Energy Efficient Hierarchical Routing For Wireless Sensor Network

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CERTIFICATE

It is certified that the work contained in this thesis entitled **"Energy Efficient Hierarchical Routing For Wireless Sensor Network",** by **Krishn Mohan Maurya** (Roll No. 1170454004), for the award of **Master of Technology** from Babu Banarasi Das University has been carried out under my supervision and that this work has not been submitted elsewhere for award of any degree.

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ABSTRACT

The popularity of Wireless Sensor Networks has increased tremendously due to the vast potential of the sensor networks to connect the physical world with the virtual world. Since these devices rely on battery power and they may deployed in hostile environments. Therefore, replacement becomes a tedious task. Thus, improving the energy of these networks becomes important. Our thesis aims to optimize the energy consumption of wide scale wireless sensor networks by deploying base station at the center of the wireless sensor network field and randomize selection of cluster head and master cluster head which provide modification on the traditional clustering of the cells of the network. In our thesis we our load balancing of each cluster in the network by selection of cluster head and master cluster head on the basis of upper and lower bound values of threshold value. The results conclude that the proposed model out performs than the existing model LEACH, LEACH-C and LEACH-E.

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LIST OF FIGURE

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LIST OF ABBREVIATION

ADV	Advertisement Message
BS	Base Station
CH	Cluster Head
CSMA	Carrier Sense Multiple Access
DSSS	Direct Sequence Spread Spectrum
FDMA	Frequency Division Multiple Access
GPS	Global Positioning System
ID	Identity
JOIN-REQ	Join Request Message
LEACH	Low Energy Adaptive Clustering Hierarchy
MTE	Minimum Transmission Energy
MAC	Medium Access Control
PSTN	Public Switched Telephone Network
RF	Radio Frequency
TDMA	Time Division Multiple Access
WSN	Wireless Sensor Network

LIST OF SYMBOL

$C_i(t)$	Cluster Head
DIS	Distance
$D^{2,}$ D^4	Power Loss
D_{TOCH}	Distance from the Node to the Cluster Head
D_{TOBS}	Distance from Cluster Head to the Base Station
$E_i(t)$	Current Energy
E_{TOTAL}	Total Energy
E_{ELEC}	Electronics Energy
$E_{CLUSTER}$	Energy dissipated in a cluster during the Frame
E_O	Initial Energy
E_{TX}	Transmission Energy
E_{RX}	Receive Energy
E_{FS}	Free Space Energy
E_{MP}	Multipath Energy
L	No. of Bits in Each Data Message
MOD	Modulation
MIN	Minimum
N	Node
Pi (t)	Probability
R_{MAX}	Maximum Round
RND	Random

Sqrt	Square Root
Temp	Temporarily

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CHAPTER 1

INTRODUCTION

With the developments in the field of microelectronics and wireless communication, Wireless Sensor Network is working as a catalyst for next generation networks. Apart from this Wireless sensor networks (WSNs) attracts a wide range of disciplines where close interactions with the physical world are essential. The distributed sensing capabilities and the ease of deployment provided by a wireless communication paradigm make WSNs an important component of our daily lives. By providing distributed, real-time information from the physical world, WSNs extend the reach of current cyber infrastructures to the physical world.

1.1: BACKGROUND

The wireless sensor networks consists sensor nodes called mote. These motes have sensing, processing and communicating capability. That makes sensor node responsible for data generation and network relay. Each node consists of sensor(s), microprocessor, and a transceiver. Through the wide range of sensors available for tight integration, capturing data from a physical phenomenon becomes standard. Through on-board microprocessors, sensor nodes can be programmed to accomplish complex tasks rather than transmit only what they observe. The transceiver provides wireless connectivity to communicate the observed phenomena of interest. Sensor nodes are generally stationary and are powered by limited capacity batteries. In static networks the locations of the nodes do not change, the network topology dynamically changes due to the power management activities of the sensor nodes. To save energy, nodes aggressively switch their transceivers off and essentially become disconnected from the network. In this situation the connectivity and optimization of energy consumption is major challenge. Where the energy-efficient operation, provides significantly prolong the network life.

1.2: OVERVIEW OF WSN

With the recent technology developments, the low-cost, low-power, multifunction sensor nodes that are small in size and communicate tethered in short distances have become feasible. The ever-increasing capabilities of these tiny sensor nodes, which include sensing, data processing, and communicating, enable the realization of wireless sensor networks (WSNs). Based on the collaborative effort of a large number of sensor nodes WSNs have a wide range of applications. In accordance with our vision [18], WSNs are slowly becoming an integral part of our lives. Recently, considerable amounts of research efforts have enabled the actual implementation and deployment of sensor networks tailored to the unique requirements of certain sensing and monitoring applications. In order to realize the existing and potential applications for WSNs, sophisticated and extremely efficient communication protocols are required. WSNs are composed of a large number of sensor nodes, which are densely deployed either inside a physical phenomenon or very close to it. In order to enable reliable and efficient observation and to initiate the right actions, physical features of the phenomenon should be reliably detected and estimated from the collective information provided by the sensor nodes [18]. The sensor node senses the sensory measures, processes and transmits only the required data. Hence, these properties of WSNs present unique challenges for the development of communication protocols.

1.3: WSN ARE CHARACTERIZED

- Energy efficiency
- Scalability

- Responsiveness
- Reliability
- Mobility
- Low cost
- Computational Power
- Communication capability
- Security and Privacy
- Distributed sensing and processing
- Dynamic Network topology
- Self organization
- Multi hop communication
- Application oriented
- Robust operation
- Small physical size

1.4: COMPONENT OF WSN

1.4.1: Sensor Field

Where sensor nodes are deployed is known as sensor field or region. Deployment of sensor nodes may be random or pre-determined depending on the project of WSN. Distance between nodes is random or predefined as in application.

1.4.2: Sensor Node

Sensor node consists of sensing unit, power supply unit, center processing unit (CPU), analog to digital converter (ADC), communication unit. Sensing unit is capable of sensing power for specified entity like temperature, pressure, light etc. Power supply unit is responsible for power management in node. Sensing unit transmits received signal to ADC and signal is forwarded to CPU from ADC. CPU is the overall controlling unit of sensor node to monitor and instruct other components of sensor node. Data signals can be transmitted to other nodes or base station by communication unit.

1.4.3: Base Station

The base station is center data collection point. The sensory measures are collectively collected and stored at base station. Remote users may request the base station and base station reply accordingly. For maintaining backup of information, copy of database can be maintained at data severs at remote location.

1.4.4: Remote Server

Location of remote servers depends on the application, for project where information is shared by researcher of different locations, one or more remote locations can be constructed. Remote location normally equipped with devices to record hug amount of data, tools for analyzing data and presentation of information. According to application the resources are pooled at remote location.

