Energy Aware PEGASIS based Fuzzy Scheduling for Wireless Sensor Network

A Dissertation Submitted in Partial Fulfillment of Requirement for the Award of Degree of

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Wireless Communications

Submitted By

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DECLARATION

I, **Yash Verma** hereby declare that the work presented in this dissertation entitled **"Energy Aware PEGASIS based Fuzzy Scheduling for Wireless Sensor Network"** in fulfillment of the requirement for the award of degree of Master of Engineering is submitted at Electronics and Communication Engineering Department, Thapar University, Patiala is an authentic record of my own work carried out under supervision of **Dr. Kulbir Singh,** Professor, ECE Department, Thapar University from 2015 to 2017. The matter presented in this dissertation have not been submitted by me either in part or full to any other university or institute for the award of any other degree.

Date: 17-July-2017

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It is certified that the above statement made by the student is true to the best of my knowledge and belief.

Date: 17-July-2017

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ABSTRACT

A wireless sensor network is an infrastructure comprising of multiple nodes that are minimal effort, less power usage, little volume and small area transmission. However, sensor nodes are installed for analysis three information's first is to detect particular area, second help users to display and third provide the aggregation of required data. For installation of sensor nodes specialists discover more proficient methods such that there is less dissipation in energy, by keeping in mind the goal to give more lifetime of the network. Subsequently, how to decrease nodes energy this is major issue in transmission of information. From numerous sorts of paper multi hop routing protocol and end to end nodes installation routing protocol is outstanding for power saving in nodes energy.

For successful routing in wireless sensor field, there are many power based data centers. These centers are installed randomly and consume a tremendous amount of energy. Every data center is governed through direct current power supply, therefore battery source limits the system. Power efficient gathering sensor information systems (PEGASIS) hierarchical routing protocol scheduling is one resolving algorithm, which minimizes the energy consumption of battery source in wireless sensor networks (WSNs). PEGASIS follows the working principle of chaining algorithm and crisp logic algorithm. In Chaining algorithm greedy approach has been used to make a successful route between the numbers of random nodes. In crisp logic algorithm energy is utilized in two levels that are zero or peak level. Only at time of peak level route is successfully discovered and select one head node. But if there is mobility in BS then fixed chain head node utilized more energy to transmit the information. So, PEGASIS dissipates more energy. To enhance energy efficiency and system lifetime, fuzzy based PEGASIS algorithm has been presented in this dissertation. In this algorithm low energy super chain head node is selected based at route discovered on less numbers of nodes and small delay time. Chain head node delivers the information to the base station and informs about the threshold energy value to the client. For better results in PEGASIS fuzzy logic three membership functions are used: battery power, workload delayed time and workload executed nodes. It is observed that a number of packets are optimally transmitted using fuzzy based Mamdani's rule. It is also observable that capacity is increased by 10% and network lifetime has been enhanced by implementing fuzzy based PEGASIS.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ADC	Analog to Digital Converter
AIMD	Additive Increase Multiplicative Decrease
BS	Base Station
CDMA	Code Division Multiple Access
CH	Cluster- Head for LEACH, Chain-Head for PEGASIS
CODA	Congestion Detection and Avoidance
EDF	Earliest Deadline First
EEPROM	Electrically Erasable Programmable Read-Only Memory
EM-Sensor	Electro-Magnetic Sensor
FIE	Fuzzy Inference Engine
FTDSR	Fuzzy Trusted Dynamic Source Routing Protocol
GB	Giga Byte
GPS	Global Positioning System
HEED	Hybrid Energy Efficient Distributed
HNA	Half Node Alive
ID-Number	Identification Number
IFRC	Interference Aware Fair Rate Control
LEACH	Low Energy Adaptive Clustering Hierarchy
LOS	Line of Sight
LPA	Local Positioning Algorithm
MAC	Media Access Control
MANET	Mobile Ad hoc Networking
OS	Operating Scheduling
PECRP	Power Efficient Clustering Routing Protocol
PEGASIS	Power Efficient Gathering in Sensor Information System
QoS	Quality of Service
RADAR	Radio Detection and Ranging
RF	Radio Frequency
RFID	Radio Frequency Identification
RPP	Routed Processed Priority
SCH	Super Chain Head
SNR	Signal to Noise Ratio

SONAR	Sound Navigation and Ranging
TCDGP	Tree Clustered Data Gathering Protocol
TREEPSI	Tree based Energy Efficient Protocol for Sensor Information
VLSI	Very Large Scale Integration
WSNs	Wireless Sensor Networks

LISTS OF FIGURES

LISTS OF TABLES

CHAPTER 1

INTRODUCTION

1.1 PREAMBLE

Progresses in sensor innovation: less power electronics gadgets and less power radio frequency (RF) designs have empowered the advancement of little, moderately cheap and less power sensors, known as smaller scale sensor nodes, those can be associated through a wireless system [1-3]. These smaller scale sensor nodes are typically disturbed and threatened by environment. Mainly they team up to watch the environment and transmit the data back to the base station (BS). Sensor systems play a basic part in crisis circumstances for example: fires, building breakdown and extraordinary climate marvels [4]. To get this information through sensor nodes a battery source is required. It is analyzed that, battery substitution is impossible for systems with thousands of physically inserted nodes, mainly hierarchical routing protocols are needed to drag out the battery source problem.

In a hierarchical routing protocol, sensor nodes utilized large amount of energy level and high RF transmission transfer speed. These limitations provide the irregularity for sending the information and provide a plenty of difficulties in quality of services (QoS). These difficulties require awareness of energy at all layers. Major objective of energy awareness in hierarchical routing protocols are that it results in enhancement in sensor lifetime and decreases the energy dissipation.

The hierarchical routing protocols consist of number of routing techniques such as low energy adaptive clustering hierarchy (LEACH), tree based energy efficient protocol for sensor information TREEPSI, tree clustered data gathering protocol (TCDGP) and PEGASIS. These routing techniques are mainly preferred because of its more energy efficiency [5]. From above mentioned techniques PEGASIS follows a chaining algorithm and all other techniques follows cluster algorithm. It is observed that chaining algorithm is more stable and efficient than cluster algorithm for ISM applications. There are many other techniques in WSNs which reduces energy dissipation and enhance the network lifetime but PEGASIS hierarchical based routing protocol is one most preferred technique as shown in Table 1.1.

Table 1.1 Approaches for Wireless Sensor Networks.

Structure	Mechanism	Workload Type	QoS Parameters
Wireless Rate Control Protocol [6]	Non-Autonomic	Homogenous	Rate Control, Delay Control
Carrier Sense Multiple Access [7]	Non-Autonomic	Homogenous	Rate Control, Congestion Detection, Delay Reduction
Interference Aware Fair Rate Control [8]	Non-Autonomic	Homogenous	Frame Control, Rate Control, Energy Efficiency
Congestion Detection Avoidance [9]	Non-Autonomic	Homogenous	Execution Time, Stability, Delay Control
Artificially Rate Control [10]	Non-Autonomic	Homogenous	Rate Control, Accuracy, Latency
PEGASIS Routing Protocol [5]	Autonomic	Homogenous	Energy Efficiency, Network Lifetime, Capacity and Execution Time

PEGASIS routing protocol utilizes its QoS optimally as compare to the other techniques. So, this dissertation mainly focuses on PEGASIS routing protocol.

1.2 OVERVIEW OF PEGASIS ROUTING PROTOCOL

PEGASIS and Hierarchical PEGASIS are a group of routing protocols and data gathering protocols in WSNs [11]. The system model considered by PEGASIS expects a homogeneous arrangement of nodes conveyed over a geological territory.

In PEGASIS routing protocol nodes are expected to have worldwide learning knowledge of the sensors. Their major duties are to accumulate and convey information to the electronic devices, normally to a remote BS. The objective is to create a routing model for decrease energy utilization and convey the collected information to the BS. From multiple routing protocols, models mainly depend on a tree algorithm and a clustering algorithm.

However, only PEGASIS utilizes the chaining based algorithm. In this model, node transfer its information to their nearest neighboring node as shown in Figure 1.1.

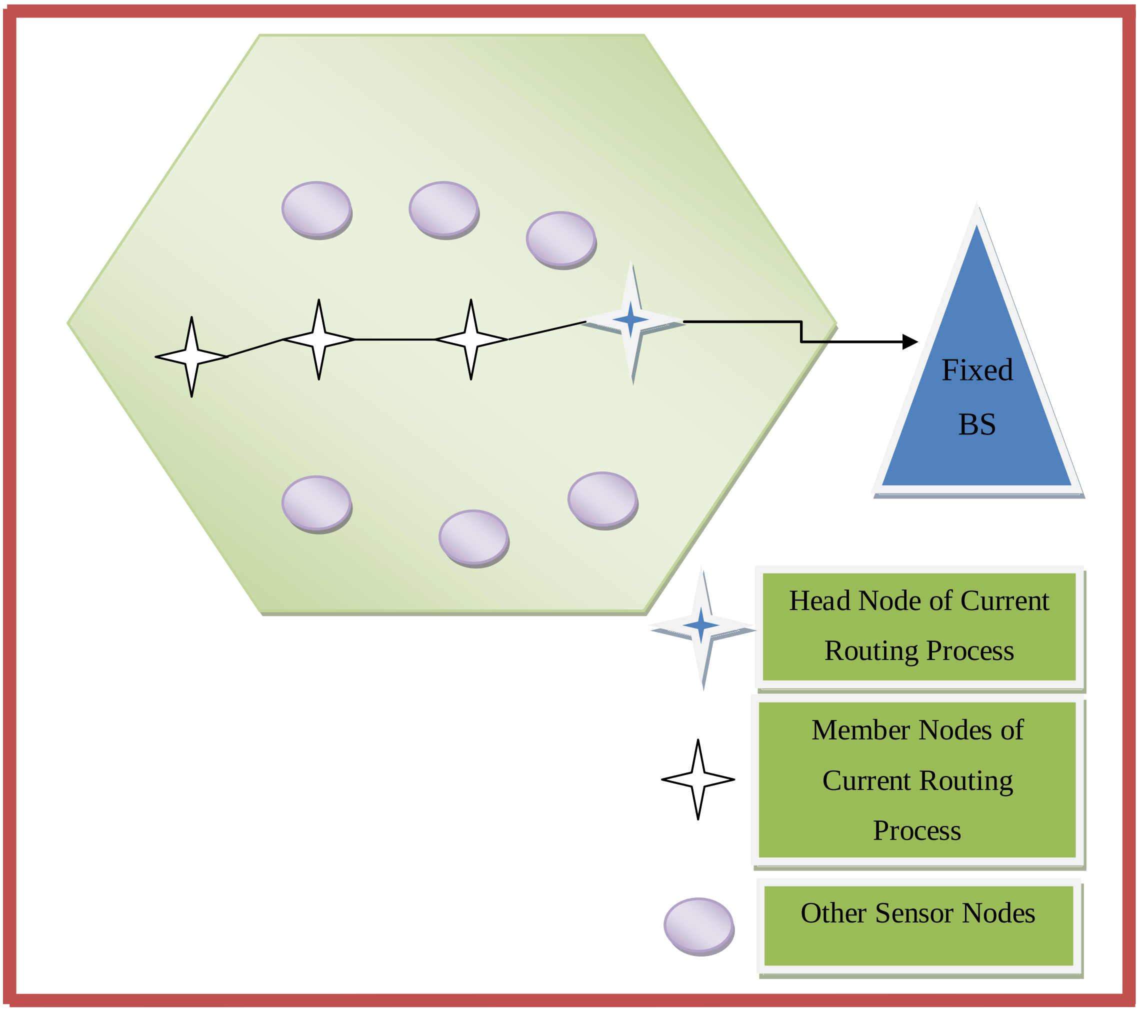

Figure 1.1 Fixed BS PEGASIS Transmission Process.

The development of the chain begins with the most needed node from the group of nodes. Arrangement in nodes is installed in the form of chain logically, beginning from the nearest neighboring node to the last nearest node. These nodes which are not in the chain route must be installed in the chain for a greedy approach. In case of deciding a nearest neighboring node, the node utilizes the strength of signal quality to calculate the separation between all the neighboring nodes. Utilizing the gathered data, the node alters the strength of signal quality such that alone nearest node must be listened to communicate with BS.

A node inside the chaining process is chosen as the chain head node. Duty of the chain head is to send the accumulated information to the BS. It moves depend upon the situation of the BS after mobility in every round. Mobility of the BS is mainly depending upon the strength of informational head node or node. After mobility, moves starting with a single round then onto the next move, it continues until the powerful guide head node issued cannot be resolved by information BS. Revolution of the leadership position among nodes of the chain guarantees by and large an adjusted utilization of energy among other system nodes. It can also be significant, that nodes are expecting a part in the chain head might be long distantly from information BS. Such that head node can send the information with large power keeping in mind the end goal to achieve the base station.

1.2.1 PEGASIS based Data Aggregation

Information collection for the PEGASIS method is accomplished within the chaining algorithm. In this a complex frame might attain the information successively through the chain head node. Initially, a chain head provides a particular ticket number at last node for made connection with the correct end node of the chain. After accepting the ticket number, the end node delivers its information at its downstream neighbors in the chaining algorithm to reach at chain head. The nearest node attained by greedy approach totals the information and delivers the data stream at its downstream nearest nodes. The greedy based procedure proceeds until the collected information is achieved by the head node. After accepting the information, by a correct route of the chain, the head node provides a ticket number to one side end node. A similar routings are processed until the information achieves the head node. Such successive plan might be important if subjectively close synchronous transmission cannot be completed without status flag interference. However, this consecutive plan of aggregation would bring large time delay before the total information is conveyed to the sink.

A potential way to deal with decrease the delay required to convey accumulated information to the BS and utilization the parallel information collection with respect to chain algorithm. Good level of parallelism might be accomplished only in two cases that the nodes would be furnished with help of CDMA technique [12]. The requirement of additional capacity to complete transmissions process without any obstruction must be utilized by conversion the various leveled hierarchy into the chaining algorithm and utilize the inserted hierarchy to initialize the information collection. In every different route, nodes that are installed levelly in the hierarchy, orders the transmission at nearby neighbor node. The PEGASIS routing protocol approach provides huge reduction in energy dissipation. For cluster based hierarchy it is ensures that $\log_2 N$ steps are initialized for accumulate the information at the head node. As in chaining algorithm mod paired aggregation process has been utilized. This procedure proceeds until the totaled information achieve a head node at the best position of the hierarchy.

