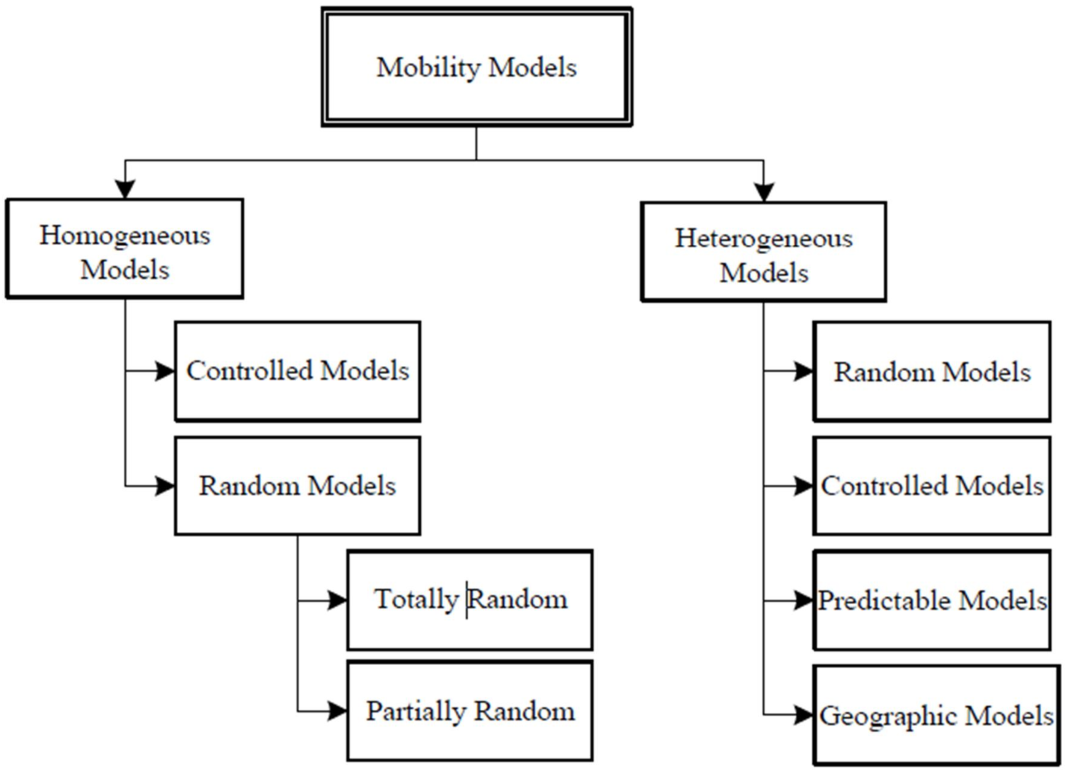

Figure 3.1: Mobility Models Classification

Homogenous Mobility Models

As mentioned before, homogenous mobility models are based on having a set of cooperating nodes moving according to a specific model in the deployment area. The number of mobile nodes varies from a subset of sensor nodes deployed in the WSN to having a WSN where all sensor nodes are mobile and moving according to a particular mobility model. From Figure 3.1, it can be observed that this category can be divided into two main sub categories namely random models and controlled models.

Heterogeneous Mobility Models

In heterogeneous mobility model, a mobile node moves independently of any other nodes that may exist in the network. Thus, the mobile node moves according to the adopted mobility model without taking the position and the mobility model adopted by other mobile nodes that may exist in the network into consideration. The models that fall under this category can be further classified into four subcategories namely random mobility, controlled mobility, predictable mobility and geographic mobility.

3.2.1. Node Mobility

The wireless sensor nodes can be mobile. The need for this type of mobility is highly application dependent. In the face of node mobility the network has to recognize itself frequently enough to be able to function correctly.

Coverage of wireless sensor networks (WSNs) is an important quality of service (QoS) metric. At initial deployment of the sensor nodes often the desired coverage is not attainable but node mobility can be used to improve the coverage by relocating sensor nodes. Coverage improvement based on node mobility depends on many parameters including number of deployed nodes (static and mobile), proportion of mobile nodes, permissible distance the mobile nodes can move and the total distance nodes moved to attain certain coverage.

3.2.2. Event Mobility

In applications like event detection and in particular in tracking applications, the cause of the events or the objects to be tracked can be mobile (these events extend or shrink). In such scenarios, it is (usually) important that the observed event is covered by a sufficient number of sensors at all time. Hence, sensors will wake up around the object, engaged in higher activity to observe the present object, and then go back to sleep. As the event source moves through the network, it is accompanied by an area of activity within the network this has been called the Frisbee model. Figure 3.2 shows the Frisbee model.

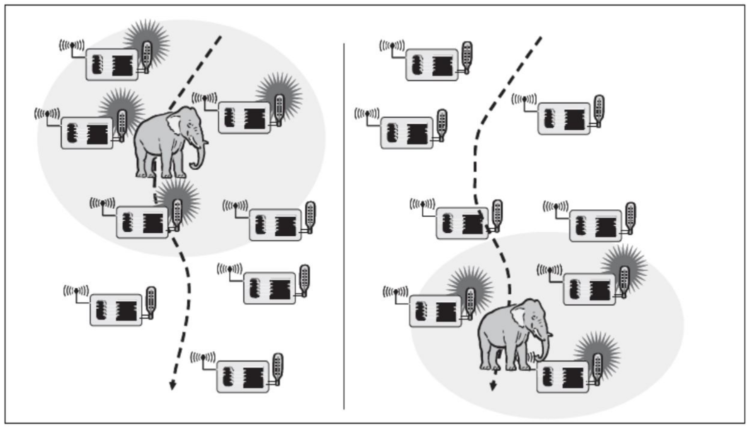

Figure 3.2: Example of Frisbee model [16]

3.2.3. Sink Mobility

Sink mobility can be a special case of node mobility. Using sink mobility instead of a static sink, for collecting the data overall network performance increases [17]. The Mobile Sinks traverse through the sensor field according to a controlled arbitrary mobility model in order to maintain a fully-connected network topology and collect data within their coverage.

There are 3 major parts involved in implementing Sink Mobility to Wireless Sensor Networks to improve the performance of network:

- Sink node movement,
- Data packets routing and
- Data gathering.

Sink Node Movement

The general idea for this sink mobility approach is to shift the burden of data processing and energy consumption from the sensors to the sink in order to extend the network lifetime as sink nodes are generally much more fertile in computational power and energy supply. However, how to traverse the whole network area is also an important issue as failure to visit some areas will potentially lead to data loss. Moreover, it is also necessary to use the energy in an efficient manner when moving the sink node. In this thesis a sink node movement algorithm is proposed to give better sink movement with maximum coverage in the network. In the proposed approach the sink node has location information about all the sensor nodes in the network. Other than the proposed algorithm there are so many existing sink mobility approaches, some of them are [13]:

I. Random Walk and Passive Data Collection.
II. Partial Random Walk with Limited Multi-hop data Propagation.
III. Biased Random Walk with Passive Data Collection.
IV. Deterministic Walk with Multi-hop data Propagation

Data Packets Routing

As mentioned in the previous sections, energy efficiency is a crucial topic in designing WSNs. Researches shown that large amount of energy consumed during data transmission from sensor-to-sensor and sensor-to-sink. Therefore an efficient transmission path will improve the energy utilization in the system and save more energy. In [13] multi-chain Power-Efficient Gathering in Sensor Information Systems (PEGASIS) using sink mobility maximizes the network lifetime.

