ENHANCED CLUSTERING MECHANISM IN WIRELESS SENSOR NETWORKS

Thesis submitted in partial fulfillment of the requirements for the award of degree of

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, **"Enhanced Clustering Mechanism in Wireless Sensor Networks"**, in partial fulfillment of the requirements for the award of degree of Master of Engineering in Computer Science and Engineering submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Dr. Neeraj Kumar** and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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Abstract

Wireless Sensor Networks (WSNs) have been used in wide areas of applications. For efficient data transmission in these networks, an intelligent clustering mechanism is required. In this thesis, we have designed and implemented a new energy efficient clustering mechanism for sensor nodes. Nodes are grouped into different cluster based upon some predefined criteria and an efficient algorithm is designed for the same. The complexity analysis of the proposed scheme is also included. The proposed scheme is simulated by varying different parameters and results obtained show that the proposed scheme performs well with respect to these parameters.

Table of Contents

List of Figures

List of Tables

Abbreviations

WSNs	Wireless Sensor Networks
ACK	Acknowledgment
MAC	Medium Access Control
MN	Mobile Node
QoS	Quality of Service
ADC	Analog to Digital Converter
DLL	Data Link Layer
TDMA	Time Division Multiple Access
CSMA	Career Sense Multiple Access
CSMA/CA	Collision Avoidance
S-MAC	Sensor MAC
RTS	Request to Send
CTS	Clear to Send
TRAMA	Traffic Adaptive MAC Protocol
DMAC	Data Gathering MAC
LEACH	Low Energy Adaptive Clustering Hierarchy
BS	Base Station
CHs	Cluster Heads

Chapter 1:

Introduction

1.1 Wireless Sensor Networks (WSNs)

Wireless Sensor Networks are a typical type of wireless networks consisting of a large number of sensor nodes. WSNs are heavily applied in many domains and it is a one of the largest growing types of network today and becoming the domain of interest of a large pool of researchers. WSNs have been used in wide area of applications such as civilian and military operations for example environment monitoring, battle field surveillance and industry process control. WSNs are deployed in a physical area to collect the data and transmit the signals to the nearest access point. The important and significant feature of wireless sensor networks make WSNs different from other contemporary networks are self-organization, low electricity usage, low memory usage, low bandwidth requirements for communication, large scale nodes, wireless and infrastructure less architecture. It is expect that in 7-12 years that the whole worked will be covered with wireless sensor networks. This can be considered as the web becoming a physical network. The new cutting edge technology with unlimited potential for various applications. WSN is composed by a large numbers of sensing the self powered nodes.

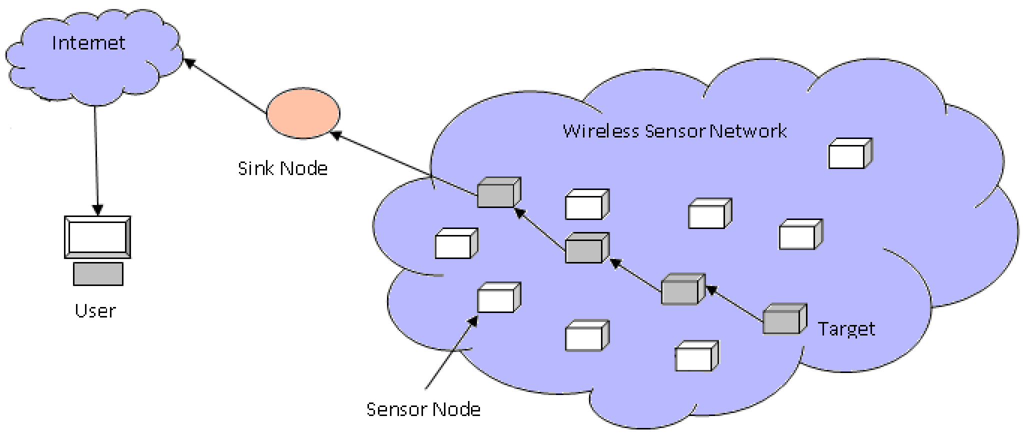

Figure 1.1: Architecture of WSNs

The WSNs is gaining popularity day by day. As the speed of processor is increasing at the higher rate but at the same time battery backup is not increasing so there is energy constraint in sensor node. The sensor node is fully dependant on energy to perform communication and computation as there is limited supply of energy there is a need of energy efficient way for performing computation and communication. In WSNs the sensor nodes sends and receive the data via wireless communication. The wireless communication is an energy consuming task. The nodes are deployed at a remote location where it is difficult to change the battery once the energy is depleted. To save the energy the sensor node works in different mode such as active, idle and sleep mode according to the demand application. In active mode the node spends energy on sending and receiving the information. In idle mode the node does not send and receive the data but it still consume the energy for computations on the other hand in sleep mode it simply stop working to save energy. The following measures can be taken for energy efficient wireless communication in WSNs [1].

- To schedule the state of the nodes (i.e. transmitting, receiving, idle or sleep).
- Changing the transmission range between the sensing nodes.
- Using efficient routing and data collecting methods.
- Avoiding the handling of unwanted data as in the case of overhearing.

The battery is the only source of energy for nodes in WSNs. The sensor nodes sense, process and transmit the collected information to the sink via wireless communication. Sensing and transmit activity consumes a lot of energy, sometimes the sensor nodes are located or deployed in harsh environment where it is not feasible to replace the battery so there is a need of energy efficient way for wireless communication. The energy efficient way for wireless communication is hot research topic in WSNs. The researchers have proposed many power aware routing protocols for wireless communication in WSNs but still there is a lot of scope of research in this field.

All the protocols that are designed and implemented in WSNs should provide some real-time support as they are applied in areas where data is sensed, processed and transmitted based on an event that leads to an immediate action. A protocol is said to have real-time support if and only if it is fast and reliable in its reactions to the changes prevailing in the network. It should provide redundant data to the base station or sink using the data that is collected among all the sensing nodes in the network. The delay in transmission of data to the sink from the sensing nodes should be short, which leads to a fast response.

1.1.1 Sensor Node Structure

A sensor node basically comprises of four parts that are as follows:-

- A sensing unit
- A processing unit
- A communication unit
- A power unit

The sensing unit is divided into two sub parts sensor and ADC. The sensor sense the physical event and produce analog signals based on the observed event. The ADCs (Analog to digital converter) is there for changing the analog signals into digital signals, which then act as an input to the processing unit. The processing unit is made up of a microprocessor or microcontroller with memory which supply sophisticated control to the sensor node. The communication unit is responsible for performing communication. It comprises of short range radio for sending and receiving information via a radio channel. The power unit is responsible for providing energy supply to the components of the sensor node. The power unit comprise of a battery for energy supply to all other components of the sensor nodes.

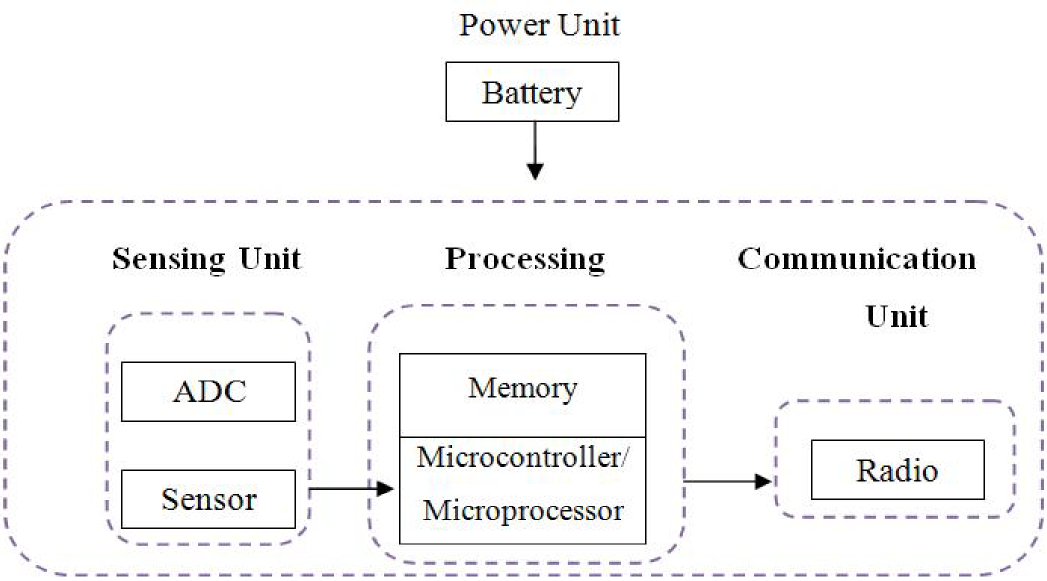

Figure 1.2: Sensor Node Structure

1.1.2 WSNs Communication Architecture

A sensor network basically made up of huge number of sensor nodes that are deployed randomly or in pre-fixed way in the sensing area. WSNs consist of one or more data sinks or base stations that are placed close to or inside the sensing area, as shown in Figure 1.3. The sink(s) sends request to the sensor nodes in the sensing region while the sensor nodes work together to carry out the sensing task and send the sensed information to the BS.