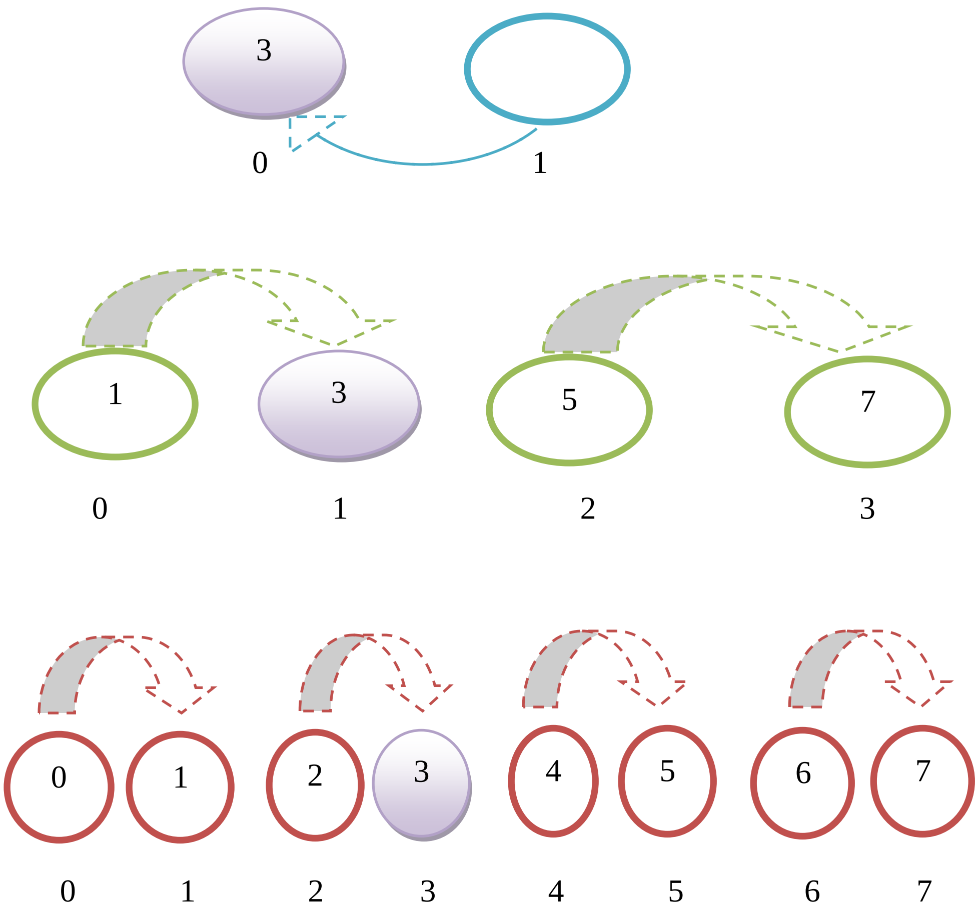

Figure 1.2 Chain based Information Aggregation Process [12].

One most significant example of chain based approach is defined in Figure 1.2. It is a data collection process; it can also be assume that each node has worldwide information of the system and utilize a greedy approach calculation to develop the chain [13]. Besides, in this one major expectation is decided that nodes would transmission in alternate criteria to the BS with the end goal would be $i \ mod \ N$, in this expression N shows to the aggregate number of nodes and i shows the routes for transmission of total information to the BS. In view of data aggregation task, total routes $i = 2$, nodes that aggregates the information let be 8, then in node 3 the head node can be declared. Since, it can be declared that by aggregation process energy utilization and capacity of the system enhances.

In Figure 1.2 it is defined that every node in an odd position must receive the information from their evenly neighbor node at one side. Node 3 keeps its position constant because it has been declare as head node in an odd position. Such that, each node at an even position aggregates the information on same time the odd neighbor transmits the information. At last hierarchy, node 3 is decided as data aggregated node.

1.3 MAJOR RESOURCES FOR PEGASIS IN WSNs

WSNs are integrated with hundreds of sensor nodes. More sensor nodes results in high accuracy over a larger geographical area. Mainly sensors have two categories inactive sensors and dynamic sensors.

Inactive sensors include pressure, gas, humidity, and temperature measuring gadgets. Inactive sensors have a tendency to utilize less energy. Dynamic sensors incorporate radio detection and ranging (RADAR), and sound navigation and ranging (SONAR) gadgets. Dynamic sensors have a tendency to be more energy frameworks. Basically, every sensor node has the working of sensing, processing, transmission, position searching, and power handling. Figure 1.3 represents the resource structuring of WSNs.

1.3.1 Power Generator

WSNs installed in an inspiring emerging area for providing the regularity between the multiple nodes. However for emerging area, power generator provides power supplies of 1.2v to the data centers. Power generator also delivers a tiny amount of power to processor unit, storage unit, modem unit and searching unit.

1.3.2 Processor and Storage Unit

The processors identify the status handling and provide the access to small scale actuators. Mainly processors are converting the mechanical language into an assembly language [14]. Basic principle of processors depends on a predefined time delay to handle the estimation.

Storage unit consists of microchips to store the bits. The microchip devices contain a nonvolatile storage process. As a rule, words may be eradicated and reinvented separately. Storage unit has capacity range from 0.01 to100 gigabytes (GB).

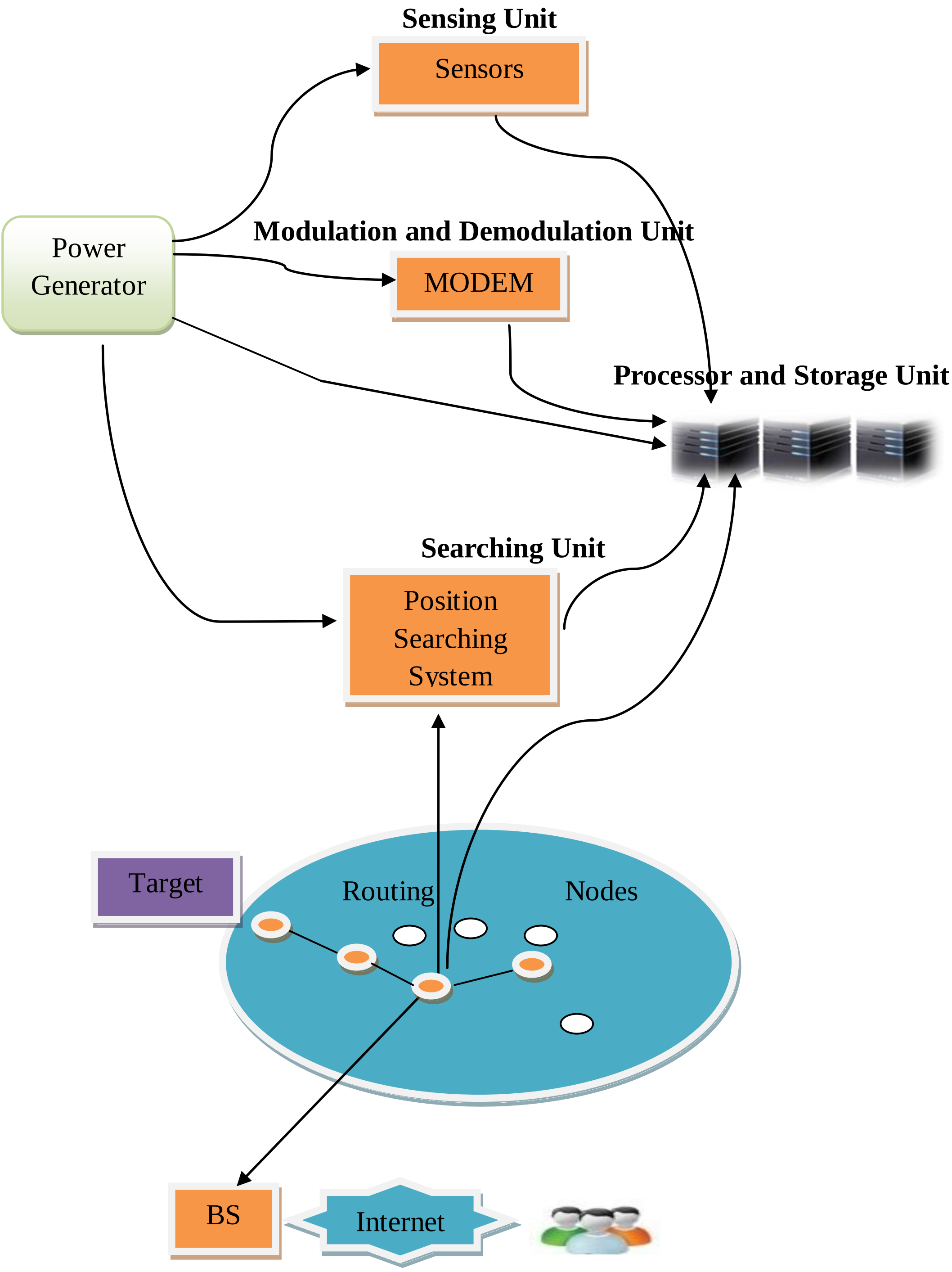

Figure 1.3 Resource Scheduling Structure for WSN.

1.3.3 Sensing Unit

Sensor works by observing the vibration of instant information. Information can be utilized by achieving the knowledge of the framework that is not detected specifically. The sensing unit has a number of inbuilt control methodologies such as electro-magnetic (EM) sensor field, RF sensors, optical infrared sensors, RADAR, and SONAR [15, 16].

1.3.4 Modulation and Demodulation Unit

Modulation is an overlapping of an intelligent data signal of lower frequency over a carrying signal of higher frequency. Modulation refers to transmit the data over long distance. Demodulation is an extracting process. This process recovers the intelligent data from the modulated carrier signal.

1.3.5 Searching Unit

WSNs have the characteristics of searching the location. Knowledge of location attained by an electronic devices such as global positioning system (GPS) and local positioning algorithm (LPA) [17– 21].

1.3.6 Routing Protocols

The routing protocols in sensor nodes are used to gather information from an objective space, and deliver the data feedback to particular destinations. Routing protocols in WSNs are flat based routing protocol, hierarchical based routing protocol, and location based routing protocol [5].

1.4 MOTIVATION OF THE DISSERTATION

All the existing methodologies in Table 1.1 consider homogeneous workload. However, fuzzy based primarily favors heterogeneous as well as homogeneous workload. Fuzzy based algorithm keep the parameters at specific optimized threshold level. This approach also accomplishes the essential parameters for calculating the energy usage. It refers to handling the heterogeneous congestion with less energy utilization and maximizes the parameters such as network lifetime, capacity and packet transmission to BS.

1.5 ORGANIZATION OF THE DISSERTATION

This dissertation is organized as in form of chapters as describe below

Chapter 2: Literature Review: This chapter involves a number of routing protocols used in previous research area as well as some contributions in this dissertation. It also includes the detail of routing protocols, gaps in study, objective and methodology for routing protocols.

Chapter 3: Energy Awareness Methods Based on Fuzzy Parameters: This chapter analyzed the different methods for fuzzy based PEGASIS. With fuzzy process, it is easy to select the route between numbers of nodes and this approach help to choose appropriate chain head node. This approach depends on energy awareness calculations, fuzzy selection algorithm and scheduling on fuzzy functions.

Chapter 4: Results and Discussions: This chapter analysis the results attained from the methodology as discussed in chapter 3. It also analyzes the fuzzy based membership functions in detail. Main focus on comparison of PEGASIS and fuzzy logic based PEGASIS has been discussed.

Chapter 5: Conclusion and Future scope: This chapter concluded the work done that is defined in this dissertation and define the future scope observations.

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

This chapter presents the literature survey related to the hierarchical routing protocol. It also includes the utilization of different strategies such as LEACH, TREEPSI and PEGASIS. These strategies provide the knowledge of data aggregation in wireless sensor networks. The gaps in study, objectives and methodology have been discussed in this chapter.

2.2 LITERATURE REVIEW

Nayak *et al.* [22] in 2016 presented the detail of sensor nodes. These sensor nodes are sending the information in an unfriendly situation to client such that, the data centers breakdown the physical route after some delay. One condition is arising from breakdown of physical route is that it is difficult to maintain the battery lifetime. From this discussion it is concluded that, reduction in the network lifetime by the estimate of energy dissipation parameter of battery source. Particular cluster head (CH) race process in LEACH is one resolving method that would result in reduction of energy dissipation significantly. This research method presented a super chain head (SCH) that is chosen from the number of independent CHs. These CHs mainly provide knowledge of reasonable fuzzy membership functions such as battery control, portability of BS, and provide the centrality knowledge from the cluster. Fuzzy derivation motor (mamdani's control) has been utilized for selection of appropriate SCH.

Choudhary *et al.* [23] in 2016 presented the arrangement of framework. In this, client can send the information randomly at different sensor nodes. Authors concentrate on information aggregation in various situations known as basic critical lattice zone. In this zone, senor nodes are heavily stacked with the data. Main goal is to increase the data rate of sensor nodes. To achieve this data rate author shapes the whole number by linear programming definition.

Chen [24] in 2015 works on wireless sensing framework. In this, author presented about low power utilization of clock sampling and fuzzy determination framework. The clock sampling of analog to digital converter (ADC) can be adaptively chosen by a fuzzy resolution controller. The resolution of the recognized signs can be adaptively changed by the quick components. Clients can set the membership functions of two conditions. The versatile fuzzy controller can create control signs to choose a correct sampling rate for the ADC with a fuzzy choice system.

Patel *et al.* [7] in 2014 presented three strategies to control the congestion and increase the network lifetime. However, these strategies rearrange its operation at specific layers of the protocol stack. In this author presented the three consequences for congestion. The first procedure is hop by hop directing stream control. The second procedure is transmitter rate controlling plan. The third procedure is organized media access control convention. In these, congestion analysis by back pressure of prior delay node. This results in reduction of packet rates. These strategies give the priority to nodes at time of accumulation.

Zhang *et al.* [25] in 2014 investigated on the workmanship of assembling sensors that made the process extraordinary. The sensors utilized the characteristics of integral metal oxide semiconductor cameras and modest receivers. In this, author presents remotely associated gadgets. These gadgets can extract the data from nature. The sort of data extracted by WSNs are video and sound streams, still pictures, and scalar sensor information. Author also presented the organization of sensor gadgets in WSNs. Organizations presented the detail regarding memory, capacity, storage ability, and remaining energy. These all gadgets are utilized with battery in wireless sensor networks.

Karthikeyan *et al.* [26] in 2014 presented the enhancement in signal to noise ratio. In this authors have empowered the utilization of modest sensors. These sensors have the capacity of detecting expansive data and propagating the data over substantial separations. Yet, the worry with sensor system is the low detection range and capacity. So to defeat this kind of issue, energy arrangement has been presented. Grouping is one method that utilized the node energy. This grouping technique utilizes the advantages of SNR for multi hoping and PEGASIS routing process.