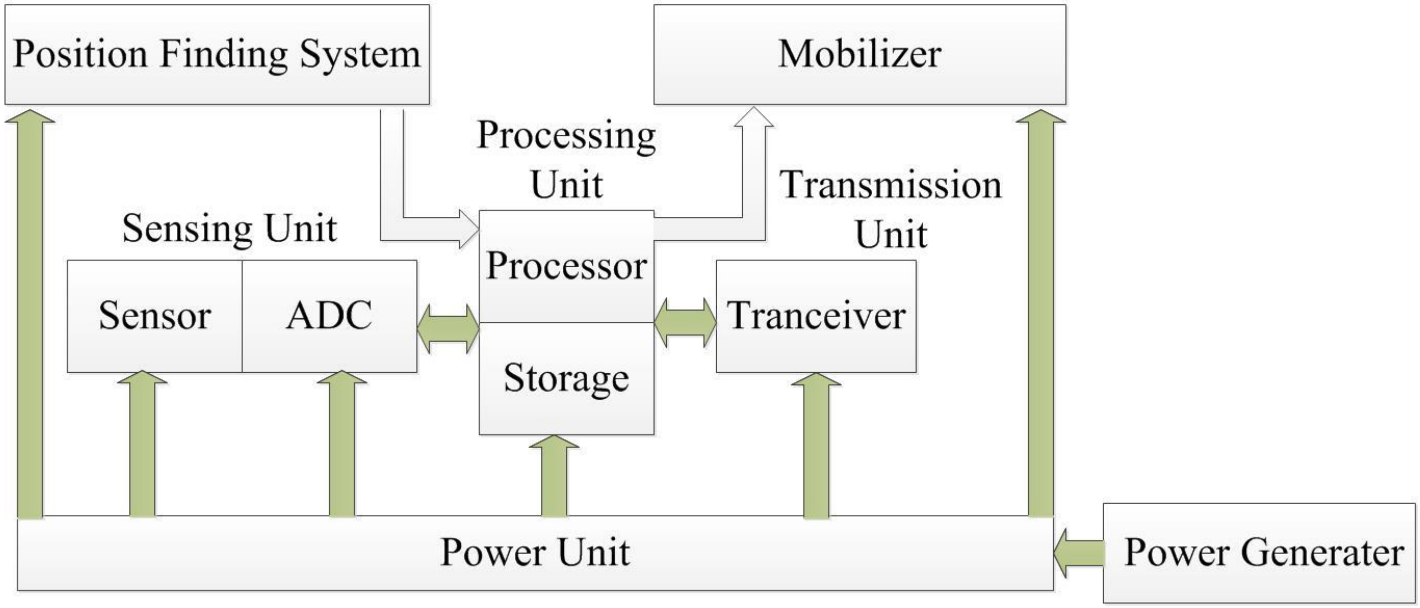

Fig: 1 components of a Sensor Node

1.5: PROTOCOL STACK

The protocol stack used by sensor nodes and sink is shown in Figure 2. The deployed protocol stack combines data, communicates power efficiently through the wireless medium, and promotes cooperative efforts of sensor nodes. The protocol stack consists of the physical layer, data link layer, network layer, transport layer, application layer, as well as synchronization plane, localization plane, topology management plane, power management plane, mobility management plane, and task management plane.

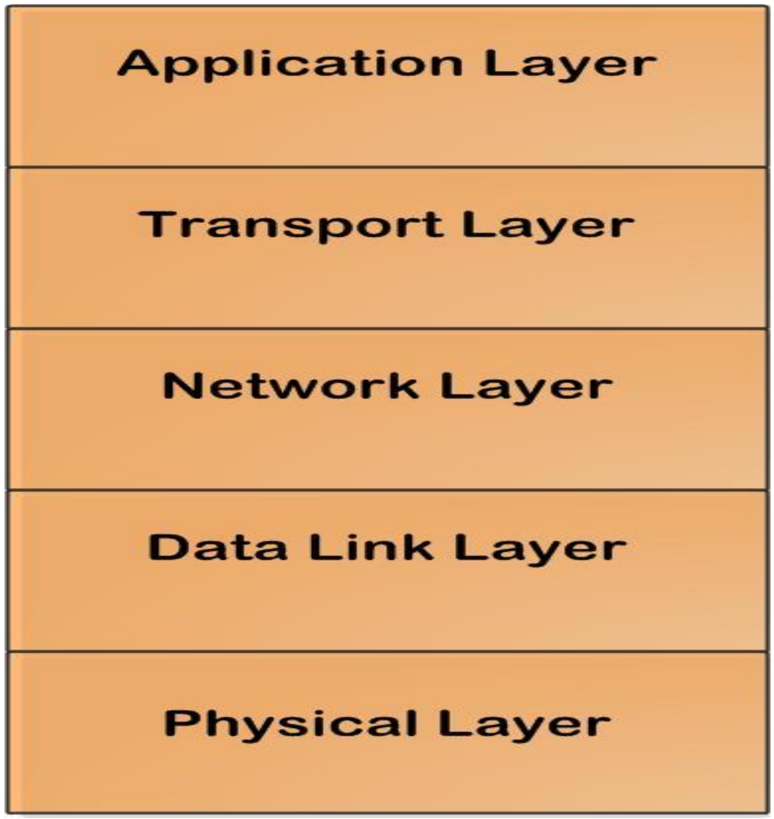

Fig: 2 Protocol Stacks of WSNs

The physical layer addresses the needs of simple but robust modulation, transmission, and receiving techniques. Since the environment is noisy and sensor nodes can be mobile, the link layer is responsible for ensuring reliable communication through error control techniques and manages channel access through the MAC to minimize collision with neighbors' broadcasts. Depending on the sensing tasks, different types of application software can be built and used on the application layer. The network layer takes care of routing the data supplied by the transport layer. The transport layer helps to maintain the flow of data if the sensor network application requires. In addition, the power, mobility, and task management planes monitor the power, movement, and task distribution among the sensor nodes. These planes help the sensor nodes coordinate the sensing task and lower the overall power consumption.

1.5.1: Physical Layer

The physical layer is responsible for frequency selection, carrier frequency generation, signal detection, modulation, and data encryption. The physical layer generally provides raw transmission facility.

1.5.2: Data Link Layer

The data link layer is responsible for the multiplexing of data streams, data frame detection, and medium access and error control. It ensures reliable point-to-point and point-to-multipoint connections in a communication network.

1.5.3: Network Layer

Sensor nodes are scattered densely in sensing field. The information collected relating to the phenomenon should be transmitted to the sink, which may be located far from the sensor field. However, the limited communication range of the sensor nodes prevents direct communication between each sensor node and the sink node. This requires efficient multi-hop wireless routing protocols between the sensor nodes and the sink node using intermediate sensor nodes as relays. The existing routing techniques, which have been developed for wireless ad hoc networks, do not usually fit the requirements of the wireless sensor networks.

The networking layer of sensor networks is usually designed considering the following principles:

- Power efficiency is always an important consideration.
- Sensor networks are mostly data-centric.
- In addition to routing, relay nodes can aggregate the data from multiple neighbors through local processing.
- Due to the large number of nodes in a WSN, unique IDs for each node may not be provided and the nodes may need to be addressed based on their data or location.

An important issue for routing in WSNs is based on data-centric queries. Based on the information requested by the user, the routing protocol should address different nodes that would provide the requested information. More specifically, the users are more interested in querying an attribute of the phenomenon rather than querying an individual node.

1.5.4: Transport Layer

The transport layer is especially needed when the network is planned to be accessed through the Internet or other external networks. TCP, with its current transmission window mechanisms, do not address for the unique challenges posed by the WSN environment. Unlike protocols such as TCP, the end-to-end communication schemes in sensor networks are not based on global addressing. These schemes must consider that addressing based on data or location is used to indicate the destinations of the data packets. Factors such as power consumption and scalability, and characteristics like data-centric routing, mean sensor networks need different handling in the transport layer.

1.5.5: Application Layer

The application layer includes the main application as well as several management functionalities. In addition to the application code that is specific for each application, query processing and network management functionalities also reside at this layer. The layered architecture stack has been initially adopted in the development of WSNs due to its success with the Internet. However, the large-scale implementations of WSN applications reveal that the wireless channel has significant impact on the higher layer protocols. Moreover, resource constraints and the application-specific nature of the WSN paradigm leads to cross-layer solutions that tightly integrate the layered protocol stack. By removing the boundaries between layers as well as the associated interfaces, increased efficiency in code space and operating overhead can be achieved.

1.6: WSN APPLICATION

1.6.1: Military Applications

WSNs can be an integral part of military command, control, communications, computing, intelligence, surveillance, reconnaissance, and targeting systems. The rapid deployment, self-organization, and fault tolerance characteristics of sensor networks make them a very promising sensing technique for military. Since sensor networks are based on the dense deployment of disposable and low-cost sensor nodes, destruction of some nodes by hostile action does not affect a military operation as much as the destruction of a traditional sensor, which makes the sensor network concept a better approach for battlefields. Some of the military applications of sensor networks are monitoring friendly forces, equipment, and ammunition, battlefield surveillance, reconnaissance of opposing forces and terrain, targeting, battle damage assessment, and Nuclear, Biological, and Chemical (NBC) attack detection and reconnaissance [2, 4, 6].