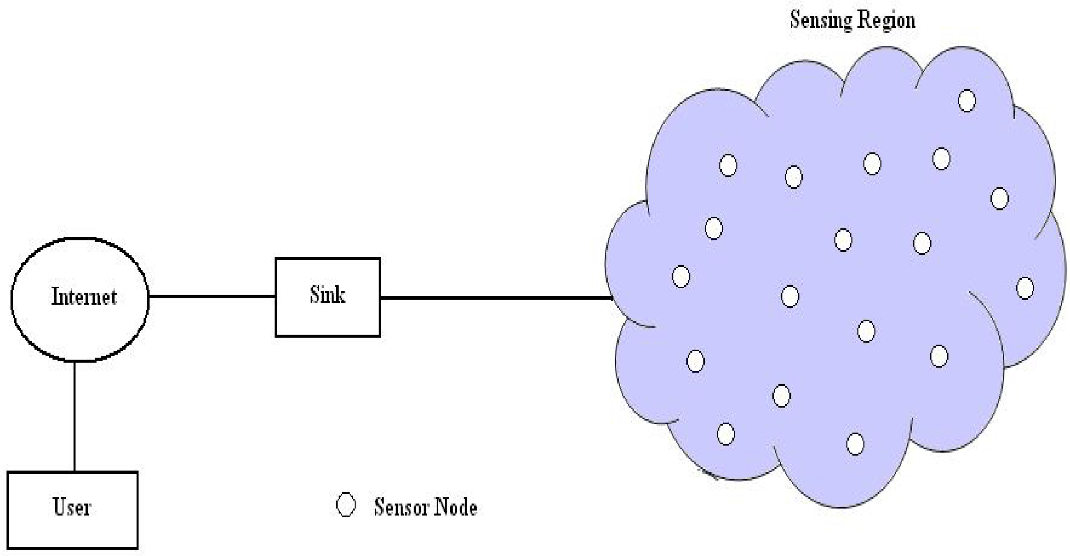

Figure 1.3: Sensor Network

This section describes the Protocol Stack of WSNs [2]. The protocol stack used by the cluster head and sensor nodes are shown in Figure 1.3. It depicts a complete picture of the WSNs i.e how it works. It is much like the traditional protocol stack shown in figure 1.4, which consists of five layers; Data Link Layer, Network Layer, Transport Layer, Application Layer. It is similar to TCP/IP protocol suite. The physical layer is responsible for frequency modulation, data encryption etc. The DLL is responsible for multiplexing, error control and also ensures the reliable communication connection. The Network Layer used for routing the data forward by the transport layer. The Network Layer must consider the power efficiency and data aggregation. The transport layer helps in the reliable delivery of the data.

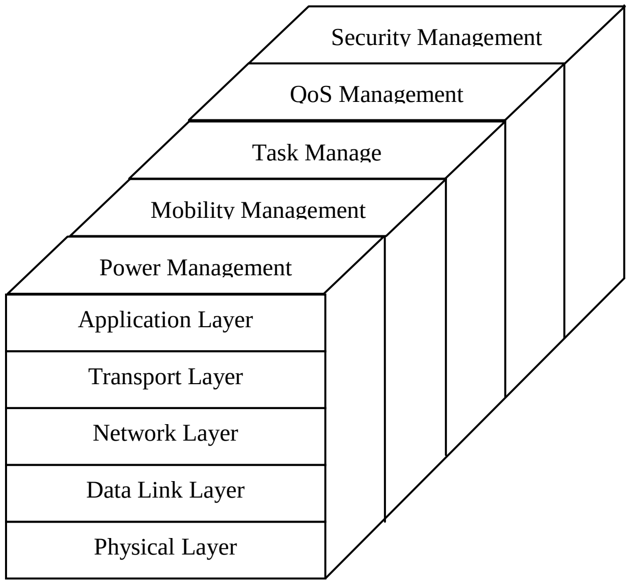

Figure: 1.4 Protocol Stack for Sensor Networks

WSNs must also take care of following management services like quality of service, power and security issue in order to function efficiently. The power management fields job is to minimize the power consumption in order to save energy [3]. QoS can be vital if there is real time need with respect to the data services. Security management manages, sniffing and controlling the security behavior of network.

1.1.3 Feature of WSNs

1. Light Weight Terminals: WSNs use the mobile nodes with less CPU processing ability, low memory size and low power storage. These kinds of devices need optimized algorithms for implementing the communicating functions.
2. Multi hop routing: Wireless routing algorithms are of two types single hop and multi hop. Single hop is simpler than multi hop in terms of structure and implementation also the functionality cost is lesser.
3. Dynamic Network Topology: The Network topology may change frequently and randomly because of the mobile nodes. It should adapt to propagation condition and the network traffic. The mobile nodes dynamically establish the routing path as they move to destination.
4. Distributed Operation: In WSNs the control and management services of the whole network are distributed among the terminals. The communicating node themselves acts as a receiver and transmitter as needed.

5. Autonomous Terminals: Every mobile terminal is an autonomous node, which can function both as a router and a host. But usually the endpoints and switches are same in WSNs.
6. Mobile and Static Network [4]: According to the mobility of sensor nodes, a sensor network can be static or mobile. In a static sensor network, all sensor nodes are static without movement, which is the case for many applications. However, some sensor applications require mobile nodes to accomplish a sensing task. A wireless biosensor network using autonomously controlled animals is a typical example of mobile sensor networks. Compared with static sensor networks, which is simpler to control and easier to implement, the design of mobile sensor networks must consider the mobility effect, which increases the complexity of implementation.
7. Nondeterministic and Deterministic Network [4]

   According to the deployment of sensor nodes, a sensor network can be deterministic or nondeterministic. In a deterministic sensor network, the positions of sensor nodes are preplanned and are fixed once deployed. This type of network can only be used in some limited situations, where the preplanned deployment is possible. In most situations, however, it is difficult to deploy sensor nodes in a preplanned manner because of the harsh or hostile environments. Instead, sensor nodes are randomly deployed without preplanning and engineering. Obviously, nondeterministic networks are more scalable and flexible, but require higher control complexity.
8. Static - Sink and Mobile - Sink Network [4]

   According to the requirement of the application the data sink in WSNs may be fixed or mobile. In a static environment, the sink(s) node is located at the fixed position. The location can be closer or inside the sensor area. All sensor nodes send their processed or collected information to the sink(s) node. The fixed sink network is easier to handle, but still faces the problem of hotspot effect. The sensor node that are located at a far distance from the sink node sends huge amount of traffic to the sensor nodes are located closer to the sink node for forwarding to the sink node. Due to this the node that are closer to the sink dies early, thus resulting in network separation and even distracting common network procedure. In a mobile environment the sink(s) node freely moves around in the sensing area to gather information from sensor nodes, which provides stability to the traffic load of nodes and remove the hotspot effect in the WSNs.

9. Single - Sink and Multi sink Network [4]

   A sensor network can have a single sink or multiple sinks. In a single - sink network, there is only one sink located close to or inside the sensing region. All sensor nodes send their sensed data to this sink. In a multi sink network, there may be several sinks located in different positions close to or inside the sensing region. Sensor nodes can send their data to the closest sink, which can effectively balance the traffic load of sensor nodes and alleviate the hotspot effect in the network.

10. Single - Hop and Multi hop Network [4]

   According to the number of hops between a sensor node and the data sink, a sensor network can be classified into single - hop or multi hop. In a single - hop network, all sensor nodes transmit their sensed data directly to the sink, which makes network control simpler to implement. However, this requires long - range wireless communication, which is costly in terms of both energy consumption and hardware implementation. The furthest nodes from the data sink will die much more quickly than those close to the sink. Also, the overall traffic load in the network may increase rapidly with the increase of the network size, which would cause more collisions, and thus increase energy consumption and delivery latency. In a multi hop network, sensor nodes transmit their sensed data to the sink using short - range wireless communication via one or more intermediate nodes. Each intermediate node must perform routing and forward the data along a multi hop path. Moreover, data aggregation can be performed at an intermediate node to eliminate data redundancy, which can reduce the total amount of traffic in the network and thus improve the energy efficiency of the network. In general, a single - hop network has simpler network architecture and thus is easier to control. It is suitable for applications in small sensing areas with sparsely deployed sensor nodes. Multi hop networks have a wider range of applications at the cost of higher control complexity.

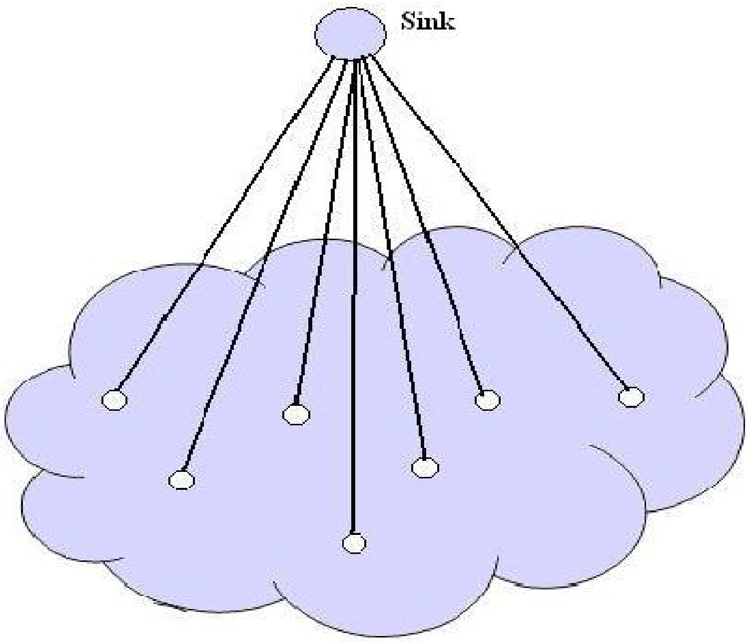

Figure 1.5: Single Hop Network

11. Self - Reconfigurable and Non - Self - Configurable Network [4]

    According to the configurability of sensor nodes, a sensor network can be self - configurable or non - self - configurable. In a non - self - configurable network, sensor nodes have no ability to organize themselves into a network. Instead, they have to rely on a central controller to control each sensor node and collect information from them. Therefore, this type of networks is only suitable for small - scale networks. In most sensor networks, however, sensor nodes are able to autonomously organize and maintain their connectivity by themselves and collaboratively accomplish a sensing task. A network with such self - configurability is suitable for large - scale networks to perform complicated sensing tasks.

12. Heterogeneous and Homogeneous Network [4]

    According to the task performed by sensor node the network can be homogeneous or heterogeneous. If the sensor nodes are performing the same task which means that the sensor nodes have the same capability in term of power, processing and memory. On the other hand the heterogeneous network comprises of sophisticated sensor node that can have the more processing and communication potential as compare to normal sensor node. In heterogeneous network the sensor node can perform more processing and communication job that increasing the lifetime of the WSNs.