Data gathering

One important issue in implementing mobile sink nodes in Wireless Sensor Networks is how the sink gathers data from static sensor nodes while sink node is moving. As the sink is moving the location of the sink changes, therefore sensor nodes can only send the data packages to the sink when sink is in their range. Therefore traditional data gathering and routing schemes are not suitable in this case. In [22] authors present an analytical model to understand the key performance metrics such as data transfer, latency to the destination, and power. Figure 3.3 describes the data gathering scenario.

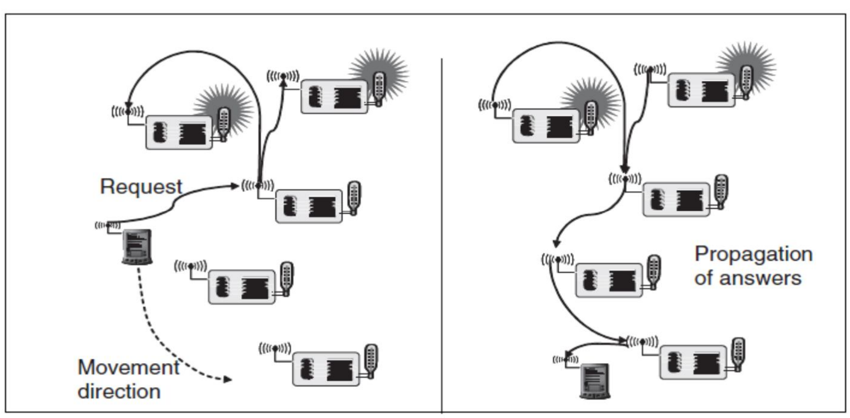

Figure 3.3: Mobile sink moves through a sensor network as information is being retrieved on its behalf.

Sink mobility can be classified into two categories according to the moving strategy used:

I. Uncontrolled (random) and

II. Controlled [18].

Uncontrolled Mobility in WSNs

Uncontrolled mobility is the scheme used when mobility in wireless networks has been introduced to WSN domain [18]. In this type of mobility, a third tier is used in the network (as seen in Fig. 3.4 - redrawn from [22]) in which mobile agents (MULEs - Mobile Ubiquitous LAN Extensions) are deployed between access points (base stations) and sensor nodes in order to collect data from sensor nodes when in close range, buffer them and finally transmit them to the sink [22]. It is called as uncontrolled, since movement is random and MULEs (for instance vehicles) move according to their needs and only exchange data if they encounter any node as a result of their movement [15].

The main motivation behind MULEs is to reduce energy cost for data transmission by using single-hop communication (from node to MULE or MULE to sink) instead of the more expensive multihop routing. Since communication cost is the most energy consuming part in network operations, this approach effectively increases network lifetime. However, since the arriving time of any MULE (either to a node or to the sink) is not known a priori, this causes two important problems: large size of buffers that nodes should have and large data latency. Sensor nodes should have large buffers in order to save all packets generated between two consecutive visits of the MULE. It is also unpredictable when a MULE comes close to the sink node and transmits packets to it.

This can cause a huge delay between the time that data is generated and received by the sink. It is obvious that there is a trade-off between latency and energy consumption. If our application is delay tolerant, then uncontrolled sink mobility becomes a good option. Packet loss risk should also be evaluated if nodes do not have large enough buffers that can save all the packets generated between two consecutive visits of a MULE.

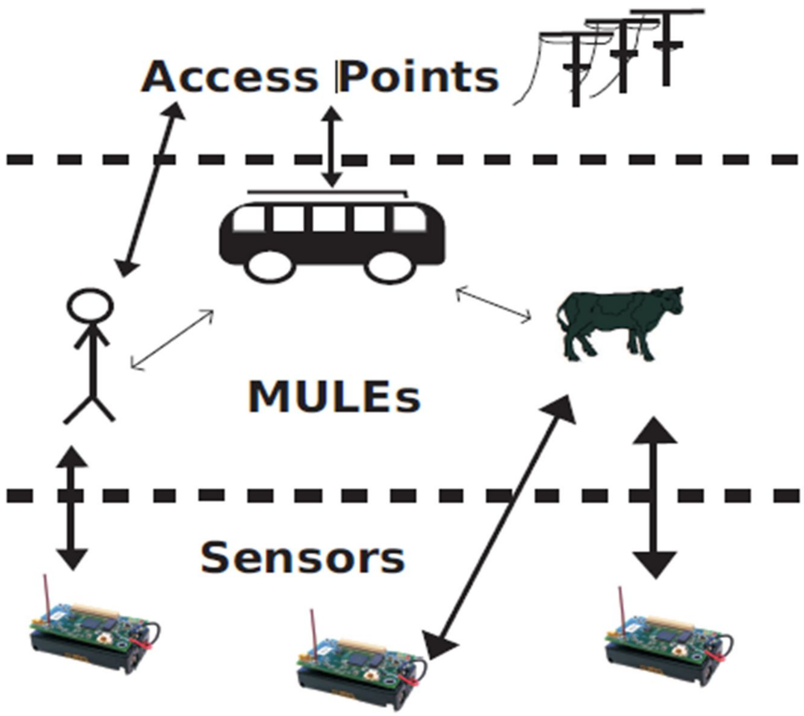

Figure 3.4: Mules with three-tier architecture [22]

Controlled Mobility in WSNs

Contrary to its counterpart, in controlled mobility, movements are done depending on the conditions of the network (like current energy map, node density in the regions, etc.) Currently, there are three main approaches used in controlled mobility. In first and mostly used one, the sink moves among the nodes and collects data without any additional entity (which is also the case in this thesis). In the second approach, mobile relays are used as forwarding agents - like MULEs, but in a controlled manner in this case - for the communication between sensor nodes and the base station. In the third approach, sensor nodes themselves are mobile [26]. Generally, sink node or relay nodes are assumed to have more powerful energy resources such that their energies are not being depleted during the network lifetime. Therefore it is expected that mobility of these types of nodes does not adversely affect the network lifetime. However, for sensor nodes this is not the case. As it was mentioned before, sensor nodes have very limited energy batteries, which cannot be wasted for mobility, topology reconstruction etc. unless it is certainly necessary. That is why; the first two approaches appear to be the more promising for energy efficiency and longer network lifetime [3]. Controlled and uncontrolled mobility in WSN domain is compared against each other using some performance measures in [4]. As discussed above, uncontrolled mobility has higher data latency but lower energy consumption than that of controlled one. When network traffic is low, deployment area is small, buffer size is large enough and MULE speed is quite fast, there is no packet loss in both approaches. However, as the deployment area grows and/or MULE becomes slower (inter-arrival time at the same cell increases), overflows occur in sensor node's buffers and packet delivery ratio decreases as a result. Moreover, since movements are done in random manner in uncontrolled mobility, computational cost is lower than that of controlled one. As a result, both mobility schemes have pros and cons. Basic comparison is summarized in Table II from [4]. Choosing the appropriate scheme completely depends on the application that we have. If we can tolerate data latency and some possible packet losses and/or we have relatively small deployment area and MULEs travel faster in that area, than it will be important to use data MULEs for communication in order to effectively reduce the energy consumption. However, if we have a critical application (which is the case in our work) that is intolerant to any latency or packet loss, like earthquakes, fire detection, or battlefield surveillance, then controlled mobility (via either relays or sink) become crucial. In this thesis, we focus on controlled mobility and we propose algorithms for controlled sink mobility case, mobile relays are out of the scope of this work.