1.6.2: Environmental Applications

The autonomous coordination capabilities of WSNs are utilized in the realization of a wide variety of environmental applications. Some environmental applications of WSNs include tracking the movements of birds, small animals, and insects, monitoring environmental conditions that affect crops and livestock, irrigation, macro instruments for large-scale Earth monitoring and planetary exploration, chemical/biological detection, precision agriculture, biological, Earth, and environmental monitoring in marine, soil, and atmospheric contexts, forest fire detection, meteorological or geophysical research, flood detection, bio complexity mapping of the environment, and pollution studies [3, 5,].

1.6.3: Health Applications

The developments in implanted biomedical devices and smart integrated sensors make the usage of sensor networks for biomedical applications possible. Some of the health applications for sensor networks are the provision of interfaces for the disabled, integrated patient monitoring, diagnostics, drug administration in hospitals, monitoring the movements and internal processes of insects or other small animals, tele monitoring of human physiological data, and tracking and monitoring doctors and patients inside a hospital [1].

1.6.4: Home Applications

As technology advances, smart sensor nodes and actuators can be buried in appliances such as vacuum cleaners, microwave ovens, refrigerators, and DVD players [9] as well as water monitoring systems [7]. These sensor nodes inside domestic devices can interact with each other and with the external network via the Internet or satellite. They allow end-users to more easily manage home devices both locally and remotely. Accordingly, WSNs enable the interconnection of various devices at residential places with convenient control of various applications at home.

1.6.5: Industrial Applications

Networks of wired sensors have been used in industrial applications such as industrial sensing and control applications, building automation, and access control. However, the cost associated with the deployment of wired sensors limits the applicability of these systems. Moreover, even if a sensor system were deployed in an industrial plant, upgrading this system would cost almost as much as a new system. In addition to sensor-based monitoring systems, manual monitoring has also been used in industrial applications for preventive maintenance [8]. Manual monitoring is generally performed by experienced personnel using handheld analyzers that are collected from a central location for analysis. While sensor-based systems incur high deployment costs, manual systems have limited accuracy and require personnel. Instead, WSNs are a promising alternative solution for these systems due to their ease of deployment, high granularity, and high accuracy provided through battery-powered wireless communication units.

1.7: FACTORS INFLUENCING WSN DESIGN

1.7.1: Hardware Constraints

The general architecture and the major components of a wireless sensor device (node) are illustrated in Figure 1. A wireless sensor device is generally composed of four basic components: a sensing unit, a processing unit, a transceiver unit and a power unit. Moreover, additional components can also be integrated into the sensor node depending on the application. These components as shown by the dashed boxes in Figure 1 include: a location finding system, a power generator, and a mobilizer. Next, each component is described in detail:

•**Sensing Unit:** The sensing unit is the main component of a wireless sensor node that distinguishes it from any other embedded system with communication capabilities. The sensing unit may generally include several sensor units, which provide information gathering capabilities from the physical world. Each sensor unit is responsible for gathering information of a certain type, such as temperature, humidity, or light, and is usually composed of two subunits: a sensor and an analog to-digital converter (ADC). The analog signals produced by the sensor based on the observed phenomenon are converted to digital signals by the ADC, and then fed into the processing unit.

•**Processing Unit:** The processing unit is the main controller of the wireless sensor node, through which every other component is managed. The processing unit may consist of an on-board memory or may be associated with a small storage unit integrated into the embedded board. The processing unit manages the procedures that enable the sensor node to perform sensing operations, run associated algorithms, and collaborate with the other nodes through wireless communication.

•**Transceiver Unit:** Communication between any two wireless sensor nodes is performed by the transceiver units. A transceiver unit implements the necessary procedures to convert bits to be transmitted into radio frequency (RF) waves and recover them at the other end. Essentially, the WSN is connected to the network through this unit.

•**Power Unit:** One of the most important components of a wireless sensor node is the power unit. Usually, battery power is used, but other energy sources are also possible. Each component in the wireless sensor node is powered through the power unit and the limited capacity of this unit requires energy-efficient operation for the tasks performed by each component.

•**Location Finding System:** Most of the sensor network applications, sensing tasks, and routing techniques need knowledge of the physical location of a node. Thus, it is common for a sensor node to be equipped with a location finding system. This system may consist of a GPS module for a high-end sensor node or may be a software module that implements the localization algorithms that provide location information through distributed calculations.

•**Mobilizer:** A mobilizer may sometimes be needed to move sensor nodes when it is necessary to carry out the assigned tasks. Mobility support requires extensive energy resources and should be provided efficiently. The mobilizer can also operate in close interaction with the sensing unit and the processor to control the movements of the sensor node.

•**Power Generator:** While battery power is mostly used in sensor nodes, an additional power generator can be used for applications where longer network lifetime is essential. For outdoor applications, solar cells are used to generate power. Similarly, energy scavenging techniques for thermal, kinetic, and vibration energy can also be used [13].

1.7.2: Fault Tolerance

The hardware constraints lead sensor nodes to frequently fail or be blocked for a certain amount of time. These faults may occur because of a lack of power, physical damage, environmental interference, or software problems. The failure of a node results in disconnection from the network. Since the WSN is interested in information regarding the physical phenomenon instead of information from a single sensor, the failure of a single node should not affect the overall operation of the network. The level of failures that is allowed by the network to adequately continue its functions defines its fault tolerance.

1.7.3: Scalability

While high-density deployment of sensor nodes in a WSN provides redundancy and improves the fault tolerance of the network, this also creates scalability challenges. The number of sensor nodes deployed for sensing a physical phenomenon may be on the order of hundreds or thousands. Therefore, the networking protocols developed for these networks should be able to handle these large numbers of nodes efficiently. The density can range from a few to hundreds of sensor nodes in a region, which can be less than 10 m in diameter [11]. The node density depends on the application for which the sensor nodes are deployed.

1.7.4: Production Costs

Since the sensor networks consist of a large number of sensor nodes, the cost of a single node is very important to justify the overall cost of the networks. If the cost of the network is more expensive than deploying traditional single sensor devices, then the sensor network will not be cost justified. As a result, the cost of each sensor node has to be kept low. The cost for Bluetooth is usually less than $10. The cost of a sensor node should be less than $1 in order for sensor networks to be practically feasible [12]. Current prices for sensor devices are much higher than even for Bluetooth. Furthermore, a sensor node may also have some additional units, Also it may be equipped with a location finding system, mobilizer, or power generator depending on the applications of the sensor networks. These units all add to the cost of the sensor devices. As a result, the cost of a sensor node is a very challenging issue given the number of functionalities.

1.7.5: WSN Topology

The large numbers of inaccessible and unattended sensor nodes which are prone to frequent failures make topology maintenance a challenging task. The major challenge is the deployment of these sensor nodes in the field so that the phenomenon of interest can be monitored efficiently. This constitutes the pre deployment and deployment phase. Topology maintenance is also important after the initial deployment, i.e., the post-deployment phase, where the protocol parameters and operations can be adopted according to the network topology. Finally, the re-deployment phase may be necessary if several nodes fail or deplete their energy to prolong the network lifetime. Overall, densely deploying a high number of nodes requires careful handling of topology maintenance.

1.7.6: Transmission Media

The successful operation of a WSN relies on reliable communication between the nodes in the network. In a multi-hop sensor network, nodes can communicate through a wireless medium creating links between each other. These links can be formed by radio, infrared, optical, acoustic or magneto-inductive links. To enable interoperability and global operation of these networks, the chosen transmission medium must be available worldwide.

1.7.7: Power Consumption

A wireless sensor node can only be equipped with a limited power source due to the several hardware constraints. Moreover, for most applications, replenishment of power resources is impossible. WSN lifetime, therefore, shows a strong dependence on battery lifetime. Thus the sources that consume energy during the operation of each node should be analyzed and maintained efficiently.

- Sensing
- Data processing
- Communication
- Operating Hardware

1.8: ADDITIONAL CHALLENGES

- Integration of Sensor Networks and the Internet
- Real-Time and Multimedia Communication
- Protocol Stack
- Synchronization and Localization
- WSNs in Challenging Environments
- Practical Considerations
- Wireless Nano-Sensor Networks

1.9: OBJECTIVE

The main objective of this thesis is to find an energy efficient routing protocol. Therefore, we will re-evaluate the performance of the LEACH, LEACH-C, and LEACH-E protocol and find out a way to optimize the energy consumption to enhance the life time of wireless sensor network.