Gupta *et al.* [27] in 2014 presented a method that depends on chaining algorithm arrangement. In this, author analyzed the method that depends on chaining algorithm. This technique selected an appropriate chain a head node. This approach results in decrement of parameter values such as measurement of energy utilization in the system. Also, this method enhances the general system lifetime. In this paper, framing chain is adjusted with respect to the chaining algorithm. In this method, level of availability has been considered and value of energy in every node.

Pantazis *et al.* [5] in 2013 presented energy effective routing protocols. These are grouped into four principle plans: structure of the network, model based on communication, topologies process and routing protocols. The routing protocols have a place with the classification as flat leveled and various leveled hierarchical. The second classification is named as query based and negotiation based. The third classification declared as delegated location based and versatile agent based. The fourth classification named as QoS based and multipath based. At all other plans, a diagnostic overview about energy utilization for WSNs have been presented.

Brante *et al.* [28] in 2013 characterized the relay determination. Relay determination has a property that expands the execution of multiple communications. In this paper, introduction of another transfer determination calculation is utilized with fuzzy process. Result in both system lifetime and throughput increases. This fuzzy method help to calculate the work in distribute method by running autonomously at every node. In this, the requirement of focal element is not necessary in case of complex and linear coordination. Main strategy follows the channel condition by keeping the transfer goal connects with a device.

Lee *et al.* [29] in 2012 presented data extraction from clustering algorithm. In this, authors divide the bunches into a cluster. Grouping gives a powerful approach to draw out the lifetime of WSNs. Clustering approach utilized two strategies: choosing group heads with more remaining energy level, and circulate the group heads. By initializing appropriate energy utilization among particular nodes in each cluster there is enhancement in the system lifetime. In many cases, a large portion of the past calculations have not considered the normal energy, which is the predicated remaining energy for being select a group head. In this paper, a fuzzy rationale based cluster approach with an expansion to the energy predication has been analyzed.

Xia *et al.* [30] in 2011 presented a mobile ad hoc networking (MANET). In this, authors have analyzed the insufferable steps from the system topology. MANET is defenseless approach against attacks from unknown nodes. With a specific goal to diminish the dangers from these malicious nodes, the creators join the idea of trust into the MANET. Authors fabricated a trust administration display which is isolated into two sections: subjective trust assessment demonstrate and put stock in evaluation model. In subjective trust assessment display, the energy of nodes can be assessed by investigative progressive system. Such that, it prepared hypothesis and fuzzy rationale rules expectation strategy. Based on the fuzzy dynamic programming hypothesis, the client exhibit a novel trusted calculation which kicked out the dishonest nodes. The use of the trusted MANET is to calculate the routing process. A novel reactive route based protocol has been presented called fuzzy trusted dynamic source routing protocol (FTDSR).

Liu *et al.* [31] in 2009 presented the system network layer of WSN. This system explained about the outline of the routing protocol that could enhance the lifetime of system. It also upgraded the associations among nodes and provided the efficient energy utilization. This paper proposes another kind of routing process for WSNs called power efficient clustering routing protocol **(**PECRP). This system presented a reasonable area for long separation in WSNs and also presented information regarding transmission (such as quiet observation production in agribusiness area). PECRP consolidates the benefits of some bunch based routing process such as hybrid energy efficient distributed (HEED), PEGASIS. PECRP enhanced the component area to select the appropriate CHs.

Huang *et al.* [32] in 2007 presented a step by step instruction to diminish node's energy. This approach is analyzed for delivering the information. From numerous sorts of analysis, numbers of hopping processes are notable for saving the power in information collecting method. In this, authors presented the detail of routing protocols such as the cluster based LEACH protocol, chaining based PEGASIS protocol and tree based TREEPSI protocols. Authors presented tree grouped information collecting convention to enhance the LEACH. This method resulted in the increment of two major parameters that are favorable circumstances and enhancement in power utilization.

Rangwala *et al.* [8] in 2006 presented an interference aware fair rate control (IFRC) technique. This technique has been utilized to overcome the blockage at a specific node by showing a normal queue length. This technique also recognized the blockage status for specific arrangement of interference. In this author has utilized the data at specific rate by utilizing an additive increase multiplicative decrease (AIMD) controlling law.

2.3 COMPARATIVE ANALYSIS OF VARIOUS APPROACHES

Various state of the art approaches related to the field of routing protocols are compared. These techniques are used to reduce the energy dissipation and increase the network lifetime of the system.

Table 2.1 Comparative Analysis of Various Approaches.

Year	Author	Strategies to Achieve the Requirements	Summary
2016	**Nayak** *et al.* [22]	LEACH, LEACH-C and Fuzzy Process	This method presented a SCH that is chosen from the number of independent CHs. These CHs mainly provide knowledge of reasonable fuzzy membership functions such as battery control, portability of BS, and centrality.
2016	**Choudhary** *et al.* [23]	Critical Lattice Sensor Node Process, Linear Programming	In this, authors concentrate on information aggregation in various situations known as basic critical lattice zone.
2015	**Chen** [24]	Fuzzy Determination Control Framework, A to D Converter	In this, author presented about low power utilization of clock sampling and fuzzy determination framework. The clock sampling of analog to digital converter (ADC) can be adaptively chosen by a fuzzy resolution controller.
2014	**Patel** *et al.* [7]	Hop by Hop Directing, Transmitter Rate Controlling Plan,	Author presented three strategies to control the congestion and increase the

		and Media Access Control	network lifetime. These strategies rearrange its operation at specific layers of the protocol stack
2014	**Zhang** *et al.* [25]	The Sensor Gadgets, Metal Oxide Semiconductor Cameras and Modest Receivers	In this, author presented remotely associated gadgets. These gadgets can extract the data from nature. The sort of data extracted by WSNs are video and sound streams, still pictures, and scalar sensor information.
2014	**Karthikeyan** *et al.* [26]	SNR for Multi Hoping and PEGASIS Routing Process	In this, author presented a bunch based data aggregation system. This technique utilizes the advantages of SNR for multi hoping and PEGASIS routing process.
2014	**Gupta** *et al.* [27]	Level of Availability and Chain based PEGASIS	In this paper, framing chain is adjusted with respect to the chaining algorithm. In this method, level of availability has been considered and value of energy in every node.
2013	**Brante** *et al.* [28]	Characterizes the Relay Determination.	In this paper, introduction of another transfer determination calculation is utilized with fuzzy process.
2012	**Lee** *et al.* [29]	Clustering Approaches and	In this, authors divide the bunches into a groups.

		Fuzzy Rationale Process	Grouping gives a powerful approach to draw out the lifetime of WSNs. Clustering approach utilized two strategies: choosing group heads with more remaining energy level, and circulate the group heads.
2011	**Xia** *et al.* [30]	MANET and FTDSR	In this, authors fabricated a trust administration display which is isolated into two sections: subjective trust assessment demonstrate and put stock in evaluation model.
2009	**Liu** *et al.* [31]	HEED, PEGASIS, and PECRP	This system presented a reasonable area for long separation in WSNs and also presented information regarding transmission.
2007	**Huang** *et al.* [32]	LEACH, PEGASIS and TREEPSI	In this, authors presented the detail of routing protocols such as the cluster based LEACH protocol, chaining based PEGASIS protocol and tree based TREEPSI protocols. Authors presented tree grouped information collecting convention to enhance the LEACH.

2.4 GAPS IN STUDY

- Sensor nodes are installed randomly in physical mode of communication to collect and transmit the information to BS. The data is not efficient to be delivered over the physical mode of communication for longer time. So, it is required to manage the energy efficiency by keeping the client updated.
- PEGASIS protocol used the TDMA and CDMA techniques to select the chain head node. PEGASIS-TDMA has the limitation of large time delay to manage the route between the nodes. So to overcome the delay of TDMA, PEGASIS-CDMA based technique is utilized. In this, binary structure is used to reduce the wastage of time delay. But, PEGASIS-CDMA also has the limitation of its complexity.
- For some cases in fuzzy logic, problem occurs during the transmission of information through the chain head node to the BS. So, there is need to refresh the fuzzy based membership functions.
- There is need to lay emphasis on PEGASIS routing protocol that can route efficiently.

2.5 OBJECTIVES

- To study and analyze the existing PEGASIS hierarchical routing protocol.
- To enhance the PEGASIS hierarchical routing protocol technique by considering the fuzzy logic membership functions such as battery power, workload delayed time, and workload executed nodes.
- To consider a heterogeneous routing for tuning the particular route which provide a better connection between BS and user.

2.6 METHODOLOGY

PEGASIS hierarchical routing protocol follows the chaining algorithm to enhance the energy utilization. In this algorithm, low energy super chain head node is chosen from the number of nodes. Chain head node delivers the information to the base station and informs about the threshold energy value to the user. For this algorithm, it is ensured that $\log_2 N$ steps are initialized for accumulation of the information at the head node. To enhance the network lifetime in PEGASIS, CDMA based sensor nodes are utilized. In this the plan regulation of its best concerning route through which the time delay has been reduced.

To achieve the better result in case of mobility fuzzy based PEGASIS protocol, three membership functions such as battery power, workload delayed time and workload executed nodes are considered. By controlling these membership functions, it is observed that the route tuning between hundreds of nodes have become easy.

CHAPTER SUMMARY

In this chapter few methods have been studied for routing protocol and congestion control in WSNs. Routing protocols such as LEACH, LEACH-C, PEGASIS and TREEPSI. Congestion control protocols such as hop by hop directing, transmitter rate controlling plan and media access control have been studied. At last of this chapter, objectives, gaps and methodology has been presented.

CHAPTER 3

ENERGY AWARENESS METHODS BASED ON FUZZY PARAMETERS

3.1 INTRODUCTION

PEGASIS and PEGASIS-TC [33, 34] are two main categories of hierarchical routing protocol. In [33, 34] authors utilized the idea of topology control for chain development. Chaining algorithm misuses the spatial node excess which results in the dissipation of energy. By usage of spatial nodes, network lifetime is reduced. This approach is less acceptable due to usage of crisp logic algorithm.

The presented fuzzy based PEGASIS is updated form of PEGASIS. With fuzzy process, it is easy to select the route between numbers of nodes and this approach help to choose appropriate chain head node. The presented approach depends on energy awareness calculations, fuzzy selection algorithm and scheduling on fuzzy functions.

3.2 ENERGY SCHEDULING BASED ON FUZZY FUNCTIONALITY

The major issue in fuzzy based PEGASIS is processing the administration and scheduling. In the resource management process, energy scheduling for fuzzy parameters is an important issue. The operating scheduling (OS) prepares security level by providing a different memory space for each procedure. Each procedure keeps the information in its own space. In some cases, this approach duplicates the information and therefore, it is not energy productive. The earliest deadline first (EDF) is used to make the PEGASIS energy efficient. The presented scheme utilizes the EDF to reduce the complexity. For fuzzy based PEGASIS energy has been calculated from radio energy dissipated model [35, 36] and radio energy propagation modes [37].

3.2.1 Radio Energy Dissipated Model

Radio energy dissipated model have three major components which help to calculate the energy such as electronics transmitter, power amplifier and electronics receiver as shown in Figure 3.1. To calculate the energy utilization between transmitter and receiver, two environmental models had been analyzed, such as free space model and multipath fading model.

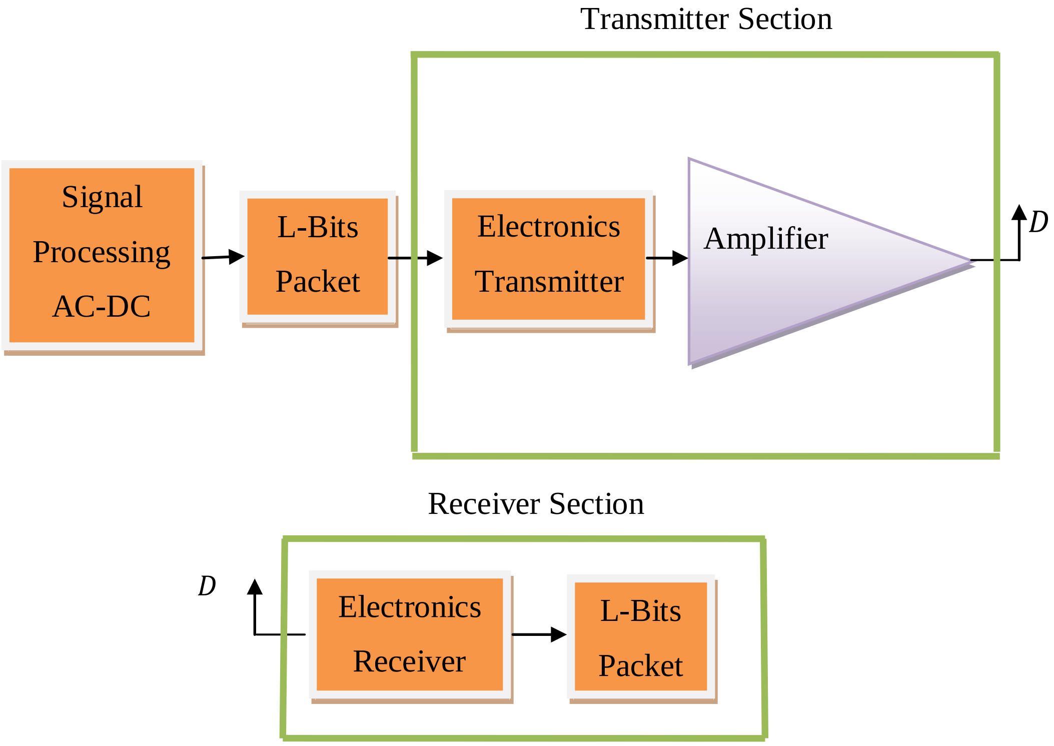

Figure 3.1 Radio Energy Dissipation Model for Transmitter and Receiver Section.