1.1.4 Applications of WSNs

Wireless Sensor Networks have the potential to enable many new applications. These can be classified as follows:-

Table 1.1: Applications of WSNs

Application	**Services**
Environment Monitoring	• Food Detection • Weather Forecasting • Determine the evolution of sandbars using image processing techniques. • Video and imaging sensors used to monitor the structural health of bridges or other civil structures. • Monitoring the changing environmental condition that affects crops and livestock.
Health Monitoring	• Patients will carry medical sensors to monitor parameters such as body temperature, blood flow, ECG, and breathing activity. Remote medical centres will monitor the condition of their patients to infer emergency situations. The nodes of light weight sensor are attached to the arm of patient which detects their heart rate and blood pressure.
Traffic Control	• Traffic Monitoring and control • Smart parking advice systems based on WSNs will detect available parking spaces and provide drivers with automated parking advice. • Monitoring the road segments with heavy traffic. • it is possible to monitor the road works as

	well as accidents.
Industrial Sensing	• Monitoring the equipment failures. • Monitoring corrosion using network of wireless corrosion sensors. • Chemical plants or oil refiners can use sensors to monitor the condition of their miles of pipelines.
Battle field Monitoring	• Sensors can be deployed in a battlefield to monitor the existence of forces and vehicles, and track their movements • Counter Terrorism Applications. • Protection from potential invasions at power plants, airports and military bases. • Locate missing persons, identify criminals or terrorists. These types of networks are used to detect and access maximum information about the enemy.

1.1.5 Challenges facing by WSNs

The below mentioned challenges shows the inefficiencies and bottlenecks that have to be overcome in WSNs environment [5].

- **Transmission Range**: The range of radio band is limited and the data rate also offers less transmission speed than a wired network. Due to this routing protocols should use bandwidth in the way so that it keeps the overhead as low as possible.
- **Battery life**: it is one of the major constraints for the wireless nodes. So to overcome this conservation of power using power saving algorithms must be considered.
- **Loss of Packets**: During transmission, large amount of packets are lost due to the different factors such as high bit error rate, congestion in the network and collisions, attenuation etc.

- **Mobility Induction**: The topology used in WSNs is of dynamic nature. So sometimes the ongoing session suffers frequent path breaks. Therefore with the presence of high bit error rate in channel it is very much difficult to deliver a reliable delivery to the destination.
- **Potentially frequent network partitions**: As the network is not centralized, therefore the communication between different-different pair of nodes in the network lead to various partitions of the network.
- **Limited wireless bandwidth** [6]: The nodes with the limited bandwidth and battery resources might be reluctant to forward data packets for other nodes, unless there is an additional mechanism in place to give an incentive to provide this service.
- **Power Conservancy**: Due to the limited power available, it becomes a necessity to conserve the power in order to make it available resources which is again a challenging task.
- **Quest for power-efficient protocols**: There has always been a need for effective better protocols and better power management schemes. Many such protocols are designed and deployed in order to accomplish an efficient power management technique.
- **Security**: The WSNs are more vulnerable to attacks due to lack of central coordination and shared wireless medium. To have a reliable and secure communication among the nodes in the network is again a challenge.

1.2 Requirements of MAC protocol for WSNs

A wireless communication technology has already set the stage for large scale development of wireless sensor network. The need to minimize the energy consumption has driven significant researches in wireless sensor networks. MAC in WSNs is essential to coordinate the channel access among competing devices. Given the energy constraints of the small, battery powered sensor devices, it is desirable that the MAC layer provides reliable, error-free data transfer with minimum efficient resource utilization. MAC layer attempts to address these issues by enforcing channel access, scheduling policies and error control, minimize control overhead and be energy-efficient.

I. Demirkol *et al.* [7] in “A Survey on MAC Protocols for Wireless Sensor Networks” proposed Reasons of energy waste and properties of a Well-Defined MAC protocol.

When a node receives more than one packet at the same time, these packets are termed collided, even when they coincide only partially. All packets that cause the collision have to be discarded and retransmissions of these packets are required, which increase the energy consumption. Although some packets could be recovered by a capture effect, a number of requirements have to be achieved for successful recovery. The second reason for energy waste is overhearing, meaning that a node receives packets that are destined to other nodes. The third energy waste occurs as a result of control-packet overhead. A minimal number of control packets should be used to make a data transmission. One of the major sources of energy waste is idle listening, that is, listening to an idle channel in order to receive possible traffic. The last reason for energy waste is over emitting, which is caused by the transmission of a message when the destination node is not ready. Given the above facts, a correctly designed MAC protocol should prevent these energy wastes.

1.2.1 Peculiarities of Efficient MAC Protocol: The following three attributes need to be considered, during the design of a good MAC protocol for the WSN’s [8].To design a good MAC protocol for wireless sensor networks, the following attributes must be considered. The first attribute is energy efficiency. We have to define energy-efficient protocols in order to prolong the network lifetime. Other important attributes are scalability and adaptability to changes. A good MAC protocol should gracefully accommodate such network changes.

- **Energy Efficiency-** The sensor nodes uses battery for increasing the circuitry and it is not possible to change or recharge batteries due to their minimum hardware specifications. To minimize the energy consumption of the battery the protocols need to be designed in such a manner that the sensor nodes consume less power and increase the overall performance of the network.
- **Latency-** It is defined as the time taken to send a data to its appropriate destination/ sink is called propagation time. But because of some reasons this process is delayed which is called latency. The latency usually depends on the transmission channel use for the communication. In case of sensor network applications all the packets must be captured either in the monitoring mode or

master mode within more specifically within real-time. This is important factor to consider for increasing the lifetime of the network.

- **Scalability-** Scalability is an important factor in wireless sensor networks. A network area is not always static, it changes depending upon the user requirements. All the nodes in the network area must be scalable or able to adjust themselves to the changes in the network structure depending upon the user [9].
- **Energy Awareness:** Every node uses energy from the battery for activities like sensing, processing, storage and transmission. A node in the network should know how much energy will be utilized to perform a new task and how much of energy is remaining to send the others packets to destination [10]. For this purpose signal to noise ratio is used for increasing the signals strength of receiving data.
- **Throughput-** Requirement of throughput varies with the variations in the applications. Some of the sensor network applications require information sampling with fine temporal resolution. In which the sink node need to be able to receive more and more data at a greater rate.
- **Network Power Usage:** All the sensor nodes in the network use a certain amount of network power which helps them to perform certain activities like sensing or processing or even forming groups within the network area. The amount of energy or power utilized by the sensor nodes or a group of sensors within the network is known as network power usage [10].
- **Data Aggregation:** Sensors nodes generates huge amount of similar packets, data aggregation is used to reduce the transmission of similar packets. Data aggregation is combination of information from different sensor nodes by applying functions like suppression, average, maximum. The routing protocol incorporates this data aggregation technique to reduce data redundancy and achieve energy efficiency.

1.2.2 Reasons of Energy Wastes in WSNs: Major causes of wastage of energy in a wireless sensor network, are basically categorized in the following three categories [11].

- **Collision-** In WSNs, energy efficiency is the major issue and during communication different nodes send data at the same to the sink or base station so collision may occur and these packets can be corrupted and for retransmission energy is consumed. When a transmitted packet is debased due to any encumbrance, occurred due any collision in the packet transiting over the network or any other mismanagement but these retransmissions increase energy consumption and wastage.
- **Overhearing-** Sometimes it happens that a node inadvertently picks up a packet that is destined to any other node. In such cases the sender is in illusion that the packets are delivered to the appropriate node, for which the packet was meant. So sue to this overhearing the nodes need to retransmit the packets, which consumes the energy along with increasing the traffic.
- **Packet Overhead-** There are some situations in which the nodes need to send the control messages to other nodes, usually these are sent to the whole network by the manager node. This is a control packet overhead. Sending and receiving the control packet is also a overhead sometimes because these packets also consumes the energy and this leads to the energy wastage as there is no data transmitted in the control messages.
- **Idle Listening-** Idle listening occurs when a sensor node is listening to the radio channel to receive possible data packets while there are actually no data packets sent in the network. In this case, the node will stay in an idle state for a long time, which results in a large amount of energy waste.

1.3 Objectives

There are various protocols that have been proposed till date in order to successfully deliver the packet from source to destination with minimum usage of energy as the battery lifetime is limited in WSNs. Battery is the only source of life for the node in WSNs. Each node depends on energy for its activities like transmitting, receiving, idle or sleep mode. The failure of one node can interrupt the entire system or application so using the efficient shortest path and data collecting methods in which the node consume less energy. All are suitable to one or more network scenarios and depends upon different type of applications. The main objective is to find power aware protocol for WSNs in order to overcome such energy efficiency problems as those stated above. The ultimate objective behind the various protocol designs is to keep the sensors in operation for as long as possible, thus extending the network's lifetime.

The energy consumption of the sensors is dominated by data transmission and reception. Therefore, protocols designed for WSNs should be as energy efficient as possible to prolong the lifetime of individual sensors, and hence the network's lifetime. In this thesis we have surveyed various MAC protocols and LEACH-based protocols and discussed how they improve energy consumption in WSNs and increase network's lifetime small and large WSNs. Furthermore, we provide a table summary showing the comparison of each protocol. Also few comparisons between the different protocols have been made in order to determine the following features:

- **Efficiency:** it should make a minimum number of transmissions to deliver a packet.
- **Scalability:** it should be able to scale for a large network.
- **Low node cost:** Sensor nodes are usually deployed in a harsh environment in large numbers and cannot be reused, reducing cost of sensor nodes is important and will result into the cost reduction of whole network.
- **Low power consumption:** Sensor nodes are powered by battery and it is often very difficult or even impossible to charge or recharge their batteries, it is crucial to reduce the power consumption of sensor nodes so that the lifetime of the sensor nodes, as well as the whole network is prolonged.
- **Reliability:** Network protocols designed for sensor networks must provide error control and correction mechanisms to ensure reliable data delivery over wireless channels.