1.10: SCOPE OF THESIS

In this thesis, hierarchy based routing protocol are discussed. They have the common objective of trying to extend the life time by reducing the energy consumption of the sensor network. Hierarchical based techniques have special advantage of scalability and efficient communication. Ordered routing control the energy consumption of sensor node and perform data aggregation which helps in decreasing the number of transmitted messages to base station.

1.11: THESIS OUTLINE

This thesis is being partitioned into 5 chapters, which are organized in the chapter sentence: In chapter 1 gives the brief overview of the thesis. This chapter covers the topics overview WSN, Scope of thesis. In Chapter 2 Gives the literature survey classification of routing protocol. It's also containing the different issues of routing protocol. The Chapter 3 covers the problem statement and formulation. It's also covers the proposed work and solution methodology. Chapter 4 Describe the system architecture of proposed network and it's also covers the simulation result and analysis and chapter 5 concludes the work and shows the future scope of the work.

CHAPTER 2

LITERATURE REVIEW

In this section gives the detailed overview of routing. Here we have picked up LEACH routing protocol and studied various advantages and disadvantages. We also present a small description of some of the existing routing protocol and their classification. Finally at the end of the chapter we have compared the existing LEACH routing protocol variants.

2.1: ROUTING

Routing is the process of selecting a path for traffic in a network or multiple networks. Broadly, routing is performed in various types of networks that including Public Switched Telephone Network (PSTN) as Circuit-Switched Networks, Computer networks etc.

In packet switching networks, routing is the higher-level decision that directs data packets from source to destination. Intermediate nodes are typically network hardware devices such as routers, gateways, firewalls or switches. General-purpose computers also forward packets and perform routing, although they have no specially optimized hardware for the task. They follow the forwarding mechanisms to move data packet at destination.

2.2: ROUTING CHALLENGES AND DESIGN ISSUES

The design of routing protocols in WSNs is influenced by many challenging factors. These factors must be considered before designing of sensor network.The some of the important routing challenges are:

•Node deployment:

Node deployment in WSNs is application dependent and affects the performance of the routing protocol. The deployment can be either deterministic or randomized. In deterministic deployment, the sensors are manually placed and data is routed through pre-determined paths. However, in random node deployment, the sensor nodes are scattered randomly creating an infrastructure in an ad-hoc manner. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network operation. Inter-sensor communication is normally within short transmission ranges due to energy and bandwidth limitations. Therefore, it is most likely that a route will consist of multiple wireless hops.

•Energy Consumption without Losing Accuracy:

Sensor nodes can use their limited energy to perform computations and transmission of information in wireless environment. The energy conservation can be performed by optimizing the communication. In WSNs, the network life depends upon the life of sensor node and sensor node depends upon the battery lifetime [14]. In a multi hop WSN, each node plays a dual role as data sender and data router. The malfunctioning of some sensor nodes due to power failure can cause significant topological changes and might require rerouting of packets and reorganization of the network.

•Data Reporting Model:

Data sensing and reporting in WSNs is dependent on the application and the time criticality of the data reporting. Data reporting can be categorized as either time-driven (continuous), event-driven, query-driven, and hybrid [19]. The time-driven delivery model is suitable for applications that require periodic data monitoring. As such, sensor nodes will periodically switch on their sensors and transmitters, sense the environment and transmit the data of interest at constant periodic time intervals. In event-driven and query-driven models, sensor nodes react immediately to sudden and drastic changes in the value of a sensed attribute due to the occurrence of a certain event or a query is generated by the base station. As such, these are well suited for time critical applications. Therefore, the routing protocol is highly influenced by the data reporting model with regard to energy consumption and route stability.

•Node or Link Heterogeneity:

In many studies, all sensor nodes were assumed to be homogeneous i.e. having equal capacity in terms of computation, communication, and power. However, depending on the application a sensor node can have different role or capability. The existence of heterogeneous set of sensors raises many technical issues related to data routing. For example, some applications might require a diverse mixture of sensors for monitoring temperature, pressure and humidity of the surrounding environment, detecting motion via acoustic signatures, and capturing the image or video tracking of moving objects. These special sensors can be either deployed independently or the different functionalities can be included in the same sensor nodes. Even data reading and reporting can be generated from these sensors at different rates, subject to diverse quality of service constraints, and can follow multiple data reporting models. For example, hierarchical protocols designate a cluster head node different from the normal sensors. These cluster heads can be chosen from the deployed sensors or can be more powerful than other sensor nodes in terms of energy, bandwidth, and memory. Hence, the burden of transmission to the base station is handled by the set of cluster-heads.

•Fault Tolerance:

Some sensor nodes may fail or be blocked due to lack of power, physical damage, or environmental interference. The failure of sensor nodes should not affect the overall task of the sensor network. If many nodes fail, MAC and routing protocols must accommodate formation of new links and routes to the data collection base stations. This may require actively adjusting transmit powers and signaling rates on the existing links to reduce energy consumption, or rerouting packets through regions of the network where more energy is available. Therefore, multiple levels of redundancy may be needed in a fault-tolerant sensor network.

•Scalability:

The number of sensor nodes deployed in the sensing area may be in the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes. In addition, sensor network routing protocols should be scalable enough to respond to events in the environment. Until an event occurs, most of the sensors can remain in the sleep state, with data from the few remaining sensors providing a coarse quality.

•Network Dynamics:

Most of the network architectures assume that sensor nodes are stationary. However, mobility of base station or sensor nodes is sometimes necessary in many applications [21]. Routing messages from or to moving nodes is more challenging since route stability becomes an important issue in addition to energy and bandwidth. Moreover, the sensed phenomenon can be either dynamic or static depending on the application. The target tracking or monitoring is good application of dynamic networks, where as forest monitoring, early fire prevention are for static network. Monitoring static events allows the network to work in a reactive mode, simply generating traffic when reporting. Dynamic events in most applications require periodic reporting and consequently generate significant traffic to be routed to the base station.

•Transmission Media:

In a multi-hop sensor network, communicating nodes are linked by a wireless medium. The traditional problems associated with a wireless channel (e.g., fading, high error rate) may also affect the operation of the sensor network. In general, the required bandwidth of sensor data will be low, on the order of 1-100 kb/s. Related to the transmission media is the design of medium access control (MAC). One approach of MAC design for sensor networks is to use TDMA based protocols that conserve more energy compared to contention based protocols like CSMA (e.g., IEEE 802.11). Bluetooth technology [26] can also be used.

•Connectivity:

High node density in sensor networks precludes them from being completely isolated from each other. Therefore, sensor nodes are expected to be highly connected. This, however, may not prevent the network topology from being variable and the network size from being shrinking due to sensor node failures. In addition, connectivity depends on the, possibly random, distribution of nodes.

•Coverage:

In WSNs, each sensor node obtains a certain view of the environment. A given sensor's view of the environment is limited both in range and in accuracy; it can only cover a limited physical area of the environment. Hence, area coverage is also an important design parameter in WSNs.

•Data Aggregation:

Since sensor nodes may generate significant redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions is reduced. Data aggregation is the combination of data from different sources according to a certain aggregation function, e.g., duplicate suppression, minima, maxima and average. This technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols. Signal processing methods can also be used for data aggregation. In this case, it is referred to as data fusion where a node is capable of producing a more accurate output signal by using some techniques such as beam forming to combine the incoming signals and reducing the noise in these signals.

•Quality of Service:

In some applications, data should be delivered in predefined time. The late delivered data shall be useless. Therefore, bounded latency for data delivery is another condition for time-constrained applications. However, in many applications, conservation of energy, which is directly related to network lifetime, is considered relatively more important than the quality of data sent. As the energy gets depleted, the network may be required to reduce the quality of the results in order to reduce the energy dissipation in the nodes and hence lengthen the total network lifetime. Hence, energy-aware routing protocols are required to capture this requirement.

2.3: ROUTING PROTOCOL

On the basis of network structure routing protocol may be classified as Flat Routing, Hierarchical Routing and Location based Routing. In Flat Routing, all nodes are typically assigned equal role. In Hierarchical Routing, nodes will play different roles in the network. As in Location based routing, sensor nodes positions are exploited to route data in the network. A routing protocol is considered adaptive if certain system parameters can be controlled in order to adapt to the current network conditions and available energy levels. Furthermore, based on the protocol operation these protocols can be sub divided into Multi Path Based, Query-based, Negotiation-based, QoS-based, or Coherent-based Routing techniques as shown in figure 3.