The energy between transmitter and receiver at a distance (D) can be calculated as [22]:

$$E_{trans-total}(L,D) = \begin{pmatrix} L*E_{elec} + L*\varepsilon_{fs}*D^2 \ if \ D<D_0 \\ L*E_{elec} + L*\varepsilon_{mp}*D^4 \ if \ D\geq D_0 \end{pmatrix}$$

$$E_{Trans}(L,D) = E_{elec-Trans}(L,D) + E_{power-amp}(L,D)$$

$$E_{rec}(L) = L * E_{elec}$$

where, E_{Trans} is a total energy required to transmit the L bit packets, L represents number of packets, D represents the distance between the transceivers measures in meters, D_0 is a threshold value. D decides the environmental model. If value of D is less then D_0 then model act as free model, otherwise model act as faded model. D_0 D_0 value obtained by the square root of ratio of ε_{fs} to the ε_{mp} as [22]:

$$D_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$$

3.2.2 Radio Energy Propagation Modes

In radio energy propagation modes, mostly free space wave or direct wave environmental modes are considered as shown in Figure 3.2. This model provides the information about the source energy which arises from radio energy signal.

This model has the knowledge about omni-directional transmission and provides the entire information about the spherical area. This model introduces the signal energy that correlates with the distance by $1/D^2$ rule and the distance increases by 20 dB per tenfold as presented in [37]. If the signal attenuates due to scattering, reflection or diffraction in the environment, then the model is not free space.

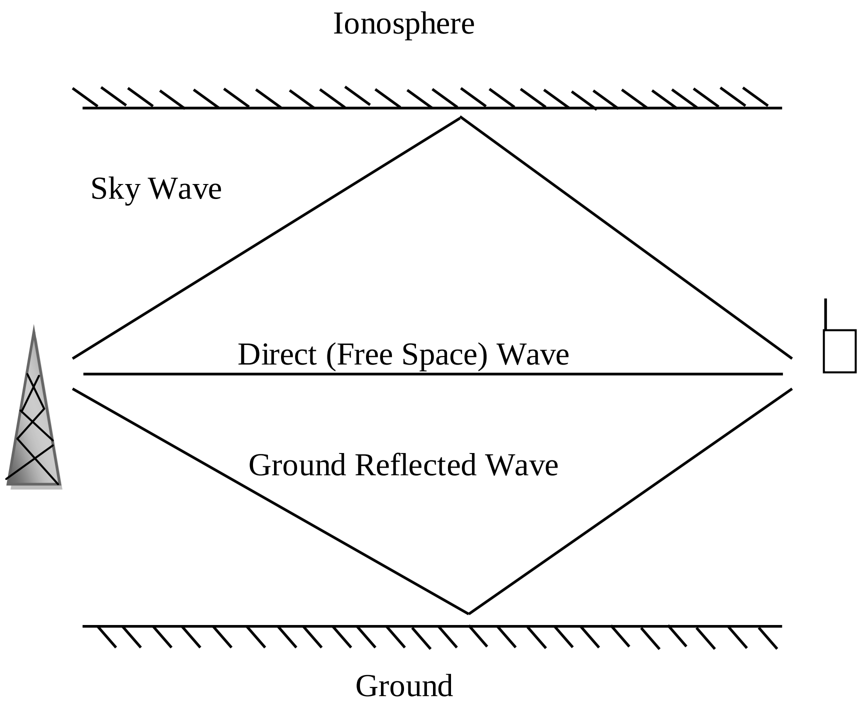

Figure 3.2 Radio Energy Propagation Modes [37].

In Table 3.1 three phenomena's have been defined that affect the radio energy propagation [38]. Signal quality also changes due to the composite signal which contains various segments from the different sources of reflections, diffraction and scattering.

Table 3.1 Basic Physical Phenomena’s Affecting the Radio Energy Signals.

S. No.	Phenomena	Summary
1.	Reflection	This mechanism takes place, when EM signal fall on surface of an object. The wavelength of the propagated signal is contrasted from a surface of the structures and dividers.
2.	Scattering	This mechanism takes place when light passes through a medium scattered to different wavelengths. These signals are delivered by unpleasant surfaces, little objects, or by different abnormalities. Practically, foliage and road signs provide scattered signal in a WSN.
3.	Diffraction	A mechanism takes places when RF signal is in center of the transceiver and obstructed from an object which is having sharp edges. Diffraction happens because of the obstructed object and on that time when LOS phenomena fails. At large frequency, diffraction and reflection depend upon the geometry of the surface.

Rather than diffraction, reflection and scattering, signal can be influenced by both mobility and stationary collectors. These changes of signals are called multipath fading. In this, signal changes can be as much as 30 to 40 dB. The quality of EM signal is attenuated by some methodologies known as large scale impact. The quality of the signal degradation due to the movement in the receiver antenna is known as small scale impacts.

3.3 ORGANIZATION OF PROTOCOL STACK FOR PEGASIS

Protocol organization plays a major role in PEGASIS based WSNs. Figure 3.3 defines protocol layered stack architecture which defines the utilization of communication system.

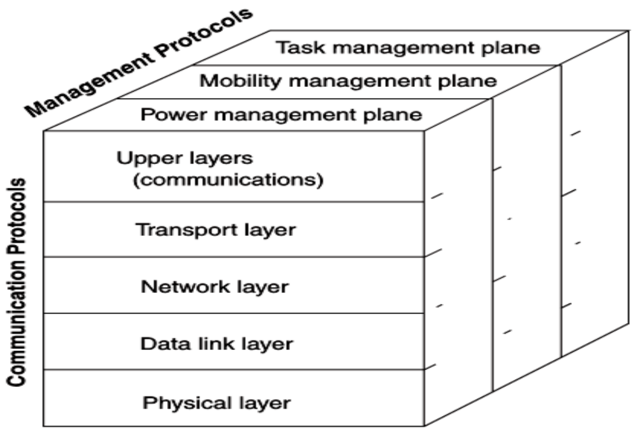

Figure 3.3 Organization of Protocol Stack [39].

3.3.1 Physical, Connectivity and Coverage Layer

Physical layer depicts that how sensor nodes can interconnect with each other in a cost effective and reliable manner. Such that it can cover all physical area required for user and it also provides the knowledge about channels followed by sensor nodes either wireless or wired channel.

3.3.2 Data Link Layer

Data link layer defines the characteristics of information. It mainly provides the knowledge that information is in frames, packets or in bytes. Also provides the detail about utilization of capacity, along with data compression [40].

3.3.3 Network Layer

Network layer having the access of security such that network lifetime can be enhanced. This layer is responsible for reliability of communication process and provides the knowledge about impairments of noise in signal and large scale issues provided by human resources.

3.3.4 Transport Layer

Transport layer is responsible for reliable transportation of information to the base station. This layer also provides CODA, scalability of nodes and robustness in communication system [41].

3.3.5 Upper Layers

Upper layers are for communication mechanisms. These layers have the responsibility for handling the degradations in environment with highly correlations of data process and provide the time accuracy of arrivals [42].

3.3.6 Power Management Plane

This plane is responsible for managing the power of the nodes. This plane also provides the maximum level of power to achieve the sensing task.

3.3.7 Mobility Management Plane

This plane is responsible to detect the movement of nodes to provide network connectivity. It also performs multi-hop routing and data hop routing.

3.3.8 Task Management Plane

This plane is used in detection and resolution of node problems. It also selects the route at which data will be sent.

3.4 FLOW CHART SCHEDULING FOR FUZZY BASED PEGASIS

Mainly flowchart is utilized to design to reduce complexity of the systems. It also signifies that with help of flow chart a process can be easily understandable, and one can easily search the flaws, errors and other important features within it.

Flow chart scheduling for fuzzy based PEGASIS defines the process go through in a WSNs as shown in Figure 3.4. It also performs constant planning for inquiries in WSN.

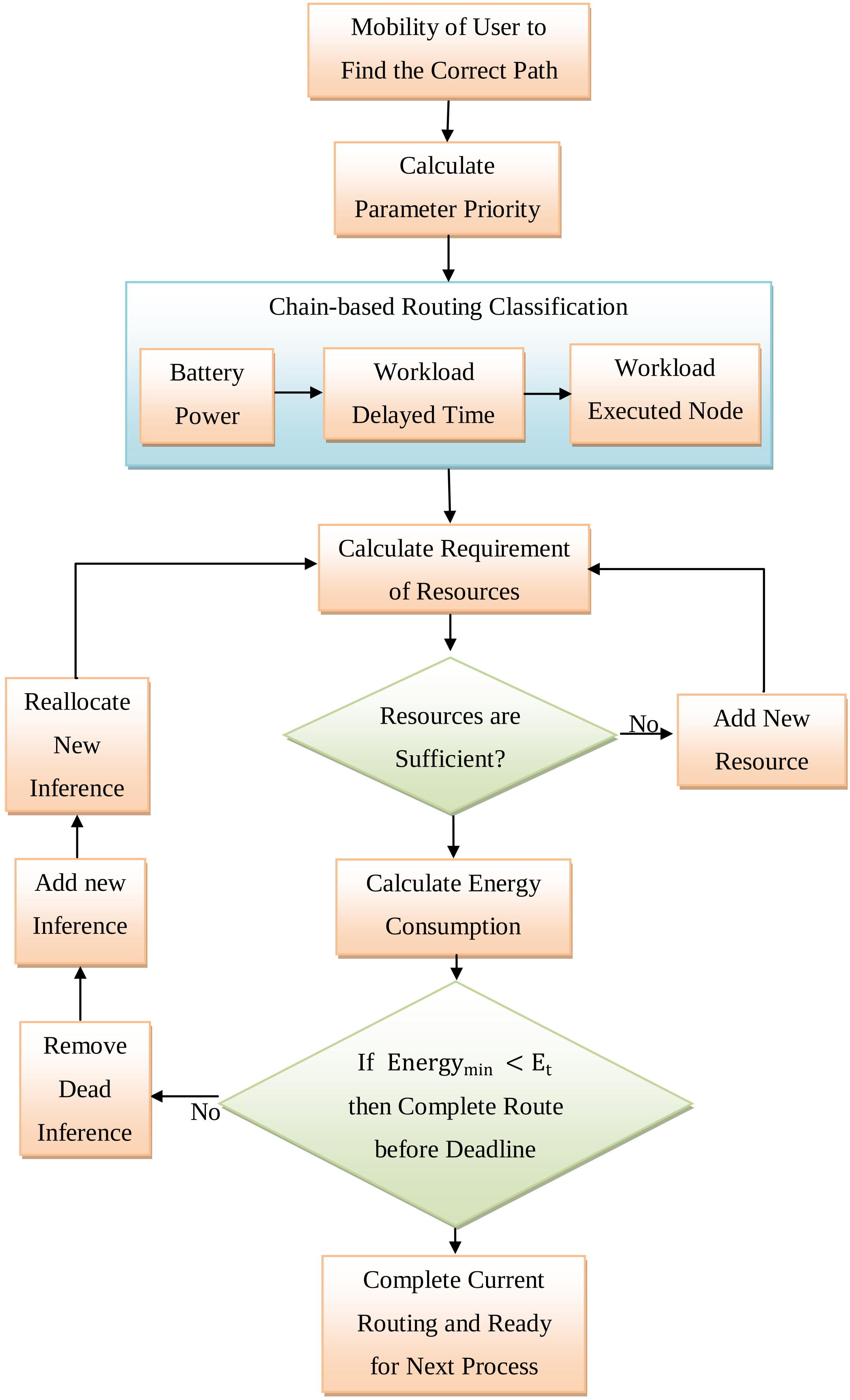

Figure 3.4 Presented Fuzzy Based PEGASIS Technique.

3.5 ALGORITHMS FOR FUZZY BASED PEGASIS

The algorithm defines the operation and management process. These algorithms extended to associate the connection for coverage a set of finite routing protocols. For fuzzy logic based PEGASIS routing protocol different algorithms are analyzed.

Algorithm-1 The Algorithm to find the parameter priority to complete the successful routing.

Loop

{

1) There is a user waiting for less delay routes.
2) For every new location due to mobility set the fuzzy parameters with its priority.
3) Execute the parameters with highest comfortable priorities.
4) State of the system updates for the same route, such that delay reduces.

}

end

Algorithm-2 The Algorithm to find the parameter priority with deadline.

Loop

{

1) For every new location due to mobility set the fuzzy parameters with its deadline threshold values.
2) Execute the parameters with highest comfortable deadline threshold values.
3) State of the system is updated with its deadline value for the same route, such that delay reduces.

}

end

Algorithm-3 The Algorithm to add a new fuzzy parameter for reduces the energy dissipation from the loop.

$\text{Energy}_{\text{min}}$ = minimum energy level required to complete the route.

E_{t} = threshold energy values for fuzzy process.

Loop

if

{

1) $\text{Energy}_{\text{min}} \geq \text{E}_{\text{t}}$ (Means route consumes more energy then decided energy);

2) then (route act as dead route and choose new fuzzy parameter).

}

end

Algorithm-4 The Algorithm to allocate the routing with less energy dissipation than the threshold value as the following.

1) Sort the fuzzy parameters in decending energy consumption process.

2) For each new location due to mobility.

Loop

if

{

3) $\text{Power}_{\text{min}} \leftarrow \text{Energy}_{\text{min}}$

4) Allocate fuzzy parameters from pool for successful routing.

5) Execute the route.

}

else if

{

6) Allocate routing as dead route.

7) Search the parameters again from the pool.

}

end

3.6 CHAPTER SUMMARY

This chapter provides the phenomena processed for the energy awareness in fuzzy based PEGASIS routing protocol. It also defines the detail about energy scheduling for different modes. The presented flow chart defines how the program goes through for fuzzy process. The analyzed algorithms define the operations held in this dissertation. By proposing membership functions with their threshold values fuzzy based process helps to reduce energy dissipation and increases network lifetime.

CHAPTER 4

FUZZY BASED FRAMEWORK FOR PEGASIS

4.1 INTRODUCTION

In previous chapter PEGASIS routing protocol chain head node is utilized for transmission of information to BS. As it is the primary issue that critical amount of energy is wasted at transmission time. So to overcome this wastage, fuzzy based PEGASIS routing protocol is used. Different fuzzy based simulation results have been observed in this chapter using mamdani's rule. It is also observable that capacity to handle more users has been increased by implementing fuzzy based PEGASIS as compared to PEGASIS.

Fuzzy logic can deal with constant applications more precisely than the probabilistic model. It adopts this strategy to deal with the instabilities for choosing the chain head. The major advantage of utilizing fuzzy logic based strategy is to remove the overheads of gathering nodes path finding, computing energy and area data of every node. A large portion of the fuzzy based chaining calculations consider the node/base station as static. Presently there are fuzzy based patterns to find the proper BS or BS portability that can reduce system rush, system delay and improves energy efficiency. The presented fuzzy based demonstration has superior performance to PEGASIS convention. To achieve the superior output, some framework assumptions have been discussed

- In presented framework, sensor nodes are installed in random criteria to screen the process constantly.
- Sensor nodes should install in static manner with the exception of the BS.
- The BS should be assumptive as portable cell phone.
- Homogeneous systems have been viewed as with the goal that the sensor nodes have equivalent energy level.
- The separation between the chain head node and the sink BS should be figured in based on membership functions of fuzzy scheduling.