1.4 Thesis Outline

This thesis consists of 6 Chapters and they are organized as follows:

Chapter 1 explain the introduction about WSNs, need in wide area of applications such as civilian and military operations like in environment monitoring, health monitoring, traffic monitoring, battle field surveillance and industry process control. Feature of WSNs and challenges faced by WSNs. Chapter 2 describes the survey on various MAC protocols, their advantages and disadvantages and comparisons. Chapter 3 introduces the assumed system model and the problem statement. In Chapter 4 the simulation study required to carry out this work in described. Chapter 5 shows the result of simulation. Finally, in Chapter 6 the thesis is concluded and future scope is given.

Chapter 2:

Literature Review

Most of the existing MAC protocols for wireless sensor networks can be divided into two categories: (i) Time Division Multiple Access (TDMA)-based and (ii) Carrier Sense Multiple Access (CSMA) based with (possible) collision avoidance (CA). Although TDMA protocols have a natural advantage of collision-free medium access, they suffer heavily from problems like clock synchronization, channel under-utilization and fixed time-slot assignments. In parallel, CSMA–CA protocols have a lower delay and better throughput potential at varying traffic loads.
Types of MAC protocols-There are a wide ambit of the MAC protocols which are designed for the wireless sensor networks. These are as follows.

2.1 Sensor-MAC [12, 13]- S-MAC is nothing but a periodic sleep and listen schedule which is based on synchronization which is locally managed. Here the time is divided into small cycles and every cycle is framed of two parts: the listen period and the sleep period. This phenomenon is elucidated in Figure 2.1

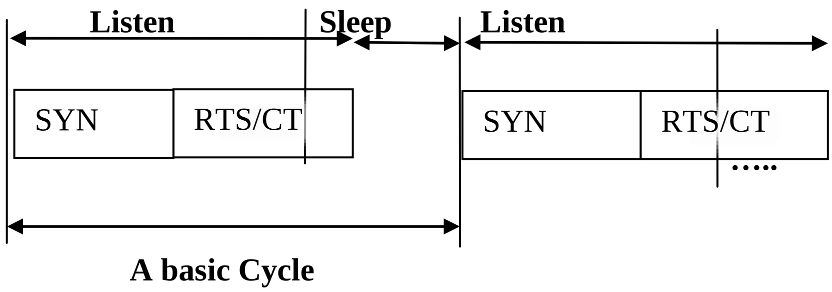

Figure 2.1: S-MAC periodic Listen/Sleep

Each sensor node can make sessions with other nodes in the network, in the listening phase. The other nodes form the virtual clusters to setup a common sleep schedule. Here they listen the channel, receive or send the packets. If two neighbouring nodes dwell in two different virtual clusters and may wake up in the listen periods of their respective clusters, to set up a common sleep schedule. A periodic SYNC packet is sent to the neighbours. By this broadcast the schedules can be exchanged between the participating nodes. This time period is called as synchronization period. The RTS /CTS packet exchanges are done to unicast the packets. The chronic and large messages are divided into smaller frames after that these are sent. This technique may help reducing the power consumption.

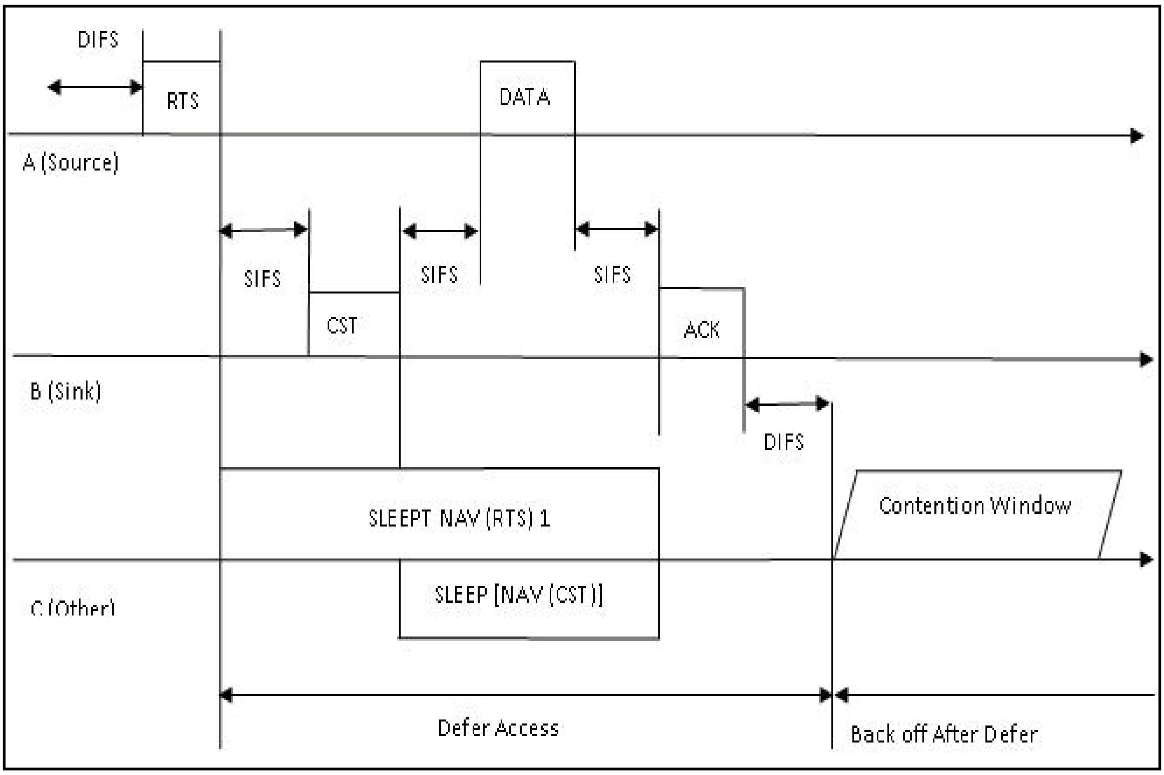

Figure: 2.2 RTS/ CTS mechanism

Advantages: This MAC protocol price to reduce the energy wastage by the data packet collision. For this purpose the participating nodes exchange RTS and CTS control packets periodically. Overhearing can be avoided up to a significant amount by switching off the node when the transmissions are not meant in the near future. By exchanging the periodic listen and the sleep control packets the time and the energy wastage can also be minimized.

Disadvantage: The broadcast data packets which are used to prevent the time synchronization overhead don't use RTS/CTS. This increases the possibilities of collision to occur. The efficiency of this MAC algorithm may decrease under fluctuating traffic loads because of the predefinition of sleep and listen periods.

2.1.1Wise MAC [14,15]- In this MAC protocol all the sensors are defined to have dual communication channels which are data channel and the control channel. The data channel is accessed using TDMA, while the Wise-MAC protocol used non-persistent CSMA. Here the idle listening is reduced by using preamble sampling technique, in which a preamble precedes each data packet for altering the receiver node. All the nodes in the network sample the channel with a common time period. If a node finds the channel busy, it continues to sense the channel until it receives a data packet or the communication channel becomes idle.

The receiver may or may not be ready when the preamble bits end, due to the factors such as interference, which causes the disturbance and the energy waste. This waste increases because of the fixed length of the preamble and the data packets. So to reduce this power consumption, Wise-MAC provides a method of dynamically determining the length of the preamble. Each node performs a refresh operation to update the table of sleep schedule of their neighbours. The Wise-MAC schedules the transmissions in such a way that the destination node's sampling time correspond to the middle of the sender's preamble.

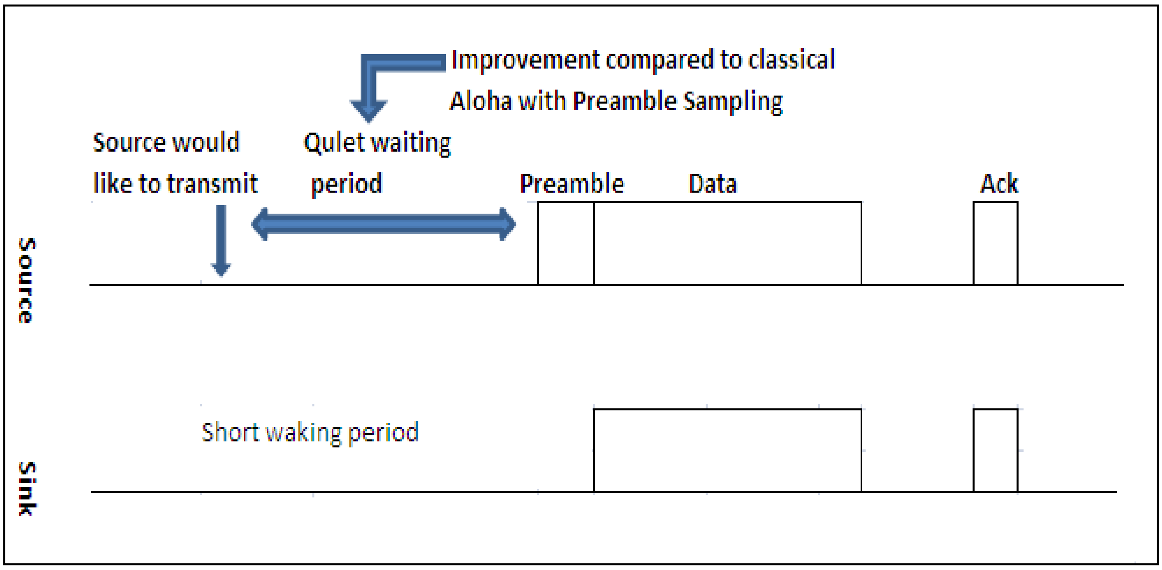

Figure 2.3: Wise MAC preamble minimization [19]

Advantages: Wise MAC performs farer than the S-MAC. The performance of S-MAC is better than other MAC protocols because of the introduction of the dynamic preamble length.