	Controlled	**Uncontrolled**
Data latency	Low	High
Energy Consumption	Medium	Low
Computational Needs	Medium	Low

Table II: General comparison between controlled and uncontrolled mobility

CHAPTER - 4

Multi-chain based hybrid routing protocol

Key Topics

- ✓ Multi-chain Concept
- ✓ P-CL Scheme
- ✓ Data Transmission
- ✓ Simulation Results
- ✓ Conclusion

We propose a Multi-chain based Hybrid Routing Protocol (MHRP) which adopts both multi-chain and P-CL selection concept. It is an improved version of PEGASIS which is highly efficient in order to reduce energy expenditure and also solely responsible for WSN node lifetime enhancement.

4.1. Chain Formation in proposed protocol

The entire monitoring area is divided into four consecutive regions on the basis of its coordinates. Each region contains equal number of nodes which form a separate chain. Since, 100 nodes are being considered in the entire area, each region contain 25-25 nodes. Chain formation occurs in the same way as of PEGASIS. It uses greedy algorithm to form the chain. In process to form a chain, each node can communicate (transmission & reception) only with the closest neighbor. Each node will take data fusion in order and ultimately a designated node (Cluster head) sends the data to the base station. Each Node take turn transmitting to the base station so that the average energy consumed by each node per round is reduced. The same process of chain construction is applied in all four regions is shown in Figure 4.1. The chain formation process will be discussed in detail in further section.

4.2. P-CL Selection and Data transmission

It mainly considers the distance between chain leader and sink. After the chain formation, sink broadcasts a message. The node which responds first is then selected as the P-CL node. Whenever any event occurs, the data is transmitted. The data is delivered from the source node to the sink via P-CL. When the data reached to the P-CL node, which is present in data delivery path, the transmission of data stopped. The received data on the P-CL node is then forwarded to the sink. The selection of the new P-CL node depends on the energy content of that particular node. Therefore, P-CL concept is adopted to evenly distribute energy among the sensor nodes.

The key idea of this MHRP protocol is to imbibe the properties of multi-chain formation as well as P-CL selection concept in order to enhance the efficiency of WSN in terms of lifetime and delay.

4.3. Simulation Results

We have performed simulation in order to evaluate the proposed algorithm. We used MatLab as simulator to evaluate the performance of PEGASIS and MHRP using several random 100-node networks. The sink is located at (50,300) in a 100m X 100m field. The system parameter value is shown in Table III below.

Parameter	Value
Network size	100 x 100 m^2
Number of nodes	100
Base station	(50,300)
Initial energy of node	1 J
E_{elec}	50 nj /bit
E_{fs}	100 pj /bit/m^2
E_{mp}	0.0013 pj /bit/m^4
Data packet	3000 bits

Table III: System parameters value

In this thesis work, these following implementations have been done in order to get the multichain formation. In this scenario, 100 nodes are deployed firstly in the entire area using uniform random distribution. The sink location is at (50,50). The implementation is shown below in Figure 4.1.

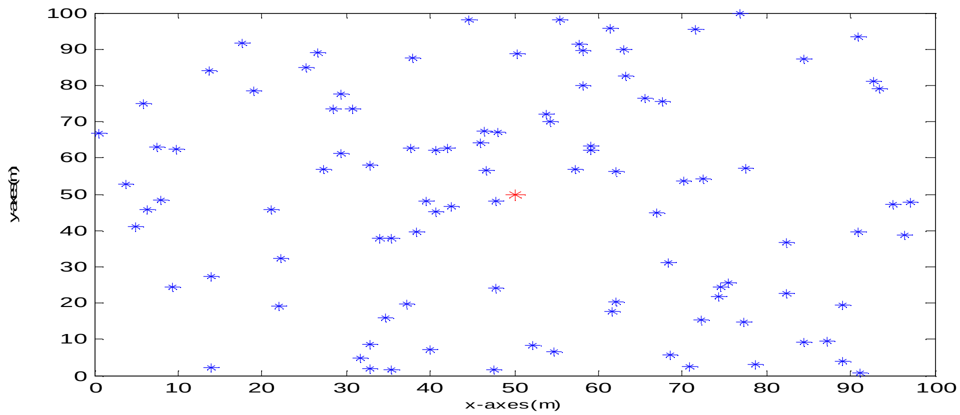

Figure 4.1.: Randomly node distribution

Since the proposed hybrid protocol is solely based on the PEGASIS protocol. The implementation of the PEGASIS protocol is done to ensure the further work ahead as shown in Figure 4.2. The PEGASIS protocol performs the chain construction using greedy algorithm which has already been discussed in detail in literature review.

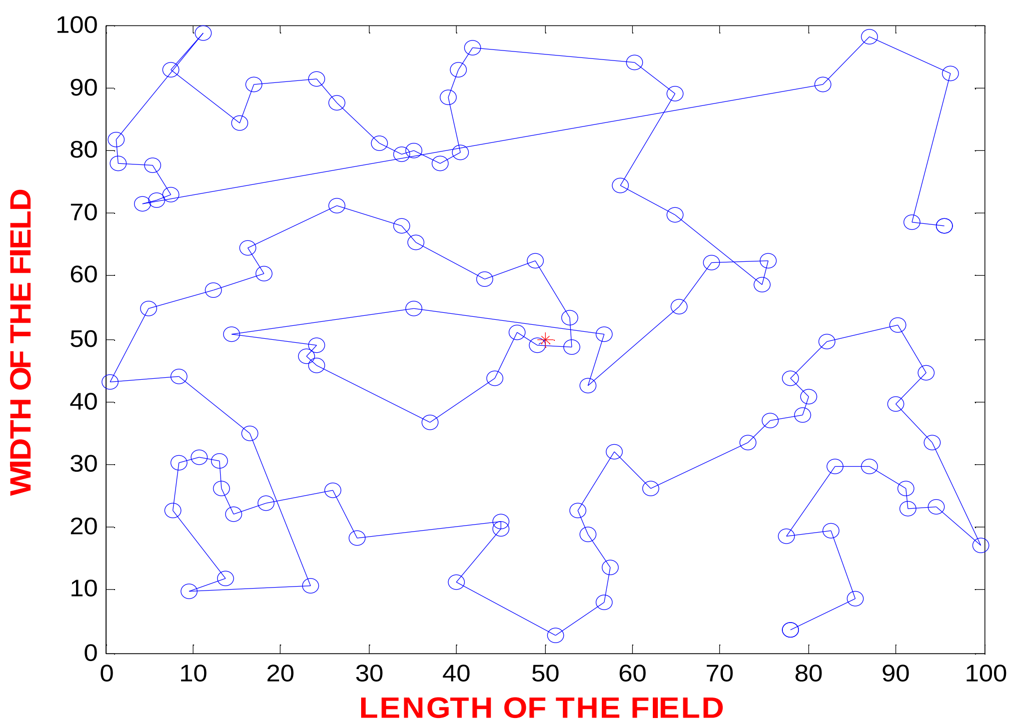

Figure 4.2: Chain formation in PEGASIS

On the basis of coordinates, the entire monitoring area is divided into four consecutive regions so that each region contains equal number of nodes which form a separate chain. Hence, 100 nodes are equally divided in 25-25 nodes. Again, the sink location is at (50,50). The implementation of this scenario in MatLab is shown in Figure 4.3.