4.2 FUZZY BASED SYSTEM MODEL FOR PEGASIS

The presented chaining based criteria follow the operation of PEGASIS routing protocol. In this chain is framed in every route. In every route, every installed node creates an arbitrary number in the range between 0 and 2. Hence, PEGASIS is a fuzzy logic methodology. If the node value is less than the threshold value T, one node from number of nodes turns into the chain head node.

Criteria for PEGASIS, the chain based developed calculation is characterized that number of chain per route is k. Ideal estimation of k in PEGASIS must be resolved logically by calculation and correspondence energy display. Such as, if N is a number of nodes installed independent of each other over $X \times X$ area, and k chains are accepted, then it can be calculated as N/k nodes per chain. It is also noticed that one chain head is selected by $((N/k) - 1)$. Every chain head scatters particular energy value by accepting the flag status and then it total the energy at last transmits the information to BS.

This is also expected that nodes only transmit the information after recognizing a route. For selecting the status flag chain node gathers the average information and sends it to the base station. The major problem regarding the routing is more mobility in base station as presented in [39]. Routing protocol has limitation to select the correct small route path in one criterion. As if the delay between two routers is same then there can be disturbance to choose the chain head node. Two fuzzy based membership functions define the information about battery power and delayed time in [43]. However in that case, it is difficult to choose the chain head.

Therefore, a new fuzzy parameter has been defined which consider the less execution time and inform about the less number of nodes travel by sensor network to reach at the base station. Result in right selection of super chain head node. To save the energy, one super chain head has been defined among the chain head which results from the third membership function. The third input parameter is named as workload executed nodes that deliver the information to BS. Rather than various chain node heads, one SCH can convey the message to base station that can diminish wastage of energy utilization and upgrades energy proficiency. The presented model is displayed in Figure 4.1.

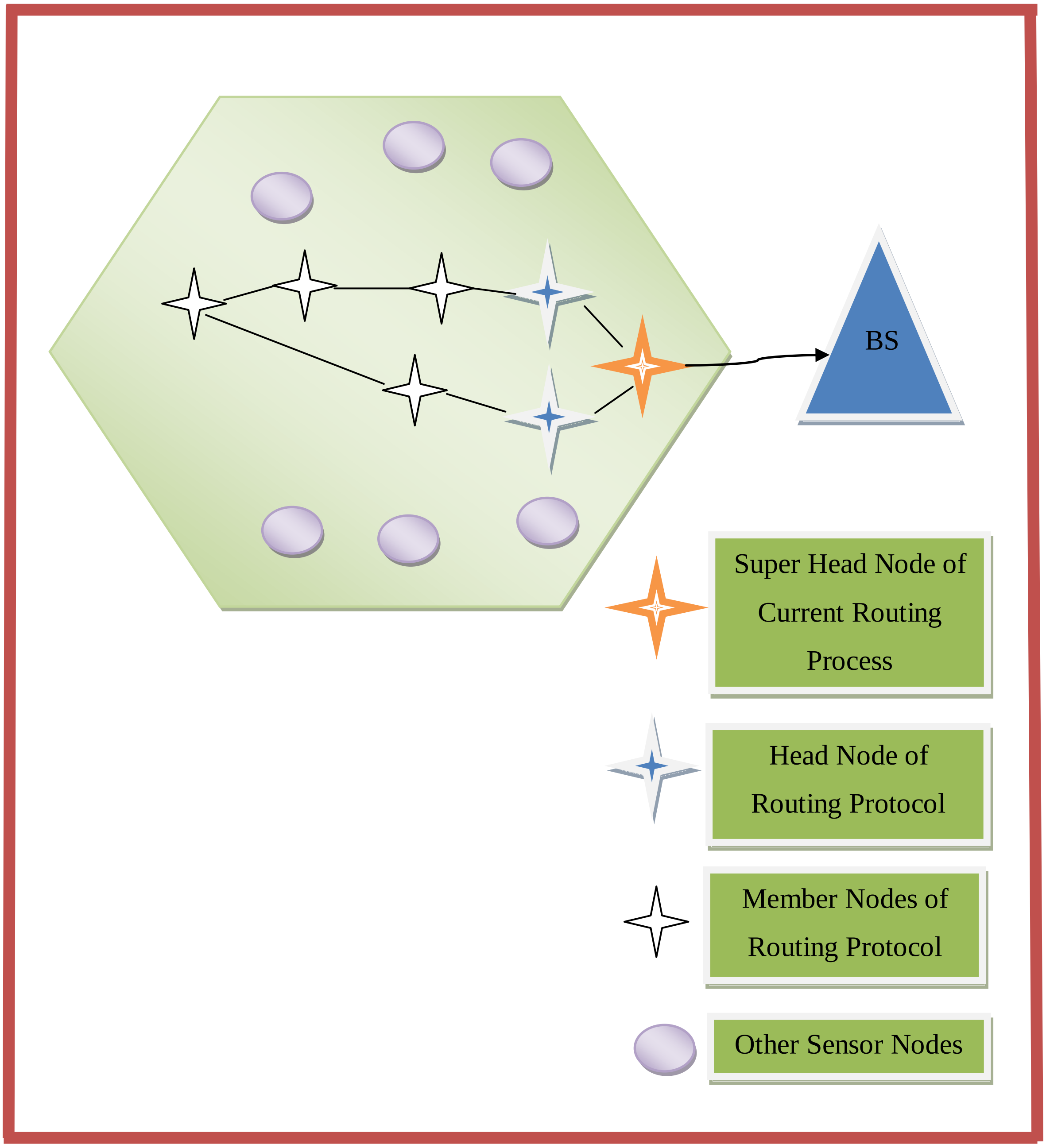

Figure 4.1 System Model for Fuzzy based PEGASIS.

One more assumption has been included that the base station has mobility which can provide the relaxation from collision of CH by giving the gathered information to SCH. BS can receive a wide range of ways to gather the data from the SCH as appeared in Figure 4.2.

Further assumption for the PEGASIS fuzzy based protocol is that battery power, workload delayed time, and workload execution nodes. These fuzzy membership functions have been monitored to analyze the process to select the SCH which delivers the message status to the base station.

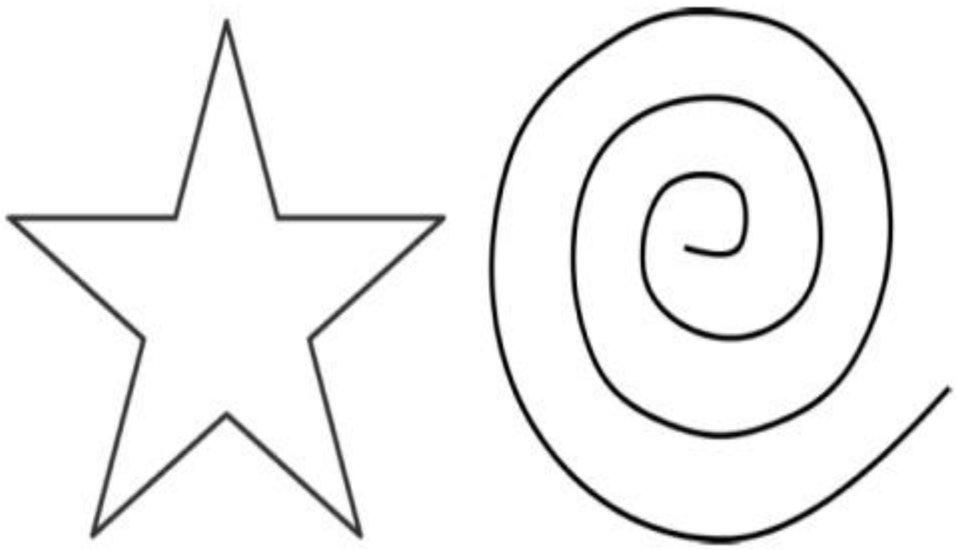

Figure 4.2 Paths Taken by Base Station [22].

4.3 ANALYSIS OF FUZZY BASED PEGASIS

PEGASIS based autonomous resources inference scheduling has strategy to execute the membership functions that has the earliest threshold value depend on energy consumption. In presented fuzzy inference system mainly four parameters has been discussed as shown in Figure 4.3.

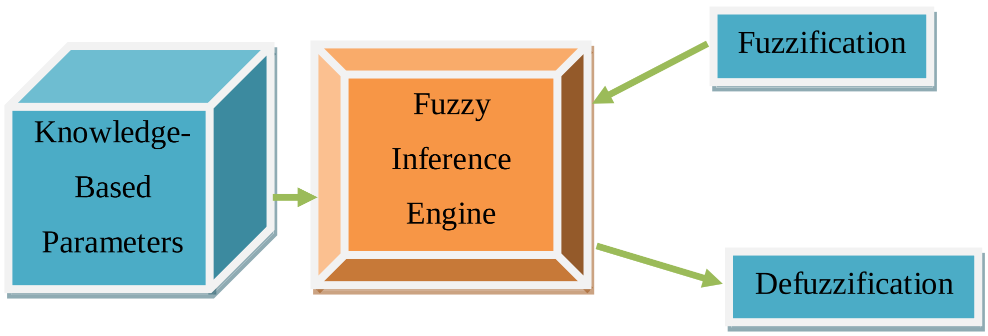

Figure 4.3 Fuzzy Based Inference.

4.3.1 Fuzzification

It transforms the crisp process into the fuzzy process and depends on three input membership functions as shown in Figure 4.4.

4.3.2 Knowledge based Parameters

The user should have the knowledge about three input membership functions such as battery power, workload delayed time, workload executed nodes and one output parameter such as routed processed priority. These parameters are defined in inference engine by if-else condition.

4.3.3 Fuzzy Inference Engine

Fuzzy inference engine simulates the knowledge based parameters, thus providing the fuzzy based ruler view. In this dissertation, mamdani inference engine has been presented as shown in Figure 4.4.

4.3.4 Defuzzification

It transforms the fuzzy process into a crisp process and depends on output membership function as routed processed priority shown in Figure 4.4.

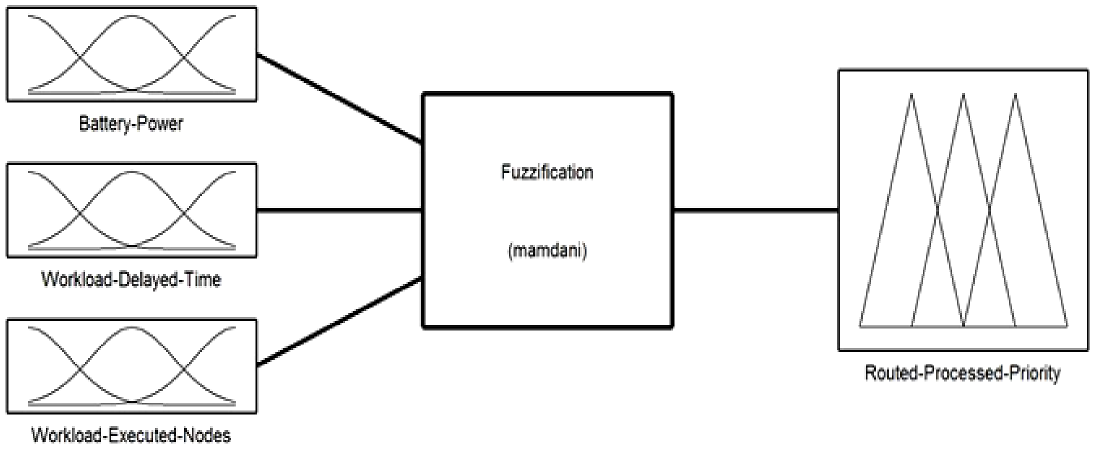

Figure 4.4 Processing of Membership Functions.

To achieve the presented fuzzification process, Mamdani method is preferred for the automation resource inference system. Mamdani rule depend on min-max operations. Most commonly number of applications utilizes the Mamdani's rule, because of its simplicity in structure. In mamdani's rule a fuzzy inference engine (FIE) is utilized to obtain the crisp values from fuzzy value. Fuzzy inference engine have four steps to generate crisp values. The steps are described in detail with the help of Figure 4.5.

- Calculate the threshold values or deadlines for every rule.
- Verify the results for every rule, such that it results in the reduction of energy value. This verification is done by output membership function.
- Aggregate the results through min-max criteria.
- Finally, defuzzification is applied to every route.

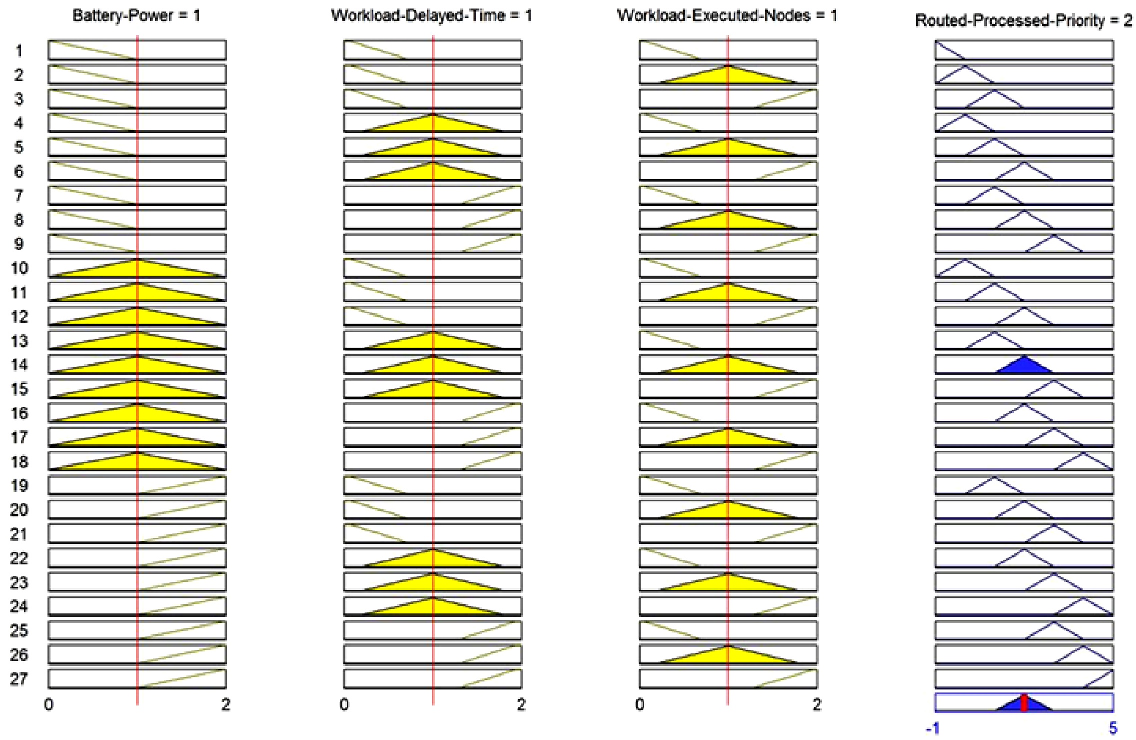

Figure 4.5 Ruler Viewer of Membership Functions.