Disadvantages: The decentralization of sleep and the listen schedule results in different sleep and wake-up times for each neighbour of a node. This hindrance occurs in the case of the broadcast messages because the broadcast messages reside in the buffer when the node is in the sleep mode and these messages are sent to the whole network each time when any node becomes alive again. This phenomenon will result in more power consumption.

2.1.2 Traffic Adaptive MAC protocol (TRAMA) [16]: It is a schedule based protocol, in other words it is distributed and have on demand construction. In this protocol the nodes need to be synchronized by time and that time is a sundered into random period and channel access period. The random access period is used to establish two hops topology and the channel is acceded based on contention. In this the broadcast and receipt of schedule is done periodically. Schedule means the two hop neighbourhood's information.

TRAMA is formed of three subparts-

- Neighbourhood Protocol
- Schedule Exchange Protocol
- Adaptive Election Algorithm

Neighbourhood Protocol- Here the execution is done in a random access fashion, so the channel does not need to be sensed periodically. The transmitted packets contain node's identification incremental neighbourhood information. When a node is not transmitting anything, it listens to it's neighbours to identify their control packets.

Schedule Exchange Protocol- In this subpart a nodes try to share their transmission schedules by which one can identify that to which node or neighbour the data packets will be sent and in which time slot this will be done. In this, a node can get the other neighbour's schedule also. Actually by using this, the slots can be allocated to the transmitters and the receivers.

Adaptive Election Algorithm: To decide that among the two participating nodes which one will become the transmitter this protocol executes a distributed adaptive election algorithm. In this algorithm a node identifies the slots to transmit and occupies it. But during this time period, it is possible that this node remaining idle, so that time slot is not used efficiently and perfectly so to allow other nodes to use this idle time slot, each node assigns priority to their to their occupied time slots and announces it. So by using the values other nodes may by able to reuse it. When the election algorithm is executed, so by this algorithm the idleness of the nodes is utilized effectively.

Advantages: Higher sleep time can be achieved. The probability of collision can be lowered, in comparison to other protocols. It is able to adjust the energy saving based on load situations.

Disadvantage: Although, TRAMA has higher throughput but it has higher delays also in comparison to other contention based protocols. TRAMA is good for small networks only. In other words it may need more computation memory or other resources when the network grows. Since the two hop neighborhood of a node is large in a dense network, so TRAMA is not a feasible solution for such a big network. The priority computation also hinders the communication and becomes overhead.

2.1.3 SIFT [17]: This is a protocol which employs non persistent CSMA MAC protocol. In this protocol, the time which immediately occurs after any transmission, is partitioned into contention slots. The duration of this slot is very small in comparison to the time taken by the node, to send a data packet. When a transmission is done each station picks up a random slot by using non uniform probability distribution function. Before their time slot to transmit comes each node senses the channel. If they identify the channel busy or the start of any other transmission, they delay their own transmission and wait. But when their own transmission slot occurs then they transmit their packets directly and the data is sent to the receiver. But by chance if two or more nodes choose a same time slot then at that movement they all will send the packet at the same times, which will result in collision. Now this dispute is resolved by using the back off algorithms accordingly, generally by using binary exponential back off.

Advantage: SIFT is able to achieve low latency for many nodes (either transmitter or receiver). This protocol is extremely simple. It tries to send, say R data packets out of total data packets say N. These R data packets are sent with very low latency and higher success probability. Instead of using uniform distribution for selecting the time slots, it usages small and fixed size contention window and geometrically raising probability distribution. In SIFT it is not needed for every sensing node to sense the channel every time.

Disadvantage: Implementing SIFT protocol results in the increased idle listening. This idle listening creeps in, because of sensing all the slots, before sending any data packet. Overhearing is the problem with SIFT. This is the problem which occurs when a node needs to listen until the end, to grab the next transmission slot. Implementation complexity is increased because it employed time synchronization. Determining R is a difficult task and can be handled only in a manual way.

2.1.4 Data Gathering MAC (DMAC)[18]: DMAC is to achieve very low latency for converge cast communications as well as be an energy efficient system. This can be said that it is the modified slotted ALOHA algorithm. Because here the transmission slots which are based on time, are allotted to the nodes. This allocation is done on the basis of their gathering of data. Hence, during the reception time period of a node, all of its child nodes may have the transmit periods and they can sense the medium for the transmissions. The subsequent time slots can be assigned to the nodes which are successive in the data transmission path. This leads to get the low communication latency.

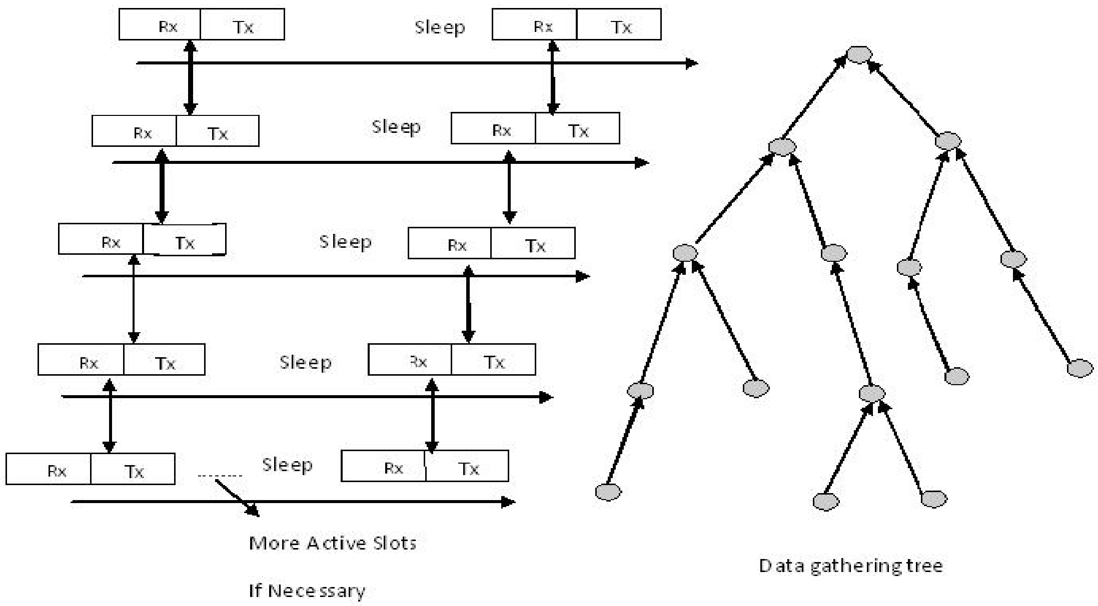

Figure 2.4: Data gathering tree in D-MAC scheme [19]

It is a schedule based MAC protocol called Data–Gathering Medium Access Control

(DMAC). Which has been planned and optimized for tree based data gathering in wireless sensor network. The low latency and still maintaining the energy efficiency is the main aim of this MAC protocol. In this the time is divided in small slots and runs carrier sensing multiple access (CSMA) with acknowledgement within each slot to transmit/receive one packet. The sensor node sometimes executes the basic sequence of '1' transmit, '1' receive and 'n' sleep slots. In this approach a single packet from a source node at depth 'k' in the tree reaches the sink node with a delay of just 'k' time slots. This delay is very small and it is in the order of tens of milliseconds. A data gathering (converge cast) tree with staggered DMAC slots is shown in Figure 2.4 D-MAC includes an overflow mechanism to handle the problem when each single source node has low traffic rate but the aggregate rate at intermediate node is larger than the basic duty cycle. In this mechanism after forwarding the packet, the sensor node will remain awake for one extra time slot. Thus, if two children were differing for parents accept slot, the loosing child will get a second opportunity to send its packet. The D-MAC uses a separate control packet named MTS (More to Send) to solve the difficulty of the interference between nodes on the dissimilar branches of the tree. The MTS packet makes all the nodes on the multi-hop path to remain active in case of nodes failure due to interference. in terms of energy efficiency, latency and throughput in both multi-hop chain topology and random data gathering tree topology.

Advantages- DMAC is able to deliver very low latency in comparison to the other sleep and the listen methods. To get such kind of latency is not an easy task for the other MAC protocols. DMAC can also achieve a better network connectivity and the spatial usage.

Disadvantages: It doesn't take collision avoidance techniques into consideration, which may further clot the path of the communication. So the situations in which the nodes which are having the same schedule, in other words the nodes which are at the same level in the communication tree, may try to send the data packets to the same node. This situation will introduce collisions. This is the very possible scenario in the event triggered sensor networks. The data transmission paths are not known beforehand in DMAC. A participating node cannot know that if the intended receiver is busy or not at a particular time period. This increases the deafness. However, this problem can be overcome by deploying the larger range of the directional antennas. But this will increases the overall cost of the network. The other disadvantage of the

DMAC is that is it has got very less ability to adapt the newer changes and the updations in the existing infrastructure. These MAC protocols are compared in the following table 2.1.