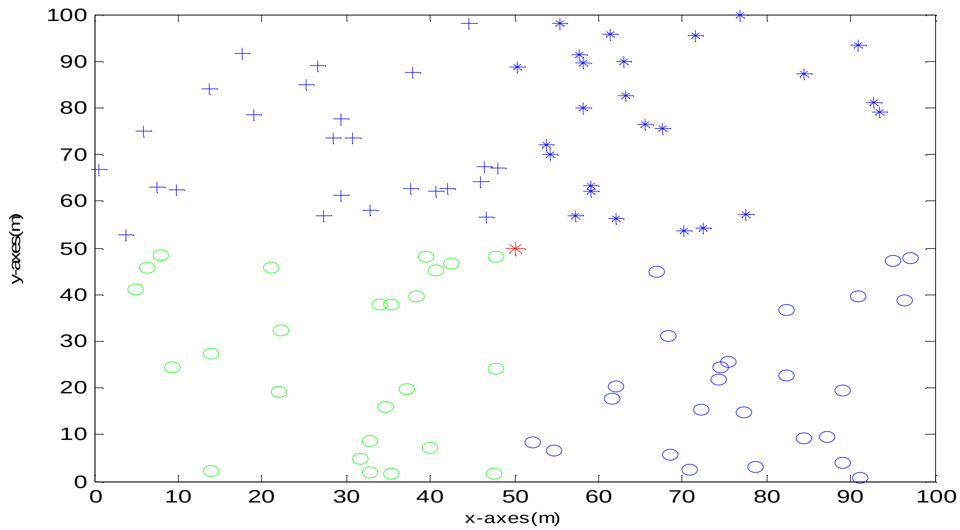

Figure 4.3: Area wise node distribution

The multiple chain formation is being implemented by using the system parameter value (Table 4.1) as shown below in Figure 4.4. In order to get the clarity in the simulation result, the less number of nodes (40 nodes) is being considered where 10-10 nodes are distributed in each equally spaced region. The sink location is at (50,50).

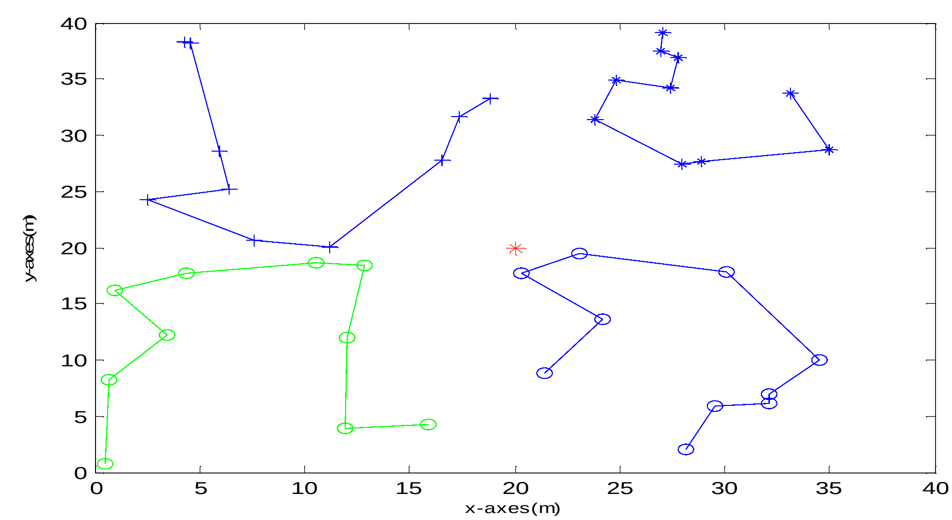

Figure 4.4: Multiple chain formation using area wise distributed node (40 nodes)

Finally, the multichain formation is implemented by using 100 nodes in MatLab as shown in below Figure 4.5. The sink location is being considered at (50,300). Each region contains 25-25 nodes and form separate chain. The Pre-Chain Leader scheme is also implemented in order to improve the deficiencies of greedy algorithm.