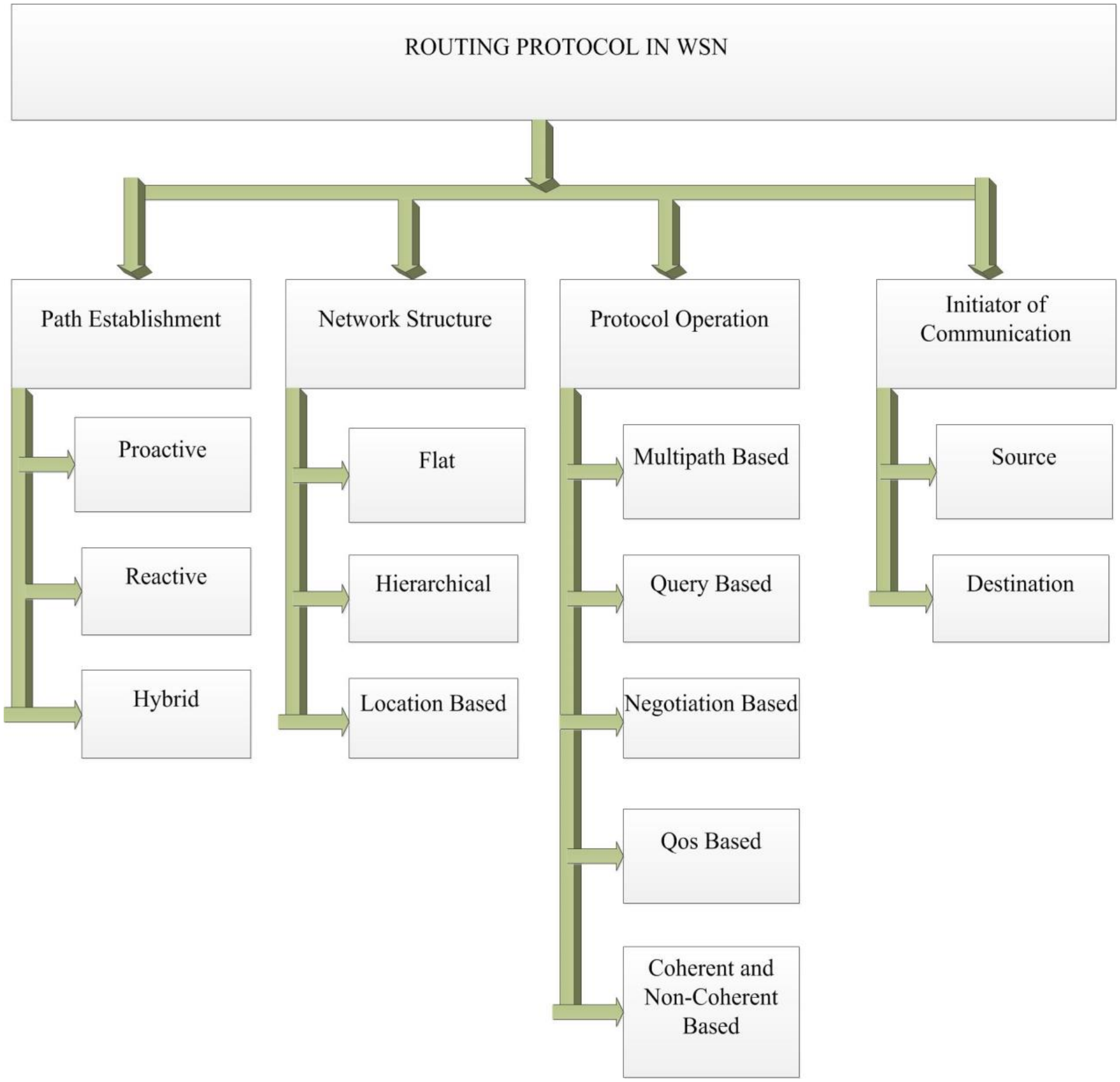

Fig 3: Classification of WSN routing protocol

2.4: CLASSIFICATION OF ROUTING PROTOCOL

The routing protocol may be classified in different ways. Some of the classifications are as:

2.4.1: BASED ON NETWORK STRUCTURE

- **Flat Routing:**

The first category of routing protocols is the multi hop flat routing protocols. In flat networks, each node typically plays the same role and sensor nodes collaborate together to perform the sensing task. Due to the large number of such nodes, it is not feasible to assign a global identifier to each node. This consideration has led to data centric routing, where the BS sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute-based naming is necessary to specify the properties of data. Early works on data centric routing, e.g., SPIN and directed diffusion [20] was shown to save energy through data negotiation and elimination of redundant data. These two protocols motivated the design of many other protocols which follow a similar concept.

- **Hierarchical Routing :**

Hierarchical or cluster-based routing, originally proposed in wire line networks. This is well-known techniques with special advantages of scalability and efficient communication. To perform energy-efficient routing in WSNs this routing uses the concept of hierarchical routing. In a hierarchical architecture, higher energy nodes can be used to process and send the information while low energy nodes can be used to perform the sensing in the proximity of the target. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption within a cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the base station. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other layer is used for routing.

- **Location based:**

In location based routing sensor nodes are addressed by means of their locations. The distance between neighboring nodes can be estimated on the basis of incoming signal strengths. Relative coordinates of neighboring nodes can be obtained by exchanging such information between neighbors [22, 23, 25]. Alternatively, the location of nodes may be available directly by communicating with a satellite, using GPS (Global Positioning System), if nodes are equipped with a small low power GPS receiver [24]. To save energy, some location based schemes demand that nodes should go to sleep if there is no activity. More energy savings can be obtained by having as many sleeping nodes in the network as possible. The problem of designing sleep period schedules for each node in a localized manner was addressed in [27, 24].

2.4.2: BASED ON PROTOCOL OPERATION

- **Multipath Routing:**

This routing protocol stores multiple paths between source and destination in order to enhance the network performance. The fault tolerance (resilience) of a protocol is measured by the likelihood that an alternate path exists between a source and a destination when the primary path fails. This can be increased by maintaining multiple paths between the source and the destination at the expense of an increased energy consumption and traffic generation. These alternate paths are kept alive by sending periodic messages. Hence, network reliability can be increased at the expense of increased overhead of maintaining the alternate paths.

- **Query based:**

In this kind of routing, the destination nodes propagate a query for data (sensing task) from a node through the network and a node having this data sends the data which matches the query back to the node, which initiates the query. Usually these queries are described in natural language, or in high-level query languages. All the nodes have tables consisting of the sensing tasks queries that they receive and send data which matches these tasks when they receive it. Directed diffusion [15] is an example of this type of routing. In directed diffusion, the base station node sends out interest messages to sensors. As the interest is propagated throughout the sensor network, the gradients from the source back to the base station are set up. When the source has data for the interest, the source sends the data along the interest's gradient path. To lower energy consumption, data aggregation is performed.

- **Negotiation based routing protocols:**

These protocols use high level data descriptors in order to eliminate redundant data transmissions through negotiation. Communication decisions are also taken based on the resources that are available to them. The SPIN protocols [16, 17] is an examples of negotiation based routing protocols. The motivation is that the use of flooding to disseminate data will produce implosion and overlap between the sent data; hence nodes will receive duplicate copies of data. This operation consumes more energy and more processing by sending the same data by different sensors. The SPIN protocols are designed to disseminate the data of one sensor to all other sensors assuming these sensors are potential base-stations. Hence, the main idea of negotiation based routing is to suppress duplicate information and prevent redundant data from being forwarded to the next sensor or to base-station by conducting a series of negotiation.

- **Quality of Service-Based Routing:**

In Quality of Service-based routing protocols, the network has to balance between energy consumption and data quality. In particular, the network has to satisfy certain Quality of Service metrics, e.g. delay, energy, bandwidth, etc. when delivering data to the BS. Sequential Assignment Routing (SAR) proposed in [18] is one of the first routing protocols for WSNs that introduces the notion of Quality of Service in the routing decisions. Routing decision in SAR is dependent on three factors: Energy Resources, Quality of Service on each path, and the priority level of each packet.