Table 2.1: Comparisons of the MAC Protocols

Protocol	**Contention Resolution Technique**	**Advantages**	**Disadvantages**
S- MAC [12,13]	CSMA	Simplicity	Increased collision
		Low synchronization	Low throughput static
		Dynamic duty cycle	Sleeping Synchronization
			Early sleeping
Wise-MAC [14,15]	Np-CSMA	Better in variable traffic	Hidden terminal problem
		Time Synchronization	Decentralized schedule
TRAMA [16]	TDMA/ CSMA	Higher Sleep Less collision	Calculation overhead
SIFT[17]	CSMA/CA	Fair trade off	Implementation complexity
			Higher idle listening
DMAC [18]	TDMA/ Slotted aloha	Low latency	Collision

To make the wireless sensor networks power economic and efficient, MAC protocols are used. There are various characteristics, which a MAC protocol must hold. Based on these requirements, there is a diverse range of the MAC protocols out of which five are discussed and then tabulated in the Table 2.1

2.1.5 LEACH [Low Energy Adaptive Clustering Hierarchy] Protocol: LEACH is one of the earlier and commonly used clustering protocol in WSNs to increase the network lifetime [20]. LEACH is an adaptive, re-locatable and clustering protocol. It uses the notion of Rounds. The protocol assumes that the BS is permanent and situated at a far distant from the sensors node, all sensor nodes are homogenous and have restricted energy supply, sensors perform sensing of the environment, process information and communicate with other sensor nodes and sensors can directly communicate with BS. The main idea behind the LEACH is to make cluster of nodes to equally distributed energy among sensor nodes in sensor network. A cluster head is selected from the nodes in the cluster. LEACH was designed by Wendi B. Heinzelman of MIT [21]. LEACH was developed to reduce the data aggregation issue. The nodes in the cluster send data to the cluster head. Cluster head aggregates the data using fusion technique that compress the amount of data gathered by the cluster head before transmitting to the BS. All sensors form a re-locatable network by allocating the role of a cluster head at least once. Cluster head is solely responsible for transmitting the information that is gathered by the nodes to the base station. This protocol tries to stable the energy dissipation inside the network and improve the network's life time by enhancing the life time of the sensors nodes [21]. LEACH protocol performs many rounds. Each round comprises two phases: setup phase and steady 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 [22].

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.

Clustering in WSNs [27]**:-** Clustering is an effective technique that can greatly contribute to lifetime, and energy efficiency in WSNs. A sensor network can be made scalable by assembling the sensor nodes into groups i.e. clusters. Every cluster has a leader, often referred to as the Cluster Head (CH). An energy-efficient communication protocol LEACH, has been introduced which employs a hierarchical clustering done based on information received by the BS. The CH collects and aggregates information from sensors in its own cluster and passes on information to the BS [23]. By rotating the cluster-head randomly, energy consumption is expected to be uniformly distributed. In each round of the cluster formation, network needs to follow the following steps

- Select cluster head
- Transfer the aggregated data.

Data is collected at the wireless sensor node, compressed, and transmitted to the BS [23]. Since sensor nodes are energy constrained, it is inefficient for all the sensors to transmit the data directly to the BS. Data generated from neighboring sensors is often redundant and highly correlated. To overcome the issue data aggregation is performed. Data aggregation involves the fusion of data at intermediate nodes and transmission of the aggregated data to the BS. Data aggregation can eliminate redundancy; minimize the number of transmissions and thus save energy [24,25].

Disadvantages of Leach Protocol [26]**:-**

- LEACH does not give any transparency about number of cluster heads and location of nodes and the in the network.
- All Cluster-Head openly communicates with BS, no matter the distance between CH and BS. It will take lot of its energy if the distance is far.

- CH consumes most of its energy for transmitting and collecting information, because, it will die earlier than other nodes.
- The CH is all the time on and when the CH die, the cluster will become useless because the information collected by cluster nodes will never arrive at the BS.

Chapter 3:
Problem Statement

The purpose of this thesis is to find protocol that are energy efficient and increase the network lifetime. Wireless sensor nodes which are battery operated are used for detecting and collecting information from the areas where there is very little scope for manual handling to recharge or change batteries. These sensing nodes collect the information and pass them on to the network towards the sink for further actions. For a better functioning and a longer lifetime for a sensing node within the network, we need to consider its energy consumption as a major factor of concern. To finding out suitable protocols that are used for increase the lifetime of network. Here these node detect and collects information regarding any object that is moving or any event that's triggered. The sensor node carrying this information uses an ordinary protocol stack which carries out the general process of transmission without any concerns for energy efficiency factor.

The following are the assumptions for the sensing area in which wireless sensor nodes are used as a frame of reference in the further study [9].

- WSNs consist of a number of sensing nodes which are distributed in a wide area. They sense an event occurring in the environment and these sensing nodes are distributed or placed according to the requirements of the application.
- The base station (sink), which collects data from other nodes, interacts with a user (someone interested in monitoring the activity). Data can be collected in many ways from a sensing node to a sink node like using hopping techniques or transmitting data at certain frequencies. Sinks have more advanced features than sensing nodes in terms of data transmissions and processing capabilities, memory size and energy reserves.
- Energy dissipation is a major factor in WSNs during communication among the nodes. Energy should be saved, so that the batteries do not get depleted or drained quickly as these are not easily replaceable in applications such as surveillance. Network should function for as long as possible. It may be impossible to recharge node batteries. Therefore, all aspects of the nodes, from the hardware to the protocols, must be designed to be energy efficient.

- Protocols should check for network stability, redundant data should be transmitted over the network for any type of traffic distribution. It also needs to maintain certain resource limiting factors, such as bandwidth, memory buffer size and processing capabilities.
- The transmission mode plays an important role in WSNs. Nodes can take single-hop or multi-hop depending upon the type of network topology chosen for communicating or transmitting data to other nodes within the network.
- The sensor nodes can be mobile or static depending on the application.
- Data from sensor nodes are typically time sensitive, so it is important to receive the data in a timely manner with shortest path.

Chapter 4:

Proposed Solution

The existing network protocols are not capable of increases the overall performance of the network up to large extends. The reason we need network protocol such as Modified LEACH is due to the fact that a node is of no use when its power is depleted. The basic protocol use for transmitting the information to the BS is LEACH. LEACH is an application specific protocol that typical sensor network support in the monitoring of a remote environment. In LEACH all the sensor nodes are classified into clusters and each cluster have a cluster head, which sends data to the BS. In LEACH the cluster head is perform more energy consuming task than the remaining non cluster head nodes, so the cluster head dies early. As the cluster head is no longer operational the nodes are not able to communicate to the cluster head. Thus, LEACH incorporates randomized rotation of the high-energy cluster head position among the sensors to avoid draining the battery of any one sensor in the network. In this way, the energy load of being a cluster head is evenly distributed among the nodes. The LEACH protocol shows better result as compared with direct transmission. The proposed protocol uses the concept of LEACH protocol and new modification to increase the efficiency of the network. The operation of LEACH is divided into many rounds. The round starts with a set-up phase in which the clusters are formed, follows by a steady-state phase in which the information is transmitted from the nodes to the cluster head and then cluster head sends aggregated information to the BS. In homogeneous networks all the sensor nodes have same capabilities in terms of battery energy and hardware constraints.

Once the cluster heads is selected, it serves for the whole lifetime of the network. The energy model for our modified LEACH is given in equation 4.1

$$T_{tr} = E_c * n_b * typeoftraffic + E_{af} + E_{at} * n_b * dis^2 \qquad (4.1)$$

Where T_{tr} = Transmission Energy,

E_c = Energy consumed in electronic circuit to transmit or receive signals

N_b = Node contains data in bits,

E_{af} = Energy consumed to find shortest path,

E_{at} = Energy consumed to transmit over shortest path,

dis = distance

The proposed solution finds the shortest path using dijkstra’s algorithm with the help of energy model employed in modified LEACH protocol. In the network consisting of homogenous nodes, the path is found by employing the dijkstra’s algorithm for finding the minimum cost route to the destination node from source node. The modified LEACH protocol energy model given in equation 4.1 is used here. On the basis of which it is given that shortest path will be found over which the transmission energy consumed will be less.

In equation 4.1 various parameters are taken such that energy consumed in the network will be less. It is given that the transmission energy required in the system will depend upon the energy consumed in electronic circuit to transmit or receive signals, energy consumed for finding the shortest path and then to transmit the bits over the shortest path.

In the network having heterogeneous nodes the path to destination can be found through nodes by assigning more processing and communication takes to sophisticated nodes by which more energy will be consumed. On the other hand, in homogenous network over various points the transmission energy in computed and then the shortest path is found over which the energy consumed will be less.

Algorithm 4.1 Novel approach for increasing the life time of WSNs

a) Deploy the sensor node randomly in an area of 100 x 100 m^2 and Base Station (BS) is located far from the sensing area (100, 100) outside the field. Nodes have no location information.

b) Calculate distance of each sensor nodes form Base Station by using following formula and stored in a list.

Distance = $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

c) Nodes whose distance is less from base station and remaining energy is greater than threshold (dead node), choose as a head node than can send a data to base station.

d) Select the source node randomly.

e) Apply Dijkstra algorithm from source node to destination (head node).

f) Send the data to the head node via other sensor nodes.

g) Reduce the energy of sensor node that taking part in communication by using proposed energy efficient modified LEACH model given in equation 4.1

h) If node remaining energy is equal to dead energy than node is remove from the network of sensing area and packet is dropped, go to the step c.

Remaining energy = main energy – used energy

i) Repeat this process until all nodes are dead and network of sensing area is considered to be dead or failure.