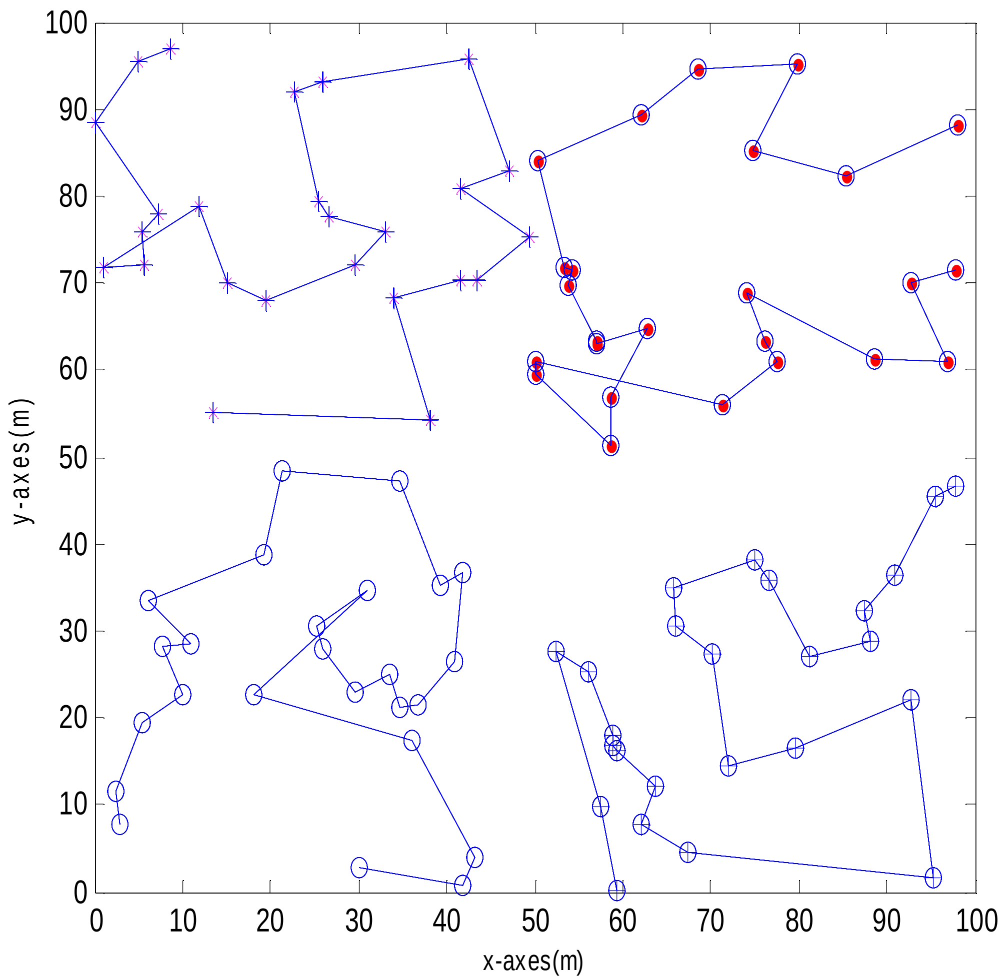

Figure 4.5: Multi-chain formation using greedy algorithm

We have performed simulation in order to evaluate the proposed algorithm. We used MatLab as simulator to evaluate the performance of PEGASIS and MHRP using several random 100-node networks. The sink is located at (50,300) in a 100m X 100m field. The Simulation which shown in Figure 4.6 focuses on energy efficiency and number of sensor nodes alive which are important indicators to measure performance of different protocols.

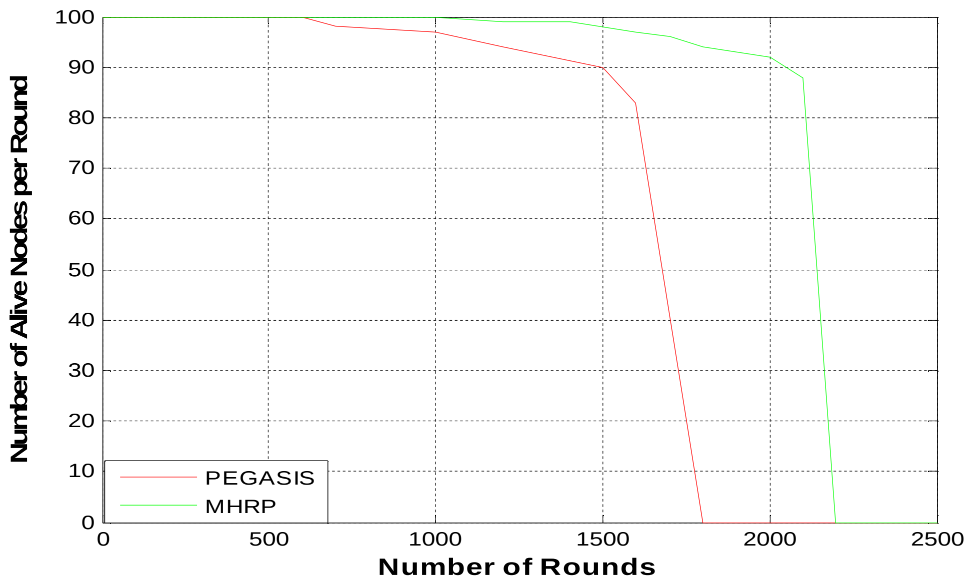

Figure 4.6: Number of nodes alive vs. Round numbers

Figure 4.6. shows the total number of nodes alive vary with the change of rounds, it can be seen that the number of nodes alive in MHRP is larger than the one in PEGASIS after each round ends, which demonstrates MHRP makes the energy consumption more balanced and the energy use more efficient.

MHRP effectively prolong the network lifetime compared with PEGASIS.

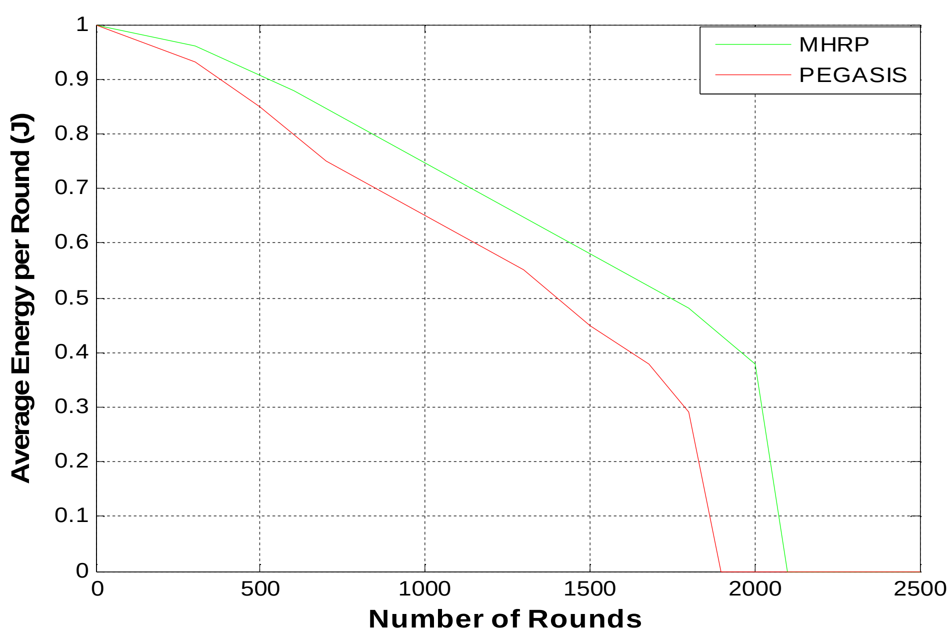

Figure 4.7: The average energy per round over Round numbers

As shown in Figure 4.7, the average remaining energy of all nodes per round in MHRP is higher than PEGASIS and the advantage is more obvious as the rounds increase. This proves that the energy efficiency of MHRP is better than PEGASIS. The PEGASIS and MHRP have been compared according to their performances and is shown in the Table IV.

Routing Protocol	**Classification**	**Scalability**	**Energy Efficiency**	**Network lifetime**
PEGASIS	Chain Based	Good	High	Good
MHRP	Chain Based	Very good	Very high	Very good

Table IV: Performance comparison of PEGASIS and MHRP

4.4. Conclusion

In this thesis work, a Multi-chain based Hybrid Routing Protocol (MHRP) is proposed in order to improve the deficiencies of PEGASIS. It adopts a joint strategy of multi-chain concept and pre-chain leader (P-CL) selection procedure to realize the increased node lifetime in wireless sensor networks (WSN). The multi-chain concept aims to balance the network overhead due to less number of nodes comparatively in chains. The pre-chain leader modifies the greedy algorithm and aims to balance the workload of head node selected among the entire node by adopting another leader node in case when head node is far away from sink node. Using this hybrid protocol, we can minimize the data delivery delay and balance the data flow to the wireless sensor networks. Hence, it provides a way to avoid the redundant data transmission and save the energy about 30% in compare with the PEGASIS protocol. Simulation analysis shows that we achieve better overall performance of the network by using these two concepts in our hybrid protocol and can be used to attain delay-intolerant applications.