- **Coherent and Non-Coherent Based:**

Data processing is a major component in the operation of wireless sensor networks. Hence, routing techniques employ different data processing techniques. In general, sensor nodes will cooperate with each other in processing different data flooded in the network area. Two examples of data processing techniques proposed in WSNs are coherent and non-coherent data processing-based routing [18]. In non-coherent data processing routing, nodes will locally process the raw data before being sent to other nodes for further processing. The nodes that perform further processing are called the aggregators. In coherent routing, the data is forwarded to aggregators after minimum processing. The minimum processing typically includes tasks like time stamping, duplicate suppression, etc. To perform energy-efficient routing, coherent processing is normally selected.

2.5: HIERARCHICAL CLUSTERING

Hierarchical clustering, also known as hierarchical cluster analysis, is an algorithm that groups similar objects into groups called clusters. The endpoint is a set of clusters, where each cluster is distinct from each other cluster, and the objects within each cluster are broadly similar to each other.

2.6: LEACH ROUTING PROTOCOL

LEACH is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network. In LEACH, the nodes organize themselves into local clusters, with one node acting as the local base station or cluster-head. If the cluster heads were chosen a priori and fixed throughout the system lifetime, as in conventional clustering algorithms, it is easy to see that the unlucky sensors chosen to be cluster-heads would die quickly, ending the useful lifetime of all nodes belonging to those clusters.

Thus LEACH includes randomized rotation of the high-energy cluster-head position such that it rotates among the various sensors in order to not drain the battery of a single sensor. In addition, LEACH performs local data fusion to “compress” the amount of data being sent from the clusters to the base station, further reducing energy dissipation and enhancing system lifetime.

In LEACH, each round is divided into two phases:

Set-up phase

In set-up phase cluster heads are decided and nodes manage themselves in particular cluster.

Steady state phase

In steady state phase, data is transferred, sensor node to cluster head. Cluster head aggregate the data from receiving sensor node and then transmit to base station.

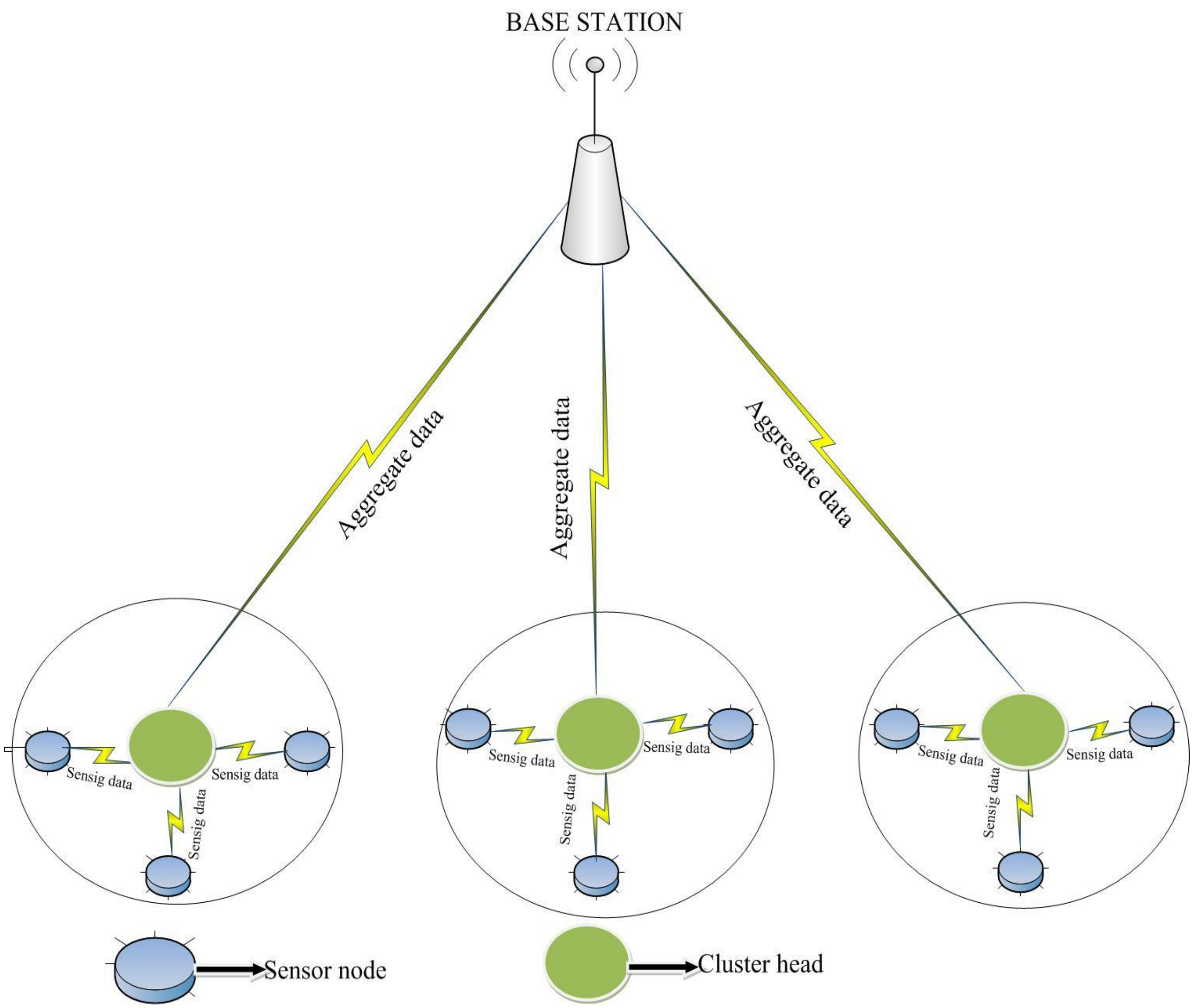

Fig: 4 Network Architecture of Leach

2.6.1: Network Architecture of LEACH

2.6.2: Cluster head selection

It is the first step of the set-up phase. Here the decision of each node to elevate as a CH is made for the current round. This decision is made by the n node by choosing a random number r between 0 and 1.The node becomes a CH if the randomly obtained value is less than a threshold T(n) which is calculated by the following formula:

$$T(n) = \begin{cases} \dfrac{p}{1-p*\left(\frac{r \bmod 1}{p}\right)} & if\ n \in G \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

Where n is the choosing a random number between 0 and 1, p is the desired percentage of cluster head, r is the current round, G is the set of nodes that have not been cluster-heads in the last 1/p rounds.

2.6.3: Cluster formation

Cluster Heads broadcasts an advertisement message (ADV) using CSMA MAC protocol.

ADV= Node id +header

Based on the received signal strength of ADV message, each non-Cluster Head node determines it's Cluster Head for this round.

Each non-Cluster Head transmits a join-request message (Join-REQ) back to its chosen Cluster Head using a CSMA MAC protocol.