4.2 Flow Chart

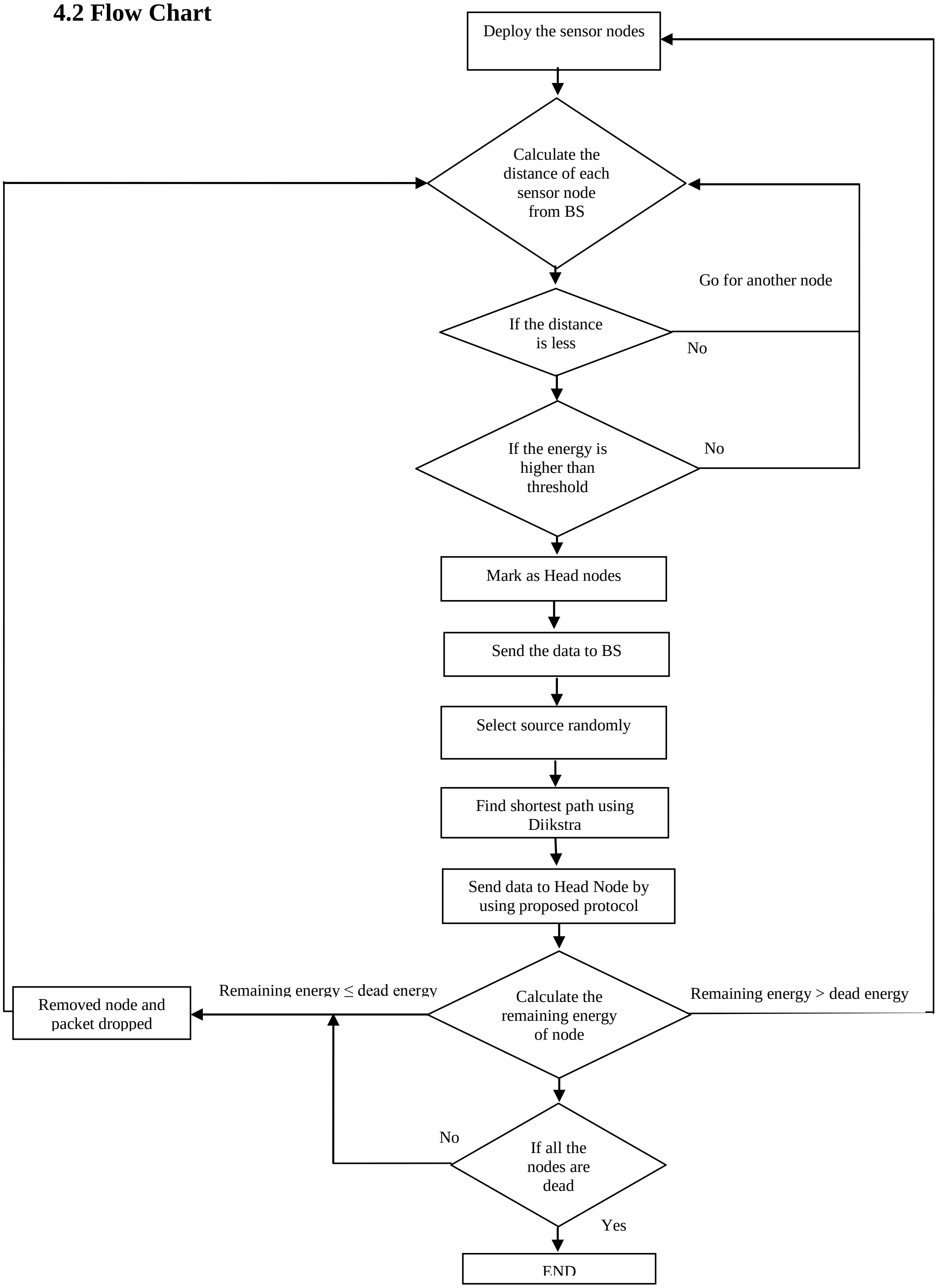

Figure: 4.1 Flow diagram which explains the flow of the entire process of the proposed protocol.

Chapter 5:

Analysis and Performance Evolution

5.1 Results

In this section, we discuss the simulations use to analyze and estimate the performance of the proposed algorithm. This thesis uses the Matlab software to simulate our propose protocol. To ensure that our proposed algorithm is more energy efficient than LEACH protocol we have compared the result with LEACH protocol.

A. Simulation Setup

The simulation parameters uses for our proposed protocol are described below in Table 5.1. For the simulation of our proposed protocol the nodes are initialized with the same energy that is 0.5J. Every node transmits a n_b bits data packet per round to its head node.

5.1 Transmission Parameters Value

Description	**Symbol**	**Value**
Energy consumed in the electronics circuit to transmit or receive the signal	E_c	50pJ/bit
Node contains data in bits	n_b	100 bits
The initial node energy	$E_{initial}$	0.5J
Energy consumed by the amplifier to find shortest distance	E_{af}	100pJ/bit/m^2
Energy consumed by the amplifier to transmit over short distance	E_{at}	10pJ/bit/m^2
The Sensing area	m x m	100m×100m

5.3 Simulations and analysis

For the simulation of our proposed protocol the network consists of 100 sensor nodes that are randomly deployed in sensing area of 100m x 100m square meters. After every rounds of communication some sensor nodes are dead and these sensor nodes are deleted from the sensing area network. The BS is located at a far distance from the sensor nodes. It has central processing unit with high computation power, a memory unit out of which small memory is used for storing the data and an unlimited power source. It collects data from the sensor field and sends to the external network. The base station communicates with outer world through internet etc. The network model for our proposed protocol is shown in Figure 5.3. For the evaluation of our proposed protocol different numbers of parameters are used. In this proposed modified LEACH, the average remaining energy of all nodes and the number of nodes alive are chosen to compare with the existing LEACH protocol, A node is considered to be dead if its remaining energy is less than zero. When the energy of all nodes is depleted we considered that our network is dead.

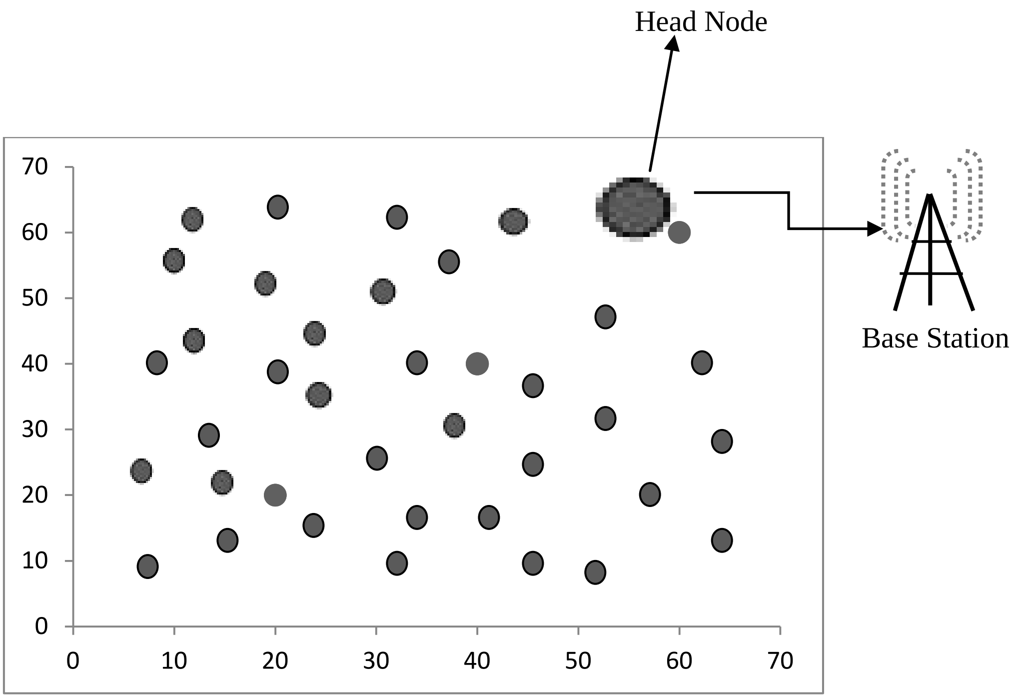

Figure 5.1: The sensing area (100m x 100m)

The criteria for performance evaluation are the network lifetime, in figure 5.2 the time taken and number of data signals received at the base station. The modified LEACH will be more efficient than LEACH because more signals will be received at base station in case of modified LEACH. The main reason of efficiency is the use of shortest path algorithm. When packets are passed at cluster head. They used shortest path to travel at cluster head. But in case of LEACH, its uses the longest path so the efficiency of the modified LEACH is high than the LEACH.

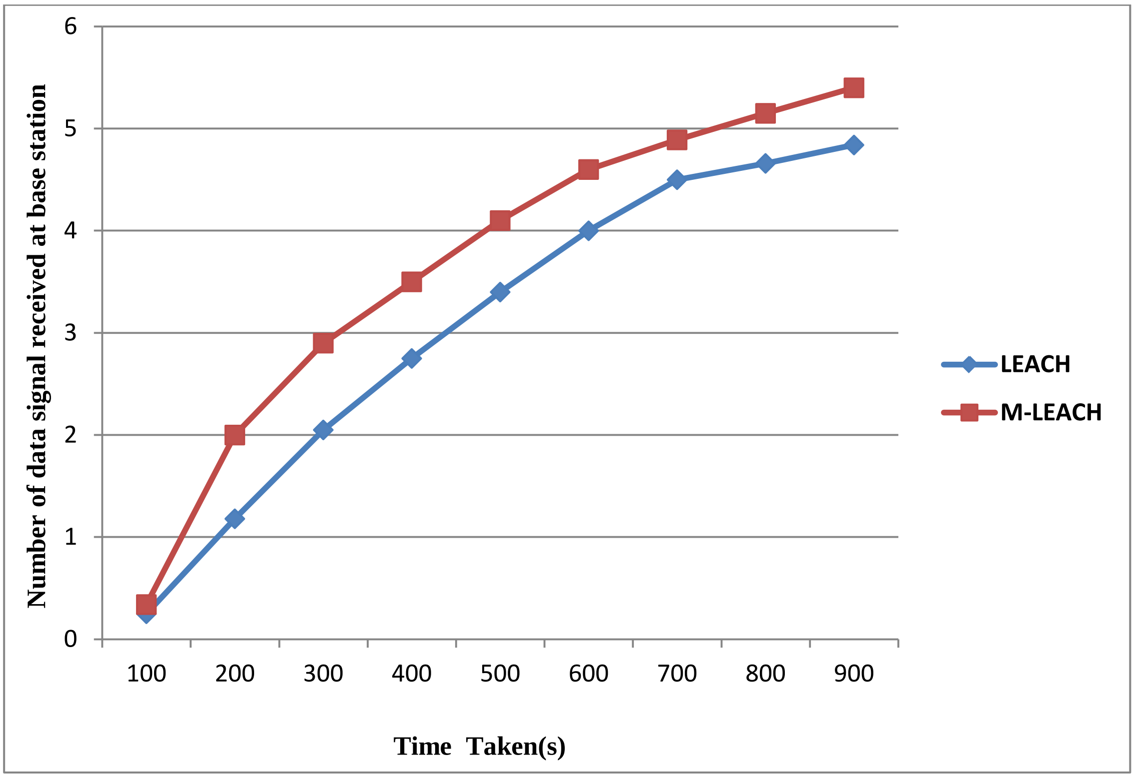

Figure 5.2: More data signals received at Base Station

In the modified LEACH number of rounds increases and the probability of dead node in the sensing area network will be more. In order to evaluate the number of dead nodes in proposed protocol, we select the metrics that number of nodes die respectively to evaluate the network performance. The number of various dead sensor nodes can show the remaining energy consumption in the sensing area network. Figure 5.3, x-coordinate show the number of rounds and y- coordinate stands for the number of dead nodes per round.