4.3.5 Fuzzy based Input-Output Parameters and Fuzzification

The first step that should be declared in fuzzy based inference is that the protocol has knowledge about input-output parameters. Some input inference parameters such as: name of the process and type of process remains constant. In PEGASIS routing protocol, Mamdani method inference engine is used for electing the best routing path which reduces the energy dissipation. In another PEGASIS fuzzy processes network lifetime is constant, but with PEGASIS routing protocol lifetime of the network increases.

In this protocol, three membership functions are declared and their min-max centroid method has been presented in Figure 4.6 which defines the battery power with its three variables such as less, medium, high as shown in Table 4.1. First and third variable in Figure 4.6 defines the property of trapezoidal and middle has the property of a triangle.

Figure 4.7 defines the workload delayed time means how much less time is taken by the nodes and base station to make a route in a successful manner, three variables such as low, moderate and frequent as shown in Table 4.1. Figure 4.8 defines the workload executed nodes in this route selected by attaining the knowledge of less number of nodes to reach up to the base station. This membership function is additional as shown in above flow chart and the variables are defined as low, moderate and high as shown in Table 4.1.

Table 4.1 Membership Functions with its Variables.

Battery Power	Workload Delayed Time	Workload Executed Nodes
Less	Low	Low
Medium	Moderate	Moderate
High	Frequent	High

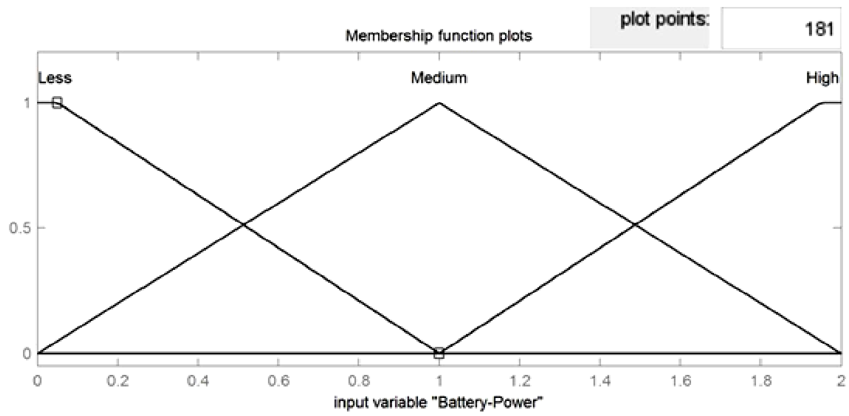

Figure 4.6 Membership Function of Battery Power.

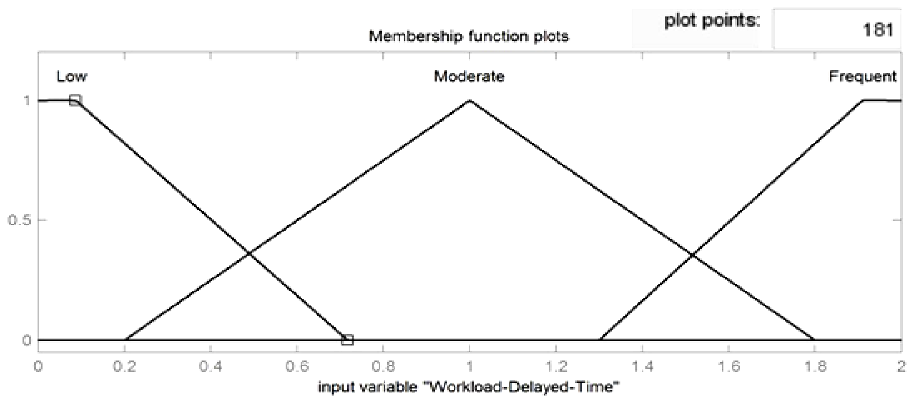

Figure 4.7 Membership Function of Workload Delayed Time.

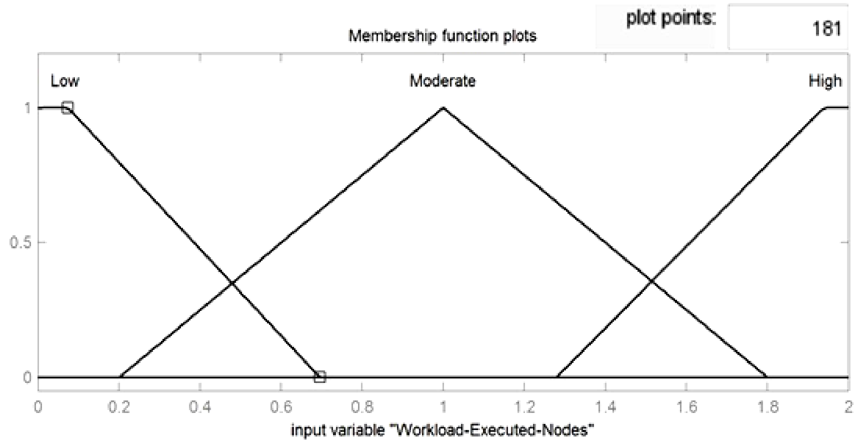

Figure 4.8 Membership Function of Workload Executed Nodes.

In fuzzy based PEGASIS hierarchical routing protocol, 27 rules have been used in the FIE. With analysis to the (4.1), routing protocol is considering an assumption of inbuilt parameter as remaining battery power that is achieved by (Battery Power – 1) [22]. However, discovery in every new route there will be little bit consumption of energy. So that, after completion of every new route, the remaining battery energy level is applicable to complete the new route. Workload delayed times and workload executed nodes have been assumed as an additional factors. These membership functions are responsible for selecting the super chain head. As workload delayed time predicts the smallest time duration to cover the route between numbers of nodes and one node is referred as chain head node. Workload executed nodes is responsible to provide the route that travel from less number of nodes. As this also provide one chain head node. From both parallel chain head, fuzzy logic predicts the route of less energy utilization and provides one super chain head. However the area around the SCH from BS is boost up or boost down depend on the mobility of sink BS.

The output function routed processed priority is getting selected with the regards of (4.1). Super chain head is obtained by utilizing the three membership status of the every node. Figure 4.9 represents the routed processed priority (RPP) as output variable for membership functions. Routed Processed Priority has values as shown in Table 4.2. To represent the output values mathematically (4.1) has been presented.

$$\text{Routed Processed Priority} = (\text{Battery Power} - 1) + \text{Workload Delayed Time} + \text{Workload Executed Node} \quad (4.1)$$

Table 4.2 Membership Notations for Routed Processed Priority.

Serial No.	Routed Processed Priority
1	Very Weak (-1)
2	Weak (0)
3	Lower Medium (1)
4	Medium (2)
5	Higher Medium (3)
6	Strong (4)
7	Very Strong (5)

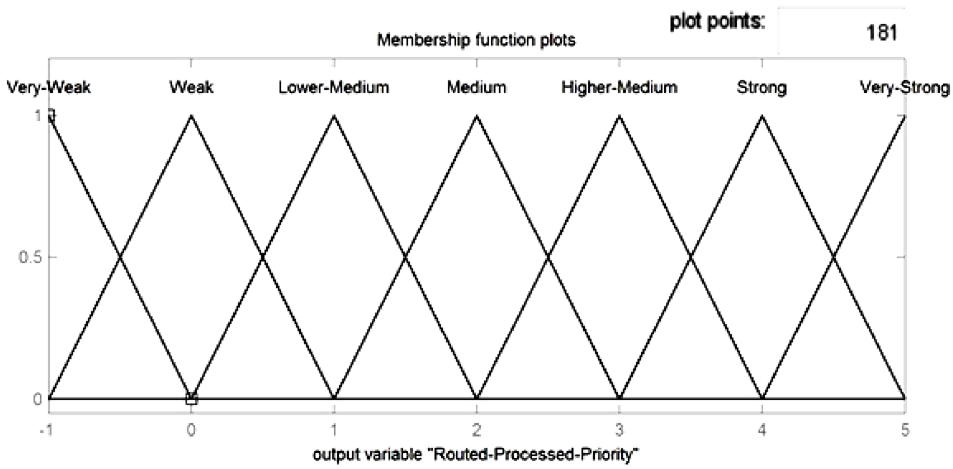

Figure 4.9 Membership Function of Routed Processed Priority.

4.4 KNOWLEDGE BASED PARAMETERS

In fuzzy based PEGASIS hierarchical routing protocol, inference engine plays a major role. By having the knowledge of membership functions researcher can achieve the optimal inference engine to handle proper utilization of energy. As discussed earlier, this inference engine consists of three different input membership functions and one output membership function. The three inputs membership functions have three different variables. So, with the regards of this input information, output routed processed priority generates $3^3 = 27$ fuzziness conditions. The routed processed priority gets the notation with the help of if-else condition and achieves the different values from (4.1) on input membership functions as represented in Table 4.3.

Table 4.3 Rules and Values for Routed Processed Priority.

Battery Power	Workload Delayed Time	Workload Executed Nodes	Routed Processed Priority
Less (0)	Low (0)	Low (0)	Very Weak (-1)
Less (0)	Low (0)	Moderate (1)	Weak (0)
Less (0)	Low (0)	High (2)	Lower Medium (1)
Less (0)	Moderate (1)	Low (0)	Weak (0)
Less (0)	Moderate (1)	Moderate (1)	Lower Medium (1)
Less (0)	Moderate (1)	High (2)	Medium (2)
Less (0)	High (2)	Low (0)	Lower Medium (1)
Less (0)	High (2)	Moderate (1)	Medium (2)
Less (0)	High (2)	High (2)	Higher Medium (3)
Medium (1)	Low (0)	Low (0)	Weak (0)
Medium (1)	Low (0)	Moderate (1)	Lower Medium (1)
Medium (1)	Low (0)	High (2)	Medium (2)
Medium (1)	Moderate (1)	Low (0)	Lower Medium (1)
Medium (1)	Moderate (1)	Moderate (1)	Medium (2)
Medium (1)	Moderate (1)	High (2)	Higher Medium (3)
Medium (1)	High (2)	Low (0)	Medium (2)
Medium (1)	High (2)	Moderate (1)	Higher Medium (3)
Medium (1)	High (2)	High (2)	Strong (4)
High (2)	Low (0)	Low (0)	Lower Medium (1)
High (2)	Low (0)	Moderate (1)	Medium (2)
High (2)	Low (0)	High (2)	Higher Medium (3)
High (2)	Moderate (1)	Low (0)	Medium (2)
High (2)	Moderate (1)	Moderate (1)	Higher Medium (3)
High (2)	Moderate (1)	High (2)	Strong (4)
High (2)	High (2)	Low (0)	Higher Medium (3)
High (2)	High (2)	Moderate (1)	Strong (4)
High (2)	High (2)	High (2)	Very Strong (5)

4.5 ANALYSIS OF PROBABILITY TO SELECT CHAIN HEAD IN PEGASIS

MATLAB is used to simulate some of the relationships between routed processed priority (RPP), battery power, workload delayed time and workload executed nodes. Different relations are analyzed to signify the probability to choose the super chain head node for the current routing protocol. Figure 4.10 represents that at time of installation of route, there is increase in consumption of battery power, decrease in workload delayed time as it increases the probability to choose the node head of routed processed priority. On the other hand, Figure 4.11 represents that starting of same route increases the consumption of battery power and reduction in workload executed nodes to reach the base station; such that increases the probability to choose the node head of routed processed priority. Hence, by comparing energy consumption on both chain heads, only one less energy dissipated super chain head is selected. From both the figures it is declared that results show the probability to choose the head node in case of workload executed time and workload delayed nodes.

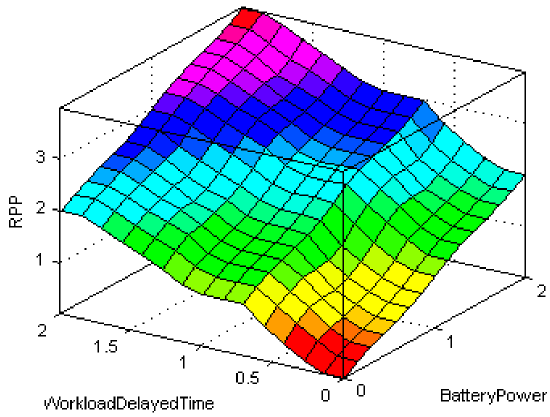

Figure 4.10 Relation between Routed Processed Priority (RPP), Workload Delayed Time, Battery Power

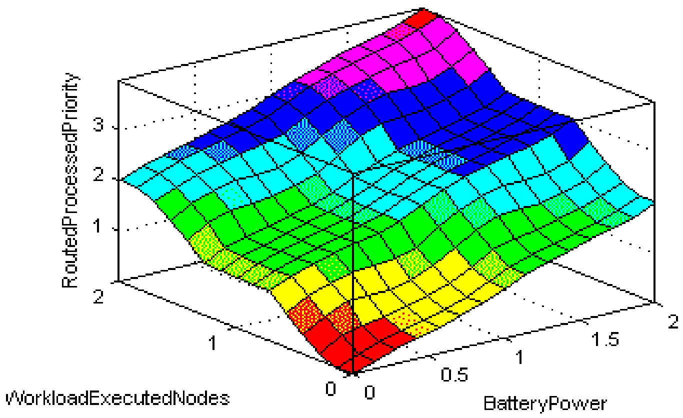

Figure 4.11 Relation between Routed Processed Priority, Workload Executed Nodes, Battery Power.