CHAPTER - 5

Mobile Sink baSed mhrp

Key Topics

- ✓ Sink Mobility Scheme
- ✓ Simulation Results
- ✓ Conclusion

Mobile sink based MHRP

Our goal with this thesis is to use mobile sink instead of static sink in the proposed protocol MHRP in order to improve the network lifetime. Since we consider that sink has unlimited amount of energy. Hence, it is the best solution to make it mobile in order to balance the energy consumption of sensor nodes and maximize the network lifetime. These are various sink mobility strategies are already being implemented in wireless sensor networks.

5.1. Sink mobility scheme

We consider a wireless sensor network that has N static sensor nodes and a mobile sink. Sensor nodes are deployed to the region of interest in a random manner. After the mobile sink moves to its initial location, it broadcasts messages in order to construct a routing topology in the entire monitoring area. Base station knows the exact location of the sensor nodes using an available technology like GPS or GPS-less [19] localization algorithms. Each packet during transmission will be received by the sink which implies there is no packet loss in the network (perfect MAC layer). Each sensor node has enough buffer size in order to avoid losing packets during the traveling time of the sink from the current site to the next one (or this time is negligible).

In typical sensor network applications (like forest fire detection), hundreds or even thousands of sensor nodes can be deployed to the region of interest. This area can be very large such that it should be very difficult to consider each node point in the area as a candidate sink site (point within the deployment area the sink can visit), since this will dramatically increase the time to decide whether to stay at the current point or move to another point in the area (and where to move if it does not stay).

In this thesis, the proposed routing protocol MHRP has been improved by using optimal trajectory of sink with the minimum energy consumption which has already been analyzed theoretically and derived in [26]. The theorem used to carry out the sink mobile strategy is as follows:

Theorem: Suppose that the monitoring area Q is a square with center O and side-length L, when sink node moves along the square with center O and side length $2L / 2$, energy consumption of network is minimal.

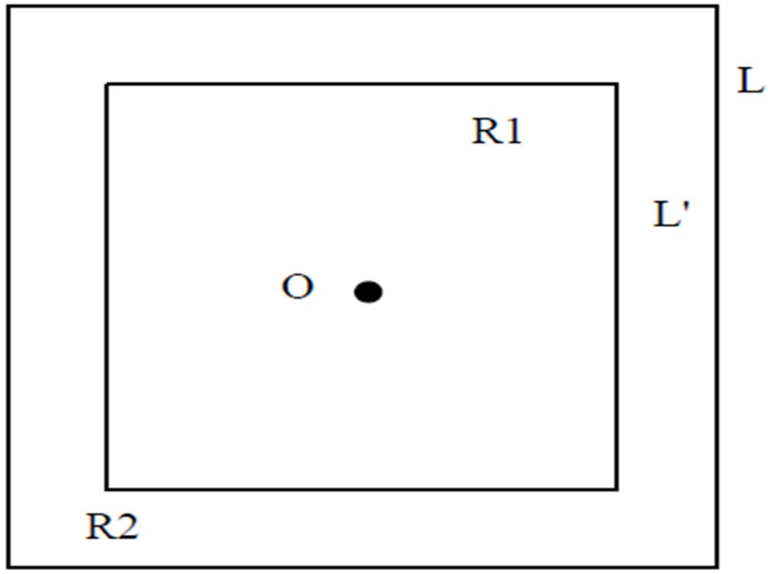

Figure 5.1: The optimal trajectory of sink

Proof: Let's divide the monitoring area Q into R1 and R2 as shown in Figure 5.1. The areas of R1 and R2 are respectively

$$S_{R1} = L'^2 , S_{R2} = L^2 - L'^2 .$$

Furthermore, as nodes in monitoring area distribute uniformly with density L, the nodes number of R1 and R2 are respectively $S_{R1} \times \rho$ and $S_{R2} \times \rho$.

The average transmission overhead of unit data is ε , when the total energy consumption of all nodes in R1 is equal to R2's, the data transmission overhead is minimal.

Here,

$$S_{R1} \times \rho \times \varepsilon = S_{R2} \times \rho \times \varepsilon,$$

It can be simplified as

$$L'^2 = L^2 - L'^2 ,$$

we get

$$L' = \sqrt{2}L/2 .$$

Theorem 1 shows that when sink node moves along a square trajectory with side-length $\sqrt{2}L/2$ in monitoring area, the network energy consumption is minimal.

5.2. Simulation Results

Now, we compare network lifetime of mobile sink based MHRP with MHRP in homogeneous network. We carry out simulations for 5000 rounds. Figure 5.1 represents the number of alive sensor nodes during the network duration. Comparison shows that network lifetime and stability period of mobile sink based MHRP is better than that of MHRP which are approximately 4300 rounds and 3000 rounds respectively. It is because; in mobile sink based MHRP, chain leaders die more slowly due to sink mobility. Unlike MHRP, mobile sink based MHRP has longer instability period which is around 2200 rounds as shown in Figure 5.2. The time duration between the death instants of the first alive node and last alive node in the network is considered as instability period. In our proposed scenario, instability time is better than of MHRP because energy distribution is done efficiently. Resourceful utilization of energy becomes possible due to modification of chain in every round.

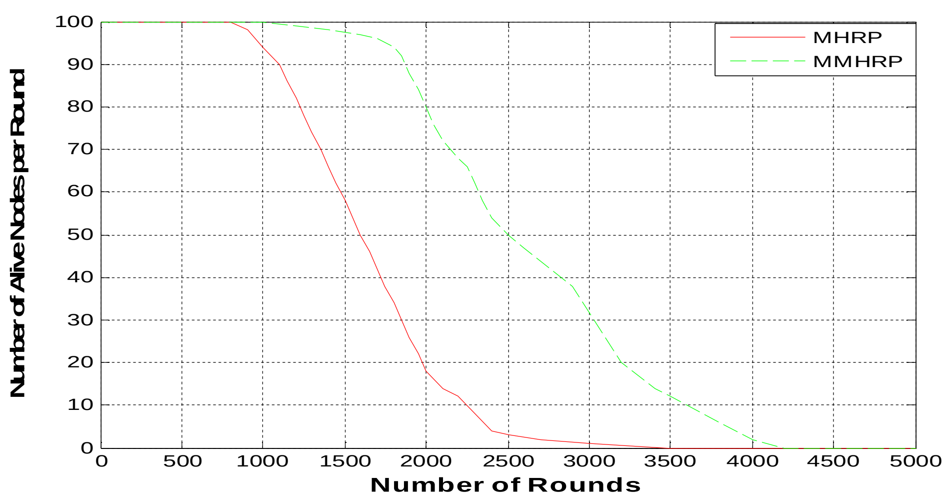

Figure 5.2: Number of alive nodes per round vs round numbers

In mobile sink based MHRP, first node dies at about 1300 round which is far better than the stability period of MHRP. Furthermore, the lifetime of first few nodes is much improved than of the afore-mentioned techniques due to reduction of load on the chain leader, thus causing global load balancing in the network. In multi-chain concept, distances between the connected nodes are less than single chain. Therefore, energy consumed in data transmission is less than the single chain. Residual energy of network in mobile based MHRP decreases more slowly than in MHRP. In mobile based MHRP, network lifetime is 49% better than the earlier technique due to efficient energy utilization. The whole network dies at 2900 rounds in MHRP while in mobile sink based network dies at 4300 rounds, so instability time in mobile sink based MHRP is 66 % more than the other protocols. The P-CL scheme reduces the data redundancy problem by sending data directly to the sink in case of remote parent node. It further diminishes the delay in data delivery to base station. Because of minor chains in MHRP, there are not much longer distances between the remaining nodes of the multi-chains after the dying of first 25 nodes in all 4 regions. There is a less data delivery delay in leader and the sink is smaller in last 1000 rounds due to the sink mobility.