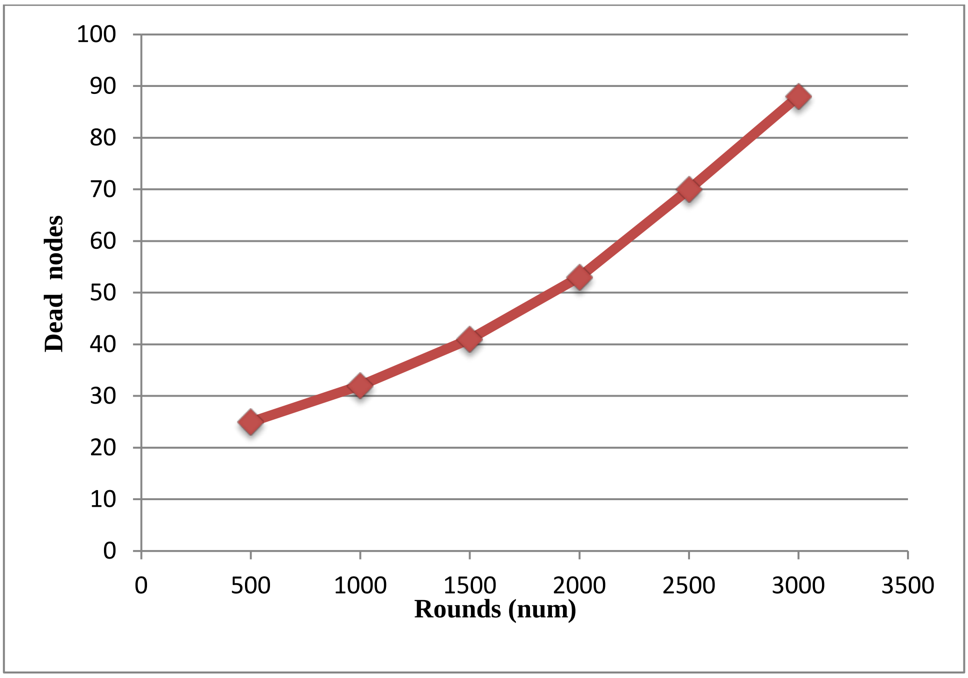

Figure: 5.3 Number of Dead nodes with number of Rounds

In Figure 5.4, it is given that as the time increases in the modified LEACH but the energy consumption will be less as compared to LEACH protocol. For calculation of energy consumed, new transmission energy is used. Thus it is it proved that the proposed modified LEACH model is enhanced the energy consumption and improves the network lifetime. It is efficient and better than LEACH.

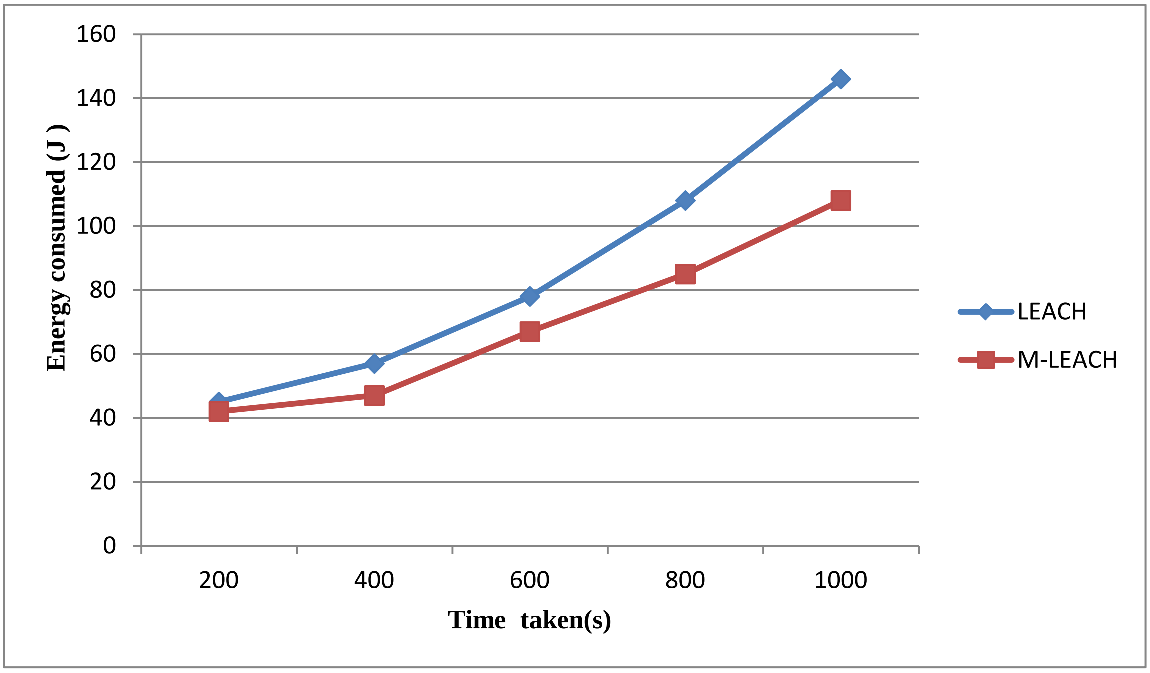

Figure 5.4: Energy consumption with variation in time

In figure 5.5, it is shown that as the sensing are increases the energy consumed over the shortest path decreases. As the modified LEACH protocol helps in finding the shortest path using dijkstra algorithm so over it the energy consumed is less. In the LEACH protocol, it does not use any shortest path algorithm instead it uses longest way to pass the packet. LEACH uses longest path to avoid collision. But modified LEACH uses shortest path and from the graph it shows that modified LEACH is more efficient then the LEACH.

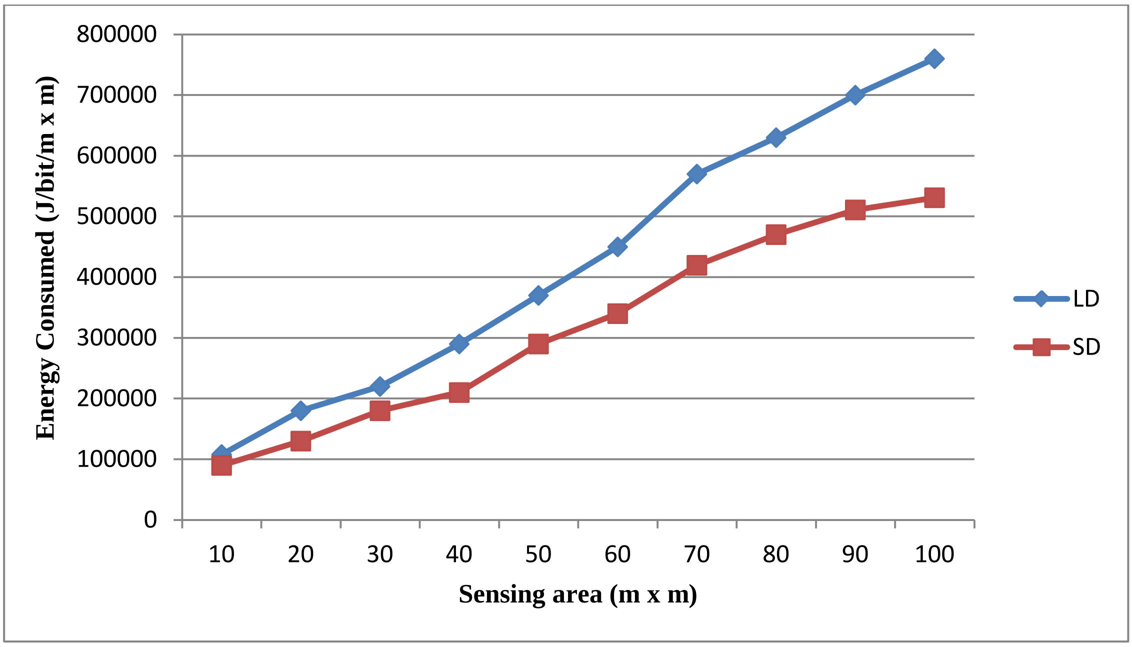

Figure: 5.5 Energy consumed with respect to coverage area

Chapter 6:

Conclusion and Future Work

6.1 Conclusion

Simulation results in MATLAB will point out that proposed modified LEACH protocol is capable of improving efficiency. In this thesis, our proposed protocol we use a fixed head node and use the dijkstra algorithm to find the shortest path from sensor node to the head node. The head node gathered data from the sensor nodes and transmit data to the BS. Simulation results show our proposed protocol is more energy efficient than LEACH protocol. It improves the balance energy consumption, thus extend the lifetime of WSNs.

6.2 Future Work

- This thesis presents only one way of implementing energy efficient Modified LEACH protocol within the sensing area, several other algorithms could be used.
- In present simulation studies, only one propagation model (Modified LEACH Energy Model) is used, there are several other models which could be deployed.
- The proposed model uses only the homogenous sensor nodes; it could be applied on heterogeneous sensor nodes as well.
- The current work is tested in MATLAB, it could be extended to other languages or simulation tools.

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