Join-REQ= Node id + Cluster head id + header

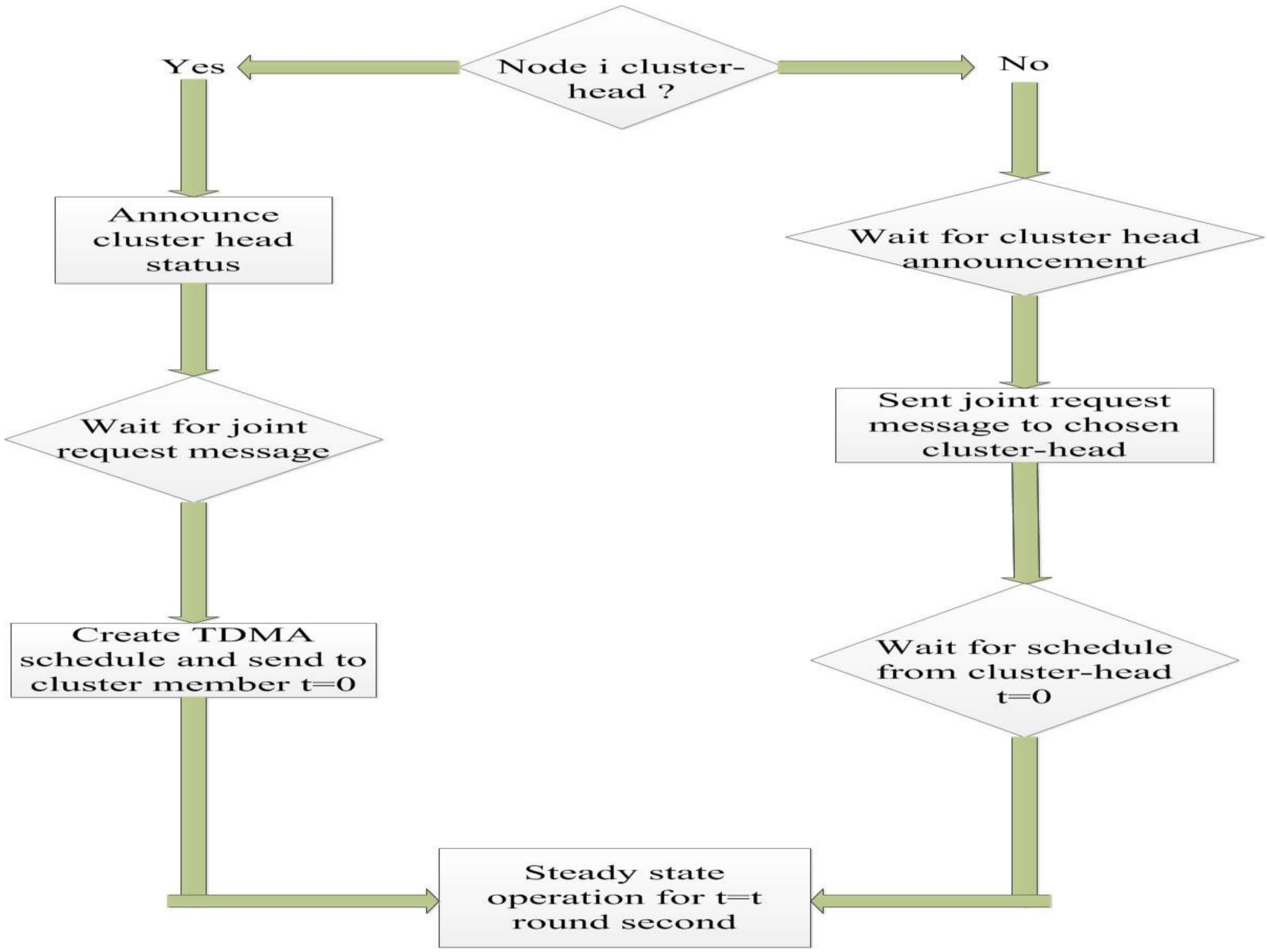

Fig: 5 Flowchart of the distributed cluster formation algorithm for LEACH

2.6.4: Scheduling

TDMA schedule is used to send data from sensor node to cluster head. Data is sent from the cluster head nodes to the BS using a fixed spreading code and CSMA.

2.6.5: Steady state phase

The steady-state operation is broken into frames, where nodes send their data to the cluster head at most once per frame during their allocated transmission slot. The duration of each slot in which a node transmits data is constant, so the time to send a frame of data depends on the number of nodes in the cluster. Fig. 6 shows the time line for one round of LEACH.

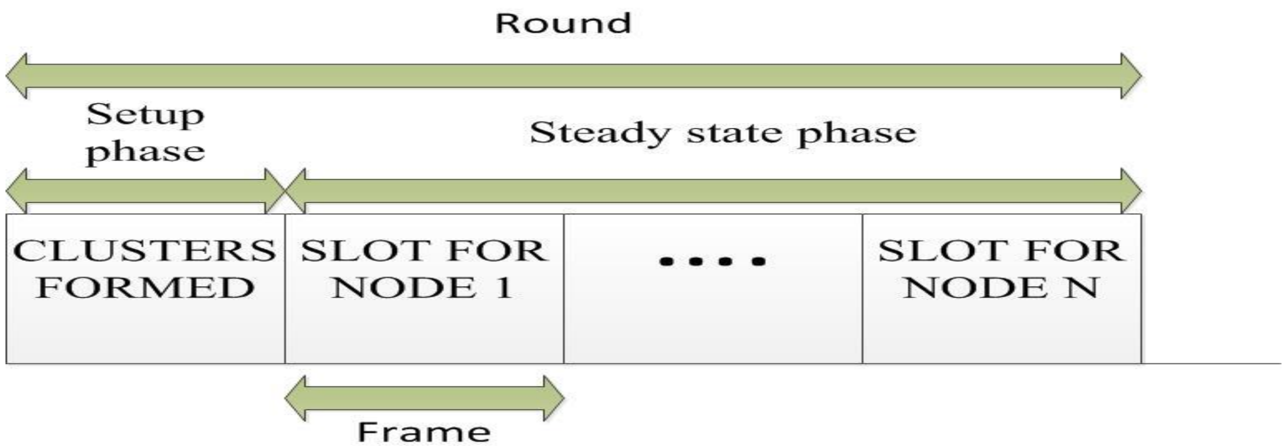

Fig: 6 Time line showing LEACH operation. Data transmissions are explicitly scheduled to avoid collisions and increase the amount of time each non-cluster head node can remain in the sleep state.

2.6.6: Radio energy dissipation model

Simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics.

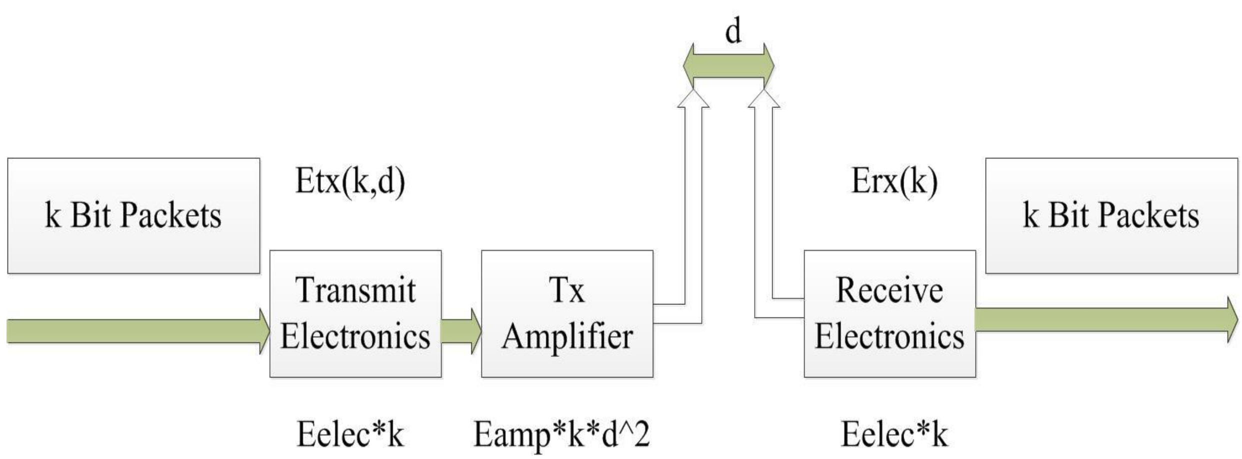

Fig: 7 Radio Energy Dissipation Model of Leach

We assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics, as shown in Fig. 7. For the experiments described here, both the free space (d^2 power loss) and the multipath fading (d^4 power loss) channel models were used, depending on the distance between the transmitter and receiver [28]. Power control can be used to invert this loss by appropriately setting the power amplifier, if the distance is less than a threshold does, the free space (f_S) model is used; otherwise, the multipath model is used. Thus, to transmit an l -bit message a distance d the radio expends

$$E_{TX} (k,d) = E_{TX} - \{ (E_{ELEC} * k) + (E_{MP} * k * d^4)\} \quad (2)$$

$$E_{TX} (k,d)= E_{TX} - \{ (E_{ELEC} * k) + (E_{FS} * k * d^2)\} \quad (3)$$

Energy consumption of receiving data (E_{RX}) is given as:

$$E_{RX} (k) = E_{RX} - (E_{ELEC} + E_{DA}) * k \quad (4)$$

2.6.7: Advantages

• LEACH is a completely distributed approach.