As the network lifetime of mobile sink based MHRP is significantly greater than the earlier one, it means that the nodes transmits more packets to BS (i.e. the throughput is high). During last 1000 rounds of instability period, nodes density is notably low, a lot of empty spaces (in term of the coverage) are formed, due to which network gets sparse. In spite of large empty spaces, mobile sink based MHRP provides better coverage in last 1000 rounds than of MHRP due to sink receives additional packets. Furthermore, it is better for the delay sensitive applications due to smaller chains. In the simulations, all the nodes have equal amount of initial energy of 0.5 joules. The nodes are termed as dead, if they losses all of their energy. Therefore, they drop transmitting or receiving capabilities. Figure 5.3 represents the contrast of energy consumption of mobile sink based MHRP with MHRP.

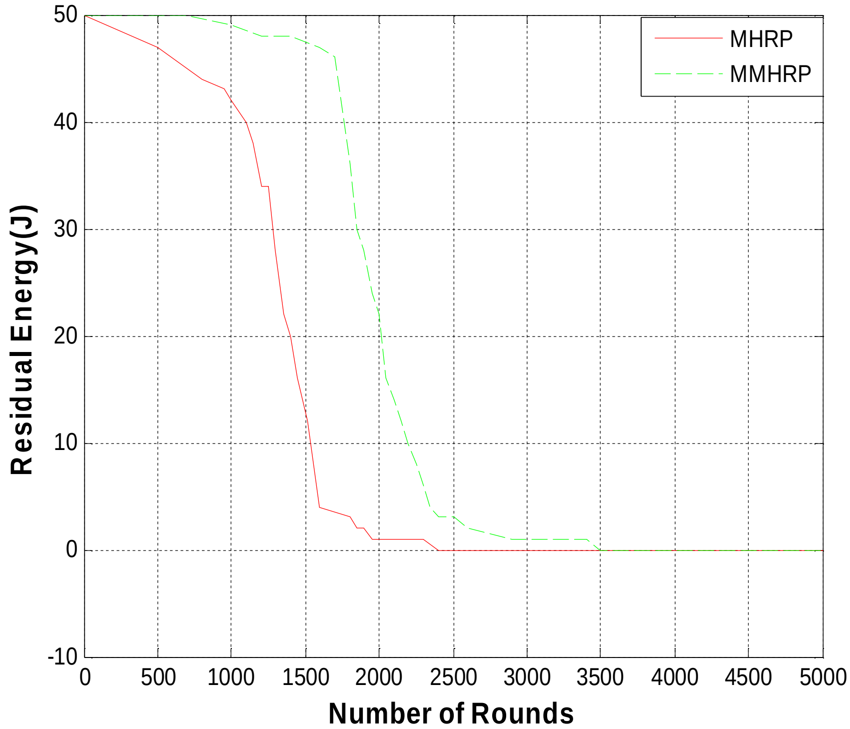

Figure 5.3: Residual energy vs. round number

5.3. Conclusion

Simulation result shows that the residual energy consumption of sensor nodes over rounds in mobile sink based MHRP is 3 % better than the previous method. The distance among sparse nodes themselves and the base station is fewer than in MHRP. This practice saves plenty of energy. Mobile sink based MHRP gives total coverage in the network if there is no physical obstacle in the sink path or the nodes in the network are not dead. As the Buffer contains minimum number of nodes therefore sink has to stay for less sojourn time at sojourn location to cover the whole area.

CHAPTER - 6

ConClusion

Key Topics

- ✓ Conclusion
- ✓ Future Work

CONCLUSION

6.1. Conclusion

This thesis has presented a hybrid approach for Multi-chain based hybrid routing protocol which implements sink mobility in the network and gives requirements like energy efficiency, better coverage of nodes by the sink node while collecting data directly from the sensor nodes.

There are several static methods available for collecting data form sensor nodes. In mobile sink based approaches, sink traverse the network in the optimal trajectory as mentioned above and collects data from the chain leader nodes. Sinks have enough energy, memory and computational power. We exploited this approach for better network coverage and enhance network stability.

The contributions of the thesis are as follows:

The thesis presents an overview of WSN. Application areas of WSN, different challenges and issues related to WSN are presented here. WSN is a modern technology and it has a very exciting application areas ranging from disaster management to healthcare and vehicle tracking. WSN consist of a large number of low power low cost tiny sensor nodes. These sensor nodes randomly deployed in a region and they collect information and send them to the sink using multi hop path. In spite of large application areas there are some design challenges and issues that affect the performance of WSN. Energy constraint, limited hardware capabilities, fault tolerance, scalability, quality of service are some of such issues. Especially for time critical application quick data delivery is also an important issue. Depending upon the study of these challenges and issues this thesis focuses on key issues such as energy efficiency and network coverage.

Here a large scale WSN is partitioned in four consecutive regions on the basis of its coordinates. Each region contains equal number of nodes which form separate chains. The advantage of this approach is it minimizes the data delivery delay due to lessen number of nodes in the chain. The advantage of Pre-Chain Leader scheme is that data transfers can be done more efficiently compared to LEACH and PEGASIS.

The optimal trajectory for sink mobility has an important role in WSN. As static sink has some drawbacks such as hotspot problem, the advantages of implementing mobility in WSN is taken into account in order to improve the network life expectancy. The performance analysis is compared with existing protocol to hybrid protocol and then static sink based hybrid protocol to mobile sink based hybrid protocol. These algorithms are not tested in real environment. Therefore these results cannot be claimed as accurate.

6.2. Future work

The thesis can be extended to introduce some new concepts to solve different challenges and issues of WSN. One future scope of this thesis is to introduce scheduling in the proposed protocol. If sleep scheduling is introduced then it may help to further achieve energy efficiency, increase network lifetime.

Then introduce an appropriate sink mobility algorithm that will give better performance for transmission of data packet to reach sink when it is not in range of sensor nodes.

There is a scope to compare this proposed hybrid protocol with different existing sink mobile algorithms as a future work of this thesis.

REFERENCES

[1] Zhao Han; Jie Wu; Jie Zhang; Liefeng Liu; Kaiyun Tian "A General Self-Organized Tree-Based Energy-Balance Routing Protocol for Wireless Sensor Network," IEEE Transactions on Nuclear Science, Vol-61, no-2, pp.732-740, April 2014.