4.6 EXPERIMENTAL ANALYSIS WITH FUZZY BASED PEGASIS

In this section, experimental results based on fuzzy based PEGASIS routing protocol have been discussed. As in PEGASIS [11], there are two energy levels: zero level and peak level. Route is installed at peak battery source level. As if BS is far to chain head node then there is more time taken to reach at BS and results in less number of routes be covered by datacenters. But in case of presented fuzzy logic, different levels are declared with appropriate threshold values. Such that only small amount of energy is utilized to reach up to the BS. The presented scheme results in the installation of more number of routes. Hence, more users can access the network. From different number of database workloads [11], capacity can be computed by (4.2). It is concluded that with presented fuzzy based PEGASIS there is increment of capacity by 10% as represented by Figure 4.12.

$$Computing\ Capacity_i = \sum_{i=1}^{n} \frac{Actual\ executed\ time\ of\ route}{Expected\ executed\ time\ of\ route} \tag{4.2}$$

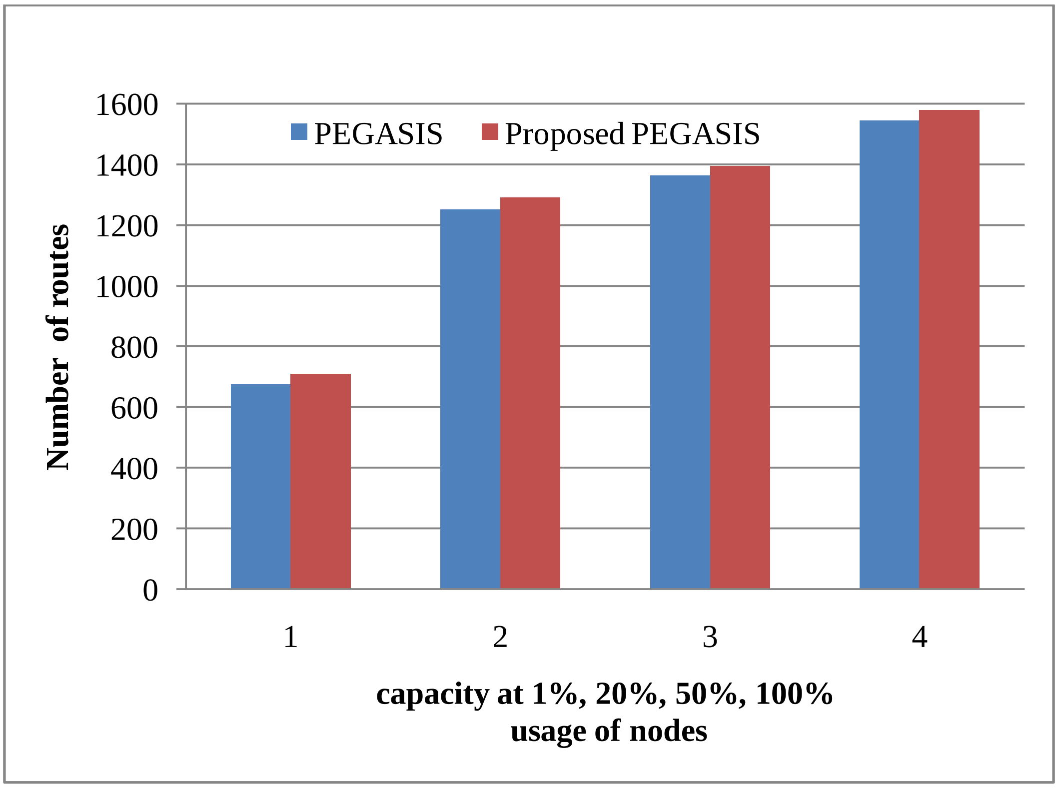

Figure 4.12 Capacity with Respect to Execution of Time.

The experimental results are based on the network area of 100×100 meters with 500 nodes [33, 34]. Different constant parameters are defined in Table 4.4.

Table 4.4: Parameters for Fuzzy based PEGASIS.

Parameter	**Value**
First Node Energy	0.5J ,2J
$\boldsymbol{E_{elect}}$	50 nJ/bit
$\boldsymbol{E_{fs}}$	10 pJ/bit/m^2
$\boldsymbol{E_{mp}}$	0.0013 pJ/bit/m^4
$\boldsymbol{E_{fusion}}$	5 nJ/bit/message
Packet Containing Data	2000 bits

Figure 4.13 signifies that energy dissipation with fuzzy process is less as compare to the PEGASIS process [34]. Main reason behind this is that fuzzy logic route can activate at any required energy level. But in crisp logic only two levels are assigned 0 or 1 such that in defined area for chain head node delivers the information to the BS. So that, more energy is dissipated at time of mobility in BS in case of PEGASIS. Presented fuzzy based chaining algorithm routing protocol is optimal for energy utilization in case of mobility. Energy dissipation is calculated by determining the energy consumed to execute the routes as shown in (4.3).

$$Energy\ Dissipation_i = \sum_{i=1}^{n} \frac{Number\ of\ routes\ executed\ successfully\ in\ battery\ sources}{Total\ energy\ utilized\ to\ complete\ these\ routes\ in\ 0.5\ J} \tag{4.3}$$

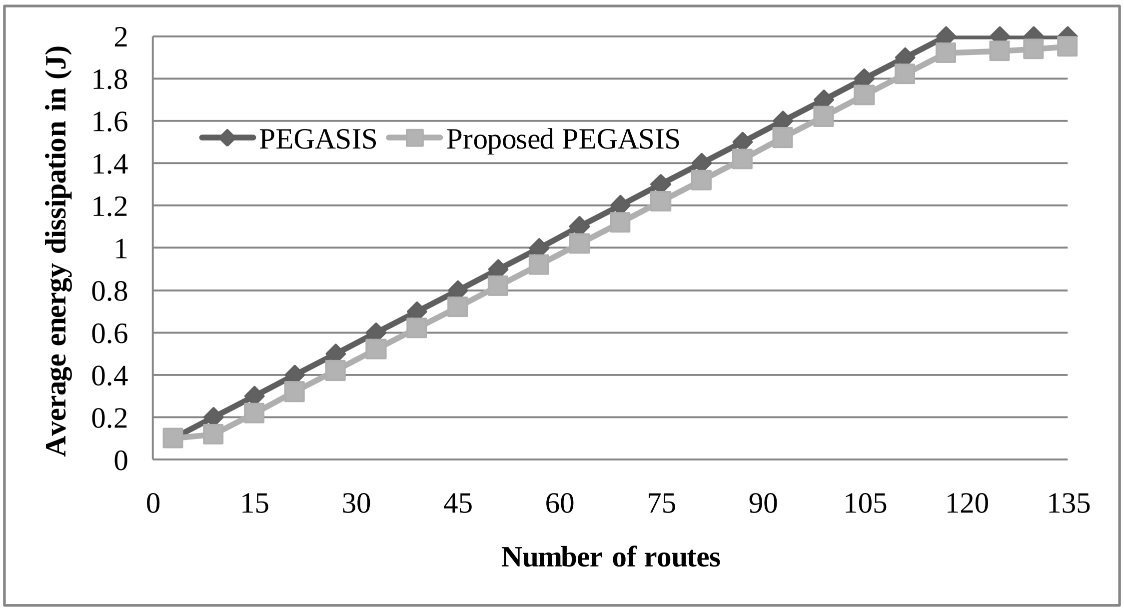

Figure 4.13 Energy Dissipation with Respect to Execution of Routes.

Figure 4.14 represents that average of nodes die earlier in case of PEGASIS. In presented fuzzy based protocol nodes are alive for more time period. So it can be concluded that, the presented system is in highly steady state condition between the periods of first node die to average of the node alive. Also Figure 4.14 monitors about the period of time when a first node gets fail to communicate. It has been concluded that very earlier first node get failed in PEGASIS [34]. As it has been noticed that presented algorithm survives more than PEGASIS.

In [42], the writer detailed about half of nodes gets alive (HNA) algorithm. With that algorithm user can calculates mathematically about the estimation of the ruler values for the route that how many nodes are dead nodes. The dead node of very earlier node and average of nodes are alive with respect to distance at km^2.This presented fuzzy based PEGASIS is also optimal when the sensor nodes are heavily installed.

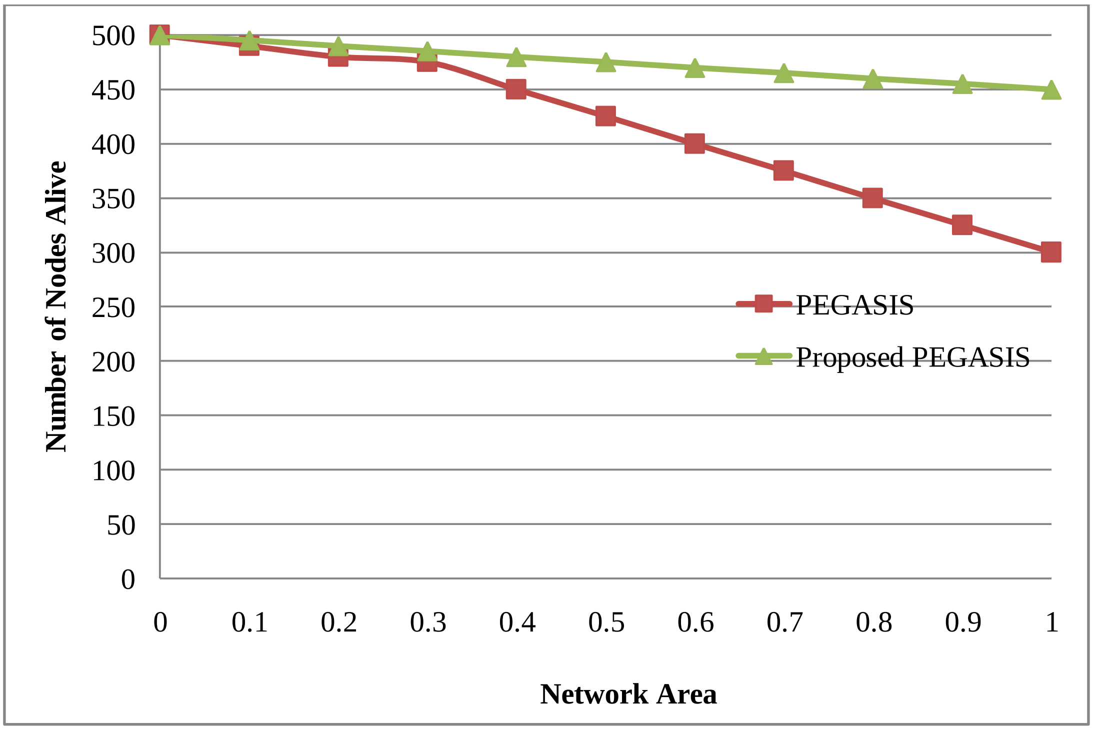

Figure 4.14 Sensor Nodes Alive Representation.

Figure 4.15 analyzed that 72% increases in packet transmission with regards to dead node in case of fuzzy based simulation. The simulation shows that only small gathered packets forward to BS in case of PEGASIS as that from presented algorithm as shown in [43]. Figure 4.15 analyzed that routing process is highly steady in nature compared from the PEGASIS.

It also displays about end to end packet transmission. It mainly defers the characterized of the node in case of packet taken by the chain to transmit the information from SCH to BS. It is clear that end to end delay time period for transmission of packets is decreased in the presented routing protocol compared with PEGASIS technique.

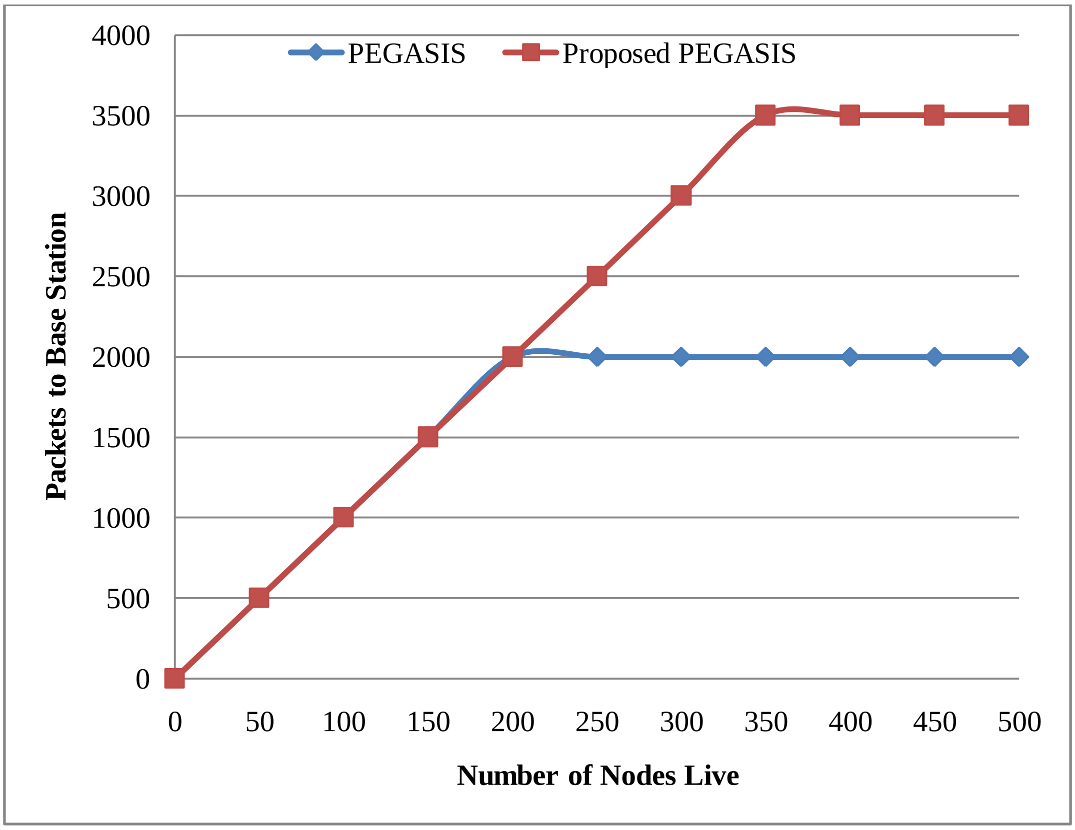

Figure 4.15 Number of Packets Sent to the Base Station.

As network lifetime and network stability are the vital parameters to assess the system execution. So, Figure 4.16 depicts the stability and network lifetime of the PEGASIS routing protocol. In presented methodology it is depicted that the objective has been declared about achievement in more system lifetime while planning a route.

To confirmation the network lifetime, it has been checked that it depends on the parameter: survival of nodes with respect to available route. To maintain a route PEGASIS [11, 34] dissipates the energy from single peak threshold level. To overcome the more wasted numbers of energy levels fuzzy logic is defined. Hence, results in restoring of residual energy in datacenters and enhancement in network lifetime.