[2] Lindsey S., Raghavendra C.S., "PEGASIS: Power-efficient gathering in sensor information systems," IEEE , Aerospace Conference Proceedings Vol.3, pp.1125-1130, 2002.

[3] Asaduzzaman Kong, Hyung Yun,"Energy efficient cooperative LEACH protocol for wireless sensor networks" Journal of Communications and Networks, vol.12, no.4, pp.358-365, Aug. 2010.

[4] Sung-Min Jung, Young-Ju Han and Tai-Myoung Chung, "The Concentric Clustering Scheme for Efficient Energy Consumption in the PEGASIS," 9th International Conference on Advanced Communication Technology, Vol.1, pp.260-265, 12-14 Feb. 2007.

[5] Hyunduk Kim, Boseon Yu, Wonik Choi, Moonju Park and Jinseok Chae, "Distance Based Pre-cluster Head Selection Scheme for a Chain-Based Protocol," 9th IEEE International Conference on Computer and Information Technology, CIT '09. Vol.2, pp.110-115, 11-14 Oct. 2009.

[6] Ting-Yu Lin, Kun-Ru Wu, Guang-Chuen Yin,"Channel-Hopping Scheme and Channel-Diverse Routing in Static Multi-Radio Multi-Hop Wireless Networks," IEEE Transactions on Computers, Vol.64, no-1, pp.71-86, Jan. 2015.

[7] Degan Zhang, Guang Li, Ke Zheng, Xuechao Ming and Zhao-Hua Pan, "An Energy-Balanced Routing Method Based on Forward-Aware Factor for Wireless Sensor Networks," IEEE Transactions on Industrial Informatics,Vol.10, no.1, pp.766-773, Feb. 2014.

[8] Harichandan P., Jaiswal A., Kumar S., "Multiple Aggregator Multiple Chain routing protocol for heterogeneous wireless sensor networks," International Conference on Signal Processing and Communication (ICSC), pp.127-131, 12-14 Dec. 2013.

[9] D. K. Ali Ghaffari and H. Bannaeian, "EER: Energy-efficient and real time routing protocol for wireless sensor networks" World Applied Sciences Journal Vol. 14, no. 2, pp.356–362, 2011.

[10] Heinzelman W.B., Chandrakasan A.P., Balakrishnan H., " IEEE Transactions on "An application-specific protocol architecture for wireless microsensor networks," Wireless Communications , vol.1, no.4, pp.660-670, Oct 2002.

[11] Anuja Arman, Nimisha Manth, Vansha Kher "PEGASIS And Its Descendant Protocols: A Survey", International Journal of Electrical, Electronics and Data Communication (IJEEDC), Volume-2, Issue-12, pp 15-19 , Dec 2014.

[12] Sanghun-Lee, Jungbong-Suk "Improvement of Energy Efficiency of LEACH Protocol for Wireless Sensor Networkss" Journal of Korea Information and communications Society, Vol. 33, No. 2, 2008.

[13] Jafri, Mohsin Raza, Nadeem Javaid, Akmal Javaid, and Zahoor Ali Khan "Maximizing the Lifetime of Multi-Chain PEGASIS Using Sink Mobility" World Applied Sciences Journal 21, no. 9, pp.1283-1289, 2013.

[14] Feng Sen, Qi Bing, Tang Liangrui,"An improved Energy-Efficient PEGASIS-Based protocol in Wireless Sensor Networks,"Eighth International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), vol.4, pp.2230-2233, 26-28 July 2011.

[15] V. Kumar, S. Jain and S. Tiwari, "Energy Efficient Clustering Algorithms in Wireless Sensor Networks: A Survey", IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 5, No 2, September 2011.

[16] D. Efstathiou, I. Kotsogiannis, S. Nikoletseas, "Energy Balanced Data Propagation in Wireless Sensor Networks with Diverse Node Mobility" in MobiWac"11, Miami, Florida, USA, October 31–November 4, 2011.

[17] T. Camp, J. Boleng, and V. Davies, "A survey of mobility models for ad hoc network research", in Proceedings of Wireless Communications and Mobile Computing, 2002.

[18] W. Liang, J. Luo, and X. Xu, "Prolonging Network Lifetime via a Controlled Mobile Sink in Wireless Sensor Networks" in IEEE Global Telecommunications Conference, 2010.

[19] I. Chatzigiannakis, A. Kinalis and S. Nikoletseas, "Sink mobility protocols for data collection in wireless sensor networks", in 9th International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems, pp.52 – 59, 2006.

[20] S. Jain, R.C Shah, W. Bunette, G. Borriello and S. Roy, "Exploiting Mobility for Energy Efficient Data Collection in Sensor Networks" in Mobile Networks and Applications, pp.327-339, 2010.

[21] W.R. Heinzelman, A. Chandrakasan, H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Micro Sensor Networks", in Procs. of the 33rd Hawaii International Conference on System Sciences, Hawaii, 2000.

[22] H. Yang and B. Sikdar "Optimal Cluster Head Selection in the LEACH Architecture," IEEE IPCCC2007, 2007.

[23] WANG Lin-ping, BI Wu, CAI Zhen and WANG Zu-feng, "Improved algorithm of PEGASIS protocol introducing double cluster heads in wireless sensor network" International Conference on Computer, Mechatronics, Control and Electronic Engineering, pp.148-151, 2010.

[24] YU Yong-chang, WEI Gang, "An Improved PEGASIS Algorithm in Wireless Sensor Network," Acta Electronica Sinica, vol.36, pp.1309-1313, July 2008.

[25] Vasanthi V., Romen Kumar M., Ajith Singh N., and Hemalatha M., " A Detailed Study of Mobility Models in Wireless Sensor Networks," Journal of Theoretical and Applied Information Technology, Vol. 33, No. 1, pp. 7-14, 2011.

[26] Sikora A., and Niewiadomska-Szynkiewicz E., "Mobility Model for Self-Configuring Mobile Sensor Network", The fifth International conference on sensor technologies and applications (SENSORCOMM 2011), pp. 97-102, France, August 2011.

[27] Gambs, S. Killijian, M. O. and del Prado Cortez, "Next place prediction using mobility Markov chains." In Proceedings of the First Workshop on Measurement, Privacy, and Mobility, p. 3. ACM, 2012.

PUBLICATIONS

[1] Anuja Arman, Davinder Singh Saini "WSN node lifetime enhancement based on hybrid protocol" *International conference on Computing, Communication and Automation- 2015,* **IEEE**, 15-16 May, 2015 (Accepted & Presented).

[2] Anuja Arman, Davinder Singh Saini "Implementation of MPLS Routing in Traditional LEACH" **IEEE** *2nd International conference on SIGNAL PROCESSING & INTEGRATED NETWORKS*, 19-20 feb, 2015 (Accepted & Presented).

[3] Anuja Arman, Davinder Singh Saini "Hybrid evolutionary MPLS Tunneling Algorithm based on high priority bits"*15th International business horizon-INBUSH ERA-2015*, **IEEE**, 25-27 feb, 2015 (Accepted & Presented).