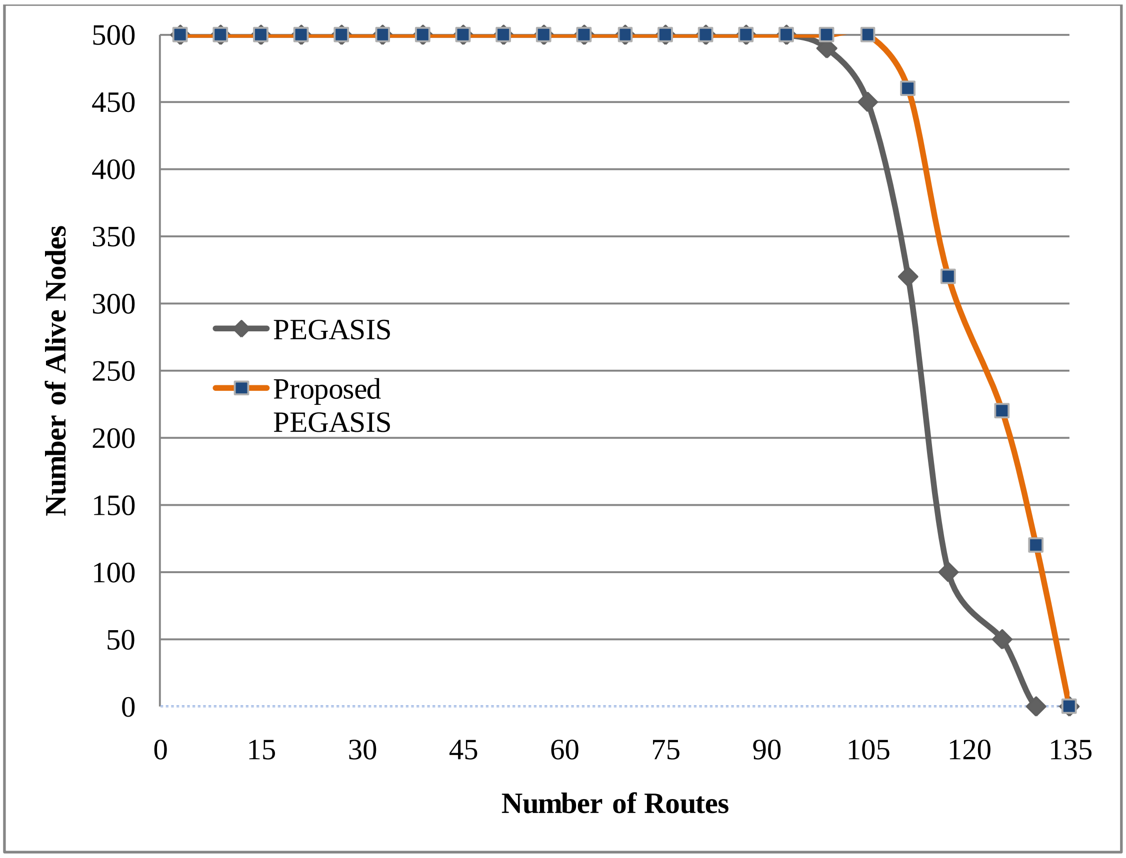

Figure 4.16 System Lifetime with Chaining Algorithm.

4.7 CHAPTER SUMMARY

This chapter provides the results obtained by fuzzy based PEGASIS. To attain the results, methodology had been discussed in chapter 3. It also provides the extreme knowledge about fuzzy logic routing protocol. Main focus on comparison of PEGASIS and fuzzy logic based PEGASIS has been presented. Parameters that have been enhanced by the presented algorithm are: the energy utilization optimally, stability and increment in network lifetime.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

The hierarchical routing protocol based on PEGASIS in [11, 34] presented the best route process using the chain algorithm. This chain based algorithm utilizes a greedy node to node connection approach. For chain arrangement, there is result in the development of long connections. Besides, selection in chain head node, energy utilization is more in case for transmission of information to BS. So that, in [11, 34] authors utilization the idea of topology control for chain development which misuses spatial node excess which reduces the network lifetime. To overcome the misuses of spatial excess in PEGASIS, fuzzy based algorithm has been discussed.

In this dissertation, a fuzzy based hierarchical PEGASIS routing protocol has been presented which randomly initialize the multi hop and end to end route between the nodes of the chain. The appropriate super chain node head has been selected by using proper selection of membership functions. Three input membership functions are: battery power, workload delayed time, workload executed nodes and one output membership function: routed processed priority is utilized. By selection of optimal membership values there is reduction in energy dissipation. It is noted that network lifetime has been increased by reducing the energy dissipation and provide the stability in nodes. This fuzzy based algorithm show that fuzzy based PEGASIS routing protocol is stable and energy efficient process compared to PEGASIS [43] for commercial as well as smaller industrial area.

5.2 FUTURE SCOPE

The design of wireless sensor network is a topic without boundaries. In further research, more experiments will be performing that enhance the network lifetime and reduces the obstacles that create problem to reduce the energy dissipation in wireless sensor nodes. Future results will be more optimal and intelligent to inform about deployment of sensor networks in large areas.

REFERENCES:

[1] R. Min, M. Bhardwaj, S. Cho, A. Sinha, E. Shih, A. Wang, and A. P. Chandrakasan, "Low Power Wireless Sensor Networks," *Proceedings of International Conference,* Bangalore, India, January 2001.

[2] J. M.Rabaey, M. J.Ammer, J. L. daSilva, D. Patel and S. Roundy, "Pico Radio supports ad hoc ultra low power wireless networking," *IEEE Computer*, Vol. 33, pp. 42-48, July 2000.

[3] K. Sohrabi, J. Gao, V. Ailawadhi, and G. Pottie., "Protocols for self organization of a wireless sensor network," *IEEE Personal Communications*, Vol. 7, No. 5, pp. 16-27, October 2000.

[4] S. Lindsey, C. Raghavendra and K. M. Sivalingam, "Data Gathering Algorithms in Sensor Networks Using Energy Metrics," *IEEE Transactions On Parallel and Distributed Systems*, Vol . 13, No. 9, September 2002.

[5] N. A. Pantazis, S. A. Nikolidakis and D. D. Vergados, "Energy-efficient routing protocols in wireless sensor networks: A survey," *IEEE Communications Surveys and Tutorials*, Vol. 15, No. 2, pp. 551-591, July 2013.

[6] A. Sridharan, and B. Krishnamachari, "Explicit and precise rate control for wireless sensor networks," *In Proceedings of the 7th ACM Conference on Embedded Networked Sensor Systems*, pp. 29-42, November 2009.

[7] J. Patel and N. Khare, "Review on Priority based Congestion Control Techniques for Wireless Sensor Network," *International Journal of Computer Applications*, Vol. 95, No. 6, January 2014.

[8] S. Rangwala, R. Gummadi, R. Govindan, and K. Psounis, "Interference-aware fair rate control in wireless sensor networks," *In ACM SIGCOMM Computer Communication Review*, Vol. 36, No. 4, pp. 63-74, June 2006.

[9] C. Y. Wan, S. B. Eisenman, and A. T. Campbell, "CODA: congestion detection and avoidance in sensor networks," *In Proceedings of the 1st International Conference on Embedded Networked Sensor Systems*, pp. 266-279. November 2003.

[10] A. Woo, and D. E. Culler, "A transmission control scheme for media access in sensor networks," *In Proceedings of the 7th Annual International Conference on Mobile Computing and Networking*, pp. 221-235, July 2001.

[11] S. Lindsey, and C. S. Raghavendra, "PEGASIS: Power-efficient gathering in sensor information systems," *In Aerospace Conference Proceedings*, Vol. 3, pp. 3-3, 2002.

[12] S.M. Jung, Y. J. Han, and T. M. Chung, "The concentric clustering scheme for efficient energy consumption in the PEGASIS," *In Advanced Communication Technology, The 9th International Conference*, Vol. 1, pp. 260-265, 2007.

[13] L. Almazaydeh, E. Abdelfattah, M. Al. Bzoor, and A. A. Rahayfeh, "Performance evaluation of routing protocols in wireless sensor networks," 2010.

[14] J. Ayres, N. Gerner, J. Ossher, L. Zhu, "Cougar: The Sensor Network Is the Database," Cornell University, Ithaca, NY, http://www.cs.cornell.edu/database/cougar/.

[15] P. A. Wayne "Mobility Technologies," http://www.mobilitytechnologies.com/ntdc/.

[16] K. Gruber, C. Jackson, ''Sensor Network Applications,'' University of California, http://wwwcsif.cs.ucdavis.edu/yick/sensor/Sensorapplication.html.

[17] C. Y. Chong, and S. P. Kumar, "Sensor networks: evolution, opportunities, and challenges," *Proceedings of the IEEE*, Vol. 91, No. 8, pp. 1247-1256, 2003.

[18] N. Bulusu, J. Heidemann, and D. Estrin, "Adaptive beacon placement," *Distributed Computing Systems in 21st International Conference*, pp. 489-498, 2001.

[19] P. Bergamo and G. Mazzini, "Localization in sensor networks with fading and mobility," *Personal, Indoor and Mobile Radio Communications in 13th IEEE International Symposium*, Vol. 2, pp. 750-754, 2002.

[20] Q. Li, M. D. Rosa, and D. Rus, "Distributed algorithms for guiding navigation across a sensor network.," *In Proceedings of the 9th Annual International Conference on Mobile Computing and Networking*, pp. 313-325, 2003.

[21] R. Iyengar, and B. Sikdar, "Scalable and distributed GPS free positioning for sensor networks," *In IEEE International Conference*, Vol. 1, pp. 338-342, 2003.

[22] P. Nayak, and A. Devulapalli, “A fuzzy logic-based clustering algorithm for WSN to extend the network lifetime,” *IEEE Sensors Journal*, Vol. 16, No. 1, pp. 137-144, January 2016.

[23] R. Choudhary, S. Kumar, A. Deepak, and D. Dash, “Data aggregation in Wireless Sensor Network: An integer linear programming formulation for energy optimization,” *In Wireless and Optical Communications Networks (WOCN)*, pp. 1-6, 2016.

[24] S. L. Chen, “A power-efficient adaptive fuzzy resolution control system for wireless body sensor networks,” *IEEE Access Networks*, Vol.*3*, pp. 743-751, 2014.

[25] Z. J. Zhang, C. F. Lai, and H. C. Chao, “A green data transmission mechanism for wireless multimedia sensor networks using information fusion,” *IEEE Wireless Communications*, Vol. 21, No. 4, pp. 14-19, 2014.

[26] A. Karthikeyan, V. Jagadeep, and A. Rakesh, “Energy efficient multihop selection with PEGASIS routing protocol for wireless sensor networks,” *In Computational Intelligence and Computing Research (ICCIC)*, pp. 1-5, 2014.

[27] M. Gupta, and L. Saraswat, “Energy aware data collection in wireless sensor network using chain based PEGASIS,” *In Recent Advances and Innovations in Engineering (ICRAIE)*, pp. 1-5, 2014.

[28] G. Brante, G. S. Peron, R. D. Souza, and T. Abrao, “Distributed fuzzy logic-based relay selection algorithm for cooperative wireless sensor networks,” *IEEE Sensors Journal*, Vol. 13, No. 11, pp. 4375-4386, 2013.

[29] J. S. Lee, and W. L. Cheng, “Fuzzy-logic-based clustering approach for wireless sensor networks using energy predication,” *IEEE Sensors Journal*, Vol. 12, No. 9, pp. 2891-2897, 2012.

[30] H. Xia, Z. Jia, L. Ju, and Y. Zhu, “Trust management model for mobile ad hoc network based on analytic hierarchy process and fuzzy theory,” *IET Wireless Sensor Systems*, Vol. 1, No. 4, pp. 248-266, 2011.

[31] T. Liu, and F. Li, “Power-efficient clustering routing protocol based on applications in wireless sensor network,” *In Wireless Communications, Networking and Mobile Computing, WiCom'09*, pp. 1-6, 2009.

[32] K. C. Huang, Y. S. Yen, and H. C. Chao, “Tree-clustered data gathering protocol (TCDGP) for wireless sensor networks,” *In Future Generation Communication and Networking (FGCN)*, Vol. 2, pp. 31-36, 2007.

[33] P. Santi, “Topology control in wireless ad hoc and sensor networks,” *ACM Computing Surveys (CSUR)*, Vol. 37, No. 2, pp. 164-194, 2005.

[34] S. D. Muruganathan, D. C. F. Ma, R. I. Bhasin, and A. O. Fapojuwo, “A centralized energy-efficient routing protocol for wireless sensor networks,” *IEEE Communications Magazine*, Vol. 43, No.3, pp. S8-13, 2005.

[35] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy-efficient communication protocol for wireless microsensor networks,” *In System Sciences, Proceedings of the 33rd annual Hawaii international conference*, pp. 10-19, 2000.

[36] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, “An application-specific protocol architecture for wireless microsensor networks,” *IEEE Transactions on Wireless Communications*, Vol. 1, No. 4, pp. 660-670, 2002.

[37] T. S. Rappaport, “An Introduction to Indoor Radio Propagation,” http://sssmag.com/indoor.html, 2001.

[38] R. H. Katz, ‘‘CS 294-7: Radio Propagation,’’ White Paper, University of California Berkeley, 1996.

[39] K. Akkaya, and M. Younis, “A survey on routing protocols for wireless sensor networks,” *Ad hoc Networks*, Vol. 3, No. 3, pp. 325-349, 2005.

[40] J. Kusuma, L. Doherty, and K. Ramchandran, “Distributed compression for sensor networks,” *In IEEE International Conference*, Vol. 1, pp. 82-85, 2001.

[41] R. R. Kompella, and A. C. Snoeren, “Practical lazy scheduling in sensor networks,” *In Proceedings of the 1st International Conference on Embedded Networked Sensor Systems*, pp. 280-291, 2003.

[42] K. Toshimitsu, Y. T. Katayama, and M. A. Ogawa, “A novel spread slotted aloha system with channel load sensing protocol,” *IEEE Journal on Selected Areas in Communications*, Vol. 12, No. 4, pp.665-672, 1994.

[43] V. Nehra, R. Pal, and A. K. Sharma, "Fuzzy-based leader selection for topology controlled PEGASIS protocol for lifetime enhancement in wireless sensor network," *International Journal of Computers and Technology*, Vol 4, No. 3, pp. 755-764, 2013.

LIST OF PUBLICATIONS:

[1] Y. Verma and K. Singh, "Energy Aware-PEGASIS based Autonomous Resources Inference Scheduling for Wireless Sensor Network," Communicated - *Journal of Science and Technology.*

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