• It does not require any global information of network.

• It is a powerful and simple routing protocol.

• It uses random rotation of cluster-Head, which provides each node to become a cluster head node in a round.

• It uses TDMA so that each node can participate in rounds simultaneously.

• Each sensor node communicates only with associated cluster head (CH). It provides localized co-ordination and control for cluster setup and operation.

• Only a cluster head node (CH) aggregates the data collected by the nodes to minimize the data redundancy.

2.6.8: Disadvantages

- In LEACH Protocol only cluster head is responsible for sending data to base station directly. So, failure of cluster head leads to lack of robustness.

- Single Hop Routing technique is used in LEACH Protocol, which needs high energy for data transmission from CH to BS directly in case of large network.
- Selection of CH in any round is random and does not consider energy level of node, which can lead to drainage of a particular node.
- Dynamic clustering technique is used in LEACH which results in extra overhead like selection of CHs and advertisement.

2.7: VARIATION

2.7.1: Fixed Cluster, Rotating Cluster Head (LEACH-F)

Like LEACH-C protocol, this protocol uses centralized approach for cluster formation. Once the cluster formation process is done, then there is no re-clustering phase in next round. The clusters are fixed and only rotation of cluster head nodes within its clusters. The steady-state is same as classical LEACH [29, 35]. The overhead of re-clustering in basic LEACH is removed by LEAC-F protocol as once the fixed number of clusters is formed. They are maintained throughout the network. But this protocol provides no flexibility of adding or removing the nodes once clusters are formed and nodes cannot adjust their behavior on node dying.

2.7.2: Base Station Cluster Formation (LEACH-C)

Centralized LEACH has steady-state same as basic LEACH protocol but varies in set-up phase. The cluster head nodes are chosen by base station. Each node send its current location and energy level to the base station and the base station uses this global knowledge via GPS or other location tracking methods to produce better clusters to reduce transmission energy. The base station will choose only those nodes to become cluster head nodes which have enough energy and broadcast this information to all nodes in the network. Advantage of this protocol over basic LEACH is the deterministic approach of choosing number of cluster head nodes in each round which is predetermined at the time of deployment. LEACH-C causes better distribution of cluster head nodes in the network. But LEACH-C requires current location information of all nodes using GPS which is not robust [29, 33].

2.7.3: Energy Leach (Leach-E)

In LEACH-E protocol, initially all nodes have same energy and same probability of becoming the cluster head. After the first round, energy level of each node changes. Then the amount of residual energy of each node is used to select cluster head nodes. The nodes with highest residual energy are preferred on rest of the nodes. LEACH-E enhance lifetime of network by balancing energy load among all nodes in the network [34, 38].

2.7.4: Energy Efficient Extended LEACH (LEACH-EEE)

The basic concept involved in increasing energy efficiency is to keep radio communication distance as possible as minimum [29]. The popular technique used to minimize communication distance is the formation of clusters between nodes rather than direct communication [29, 35]. The more we increase the number of clusters, the more communication distance decreases and as a result energy efficiency of the protocol increases. So, we can say that the number of clusters and communication distance are inversely proportional to each other.

2.7.5: LEACH-B

LEACH-B uses decentralized approach of cluster formation in which each sensor node knows about its own position and position of final destination irrespective of position of rest of the nodes in the network. LEACH-B works in three stages: Cluster head selection, Cluster formation and data transmission with multiple accesses. According to energy dissipated in the path between a node and final receiver, each node chooses its cluster head. LEACH-B has better energy efficiency than basic LEACH protocol [30, 37, 38].

2.7.6: Mobile LEACH (LEACH-M)

LEACH-M protocol was proposed for mobility issue in LEACH protocol. This protocol provides mobility to the both non-cluster head nodes and cluster head nodes while the set-up and the steady-state. Nodes are homogeneous and location of each node is calculated by GPS. The nodes with minimum mobility and the lowest attenuation are being selected as cluster head nodes and the role of cluster head nodes is broadcasted to all nodes within its transmission range [32, 38].

2.7.7: Improved Leach (LEACH-I)

Detection of Twin nodes and assignment of Sub-Cluster Head (SCH) nodes are the two functions served by Improved-LEACH protocol. Randomly deployment of nodes results in high probability of two nodes located very close to each other called Twin nodes. It is necessary to keep one node sleep until the energy of another node depletes. Therefore LEACH-I has uniform distribution of cluster head so that it doesn't run out of energy when longer distance transmission takes place. This protocol uses threshold approach for managing number of cluster members for each cluster head in the network at a time [34] [37].

2.7.8: Advanced Leach (LEACH-A)

LEACH protocol has a problem that the cluster head node consumes more energy than normal nodes. Advanced-LEACH protocol, a heterogeneous protocol used to decrease probability of failure nodes and for extending the time interval before the death of the first node (called stability period). Each sensor knows the starting of each round using synchronized clock. Let n be the total number of nodes and m be the fraction of n that have energy more than other nodes called CGA nodes (nodes selected as gateways or cluster heads). The rest of (1-m)*n nodes act as normal nodes [31, 32, 35].

2.7.9: Multi-hop Leach (LEACH -MH)

In LEACH protocol, the cluster head nodes send data to the base station directly irrespective of distance between them. This will cause high energy dissipation of cluster head node if base station is located far away from it. As the network diameter increases, the distance between base station and cluster head nodes increases. To increase energy efficiency of the protocol, multi hoping communication is introduced. Firstly cluster member nodes send data to their respective cluster head nodes which further transfer data to cluster head rather than base station directly. This protocol adopts an optimal path between cluster head and the base station

[33, 36].

2.7.10: Two-level Leach (LEACH -TL)

Unlike LEACH protocol where cluster heads send data to the base station directly in a single hop, LEACH-TL protocol works in two-level hierarchy. The aggregated data from each cluster head is collected by a cluster head lies between cluster heads and the base station, instead of sending directly to the base station. Advancement of this protocol reduces data transmission energy. Cluster head nodes die early compared to other nodes, far away from base station and LEACH-TL improves energy efficiency by using a cluster head node as relay node in between cluster head nodes [30, 36].

2.8: COMPARE OF LEACH, LEACH-C AND LEACH-E

In LEACH, We simulated LEACH (with 5% of the nodes being cluster-heads) using MATLAB with the random network shown in Figure 8. These algorithms compare using E_{ELEC}=50nJ/bit as the diameter of the network is increased.

In LEACH-C, we used a 100-node network where nodes were randomly distributed between (x=0,y=0) and (x=100,y=100) with the BS at location (50,175). We assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics.

In LEACH-E, the basic simulation parameters for our model are mentioned in Table I. The experiment is carried out by using the same energy source whose initial energy is 0.5J. The fusion coefficient is 0.5. Every node transmits a k bits data packet per round to its cluster head.

A hundred sensor nodes are arranged randomly in the field of 100×100 square meters. The sink node is located at position (50, 140) and all nodes are no longer mobile as long as they are placed.

The required parameters to compare of LEACH, LEACH-C and LEACH-E are given in table 1.

2.8.1: Simulation Parameters

Sl.No.	Description	Symbol	Value
1	The Sensing Area	M×M	100m×100m
2	Number of Nodes	N	100
3	The Initial Node Energy	$E_{INITIAL}$	0.5J
4	Energy Consumed by the Amplifier to Transmit at a Short Distance	E_{FS}	10pJ/bit/m2
5	Energy Consumed by the Amplifier to Transmit at a Longer Distance	E_{MP}	0.0013pJ/bit/m4
6	Energy Consumed in the Electronics Circuit to Transmit or Receive the Signal	E_{ELEC}	50pJ/bit

7	Data Aggregation Energy	E_{DA}	5pJ/bit/report
8	The Cluster Probability of LEACH,LEAH-C	P	0.1
9	The Cluster Probability of LEACH-E	P	0.5
10	No. of Round	R_{MAX}	4000

Table: 1

2.8.2: **Sensor Node Deploy**

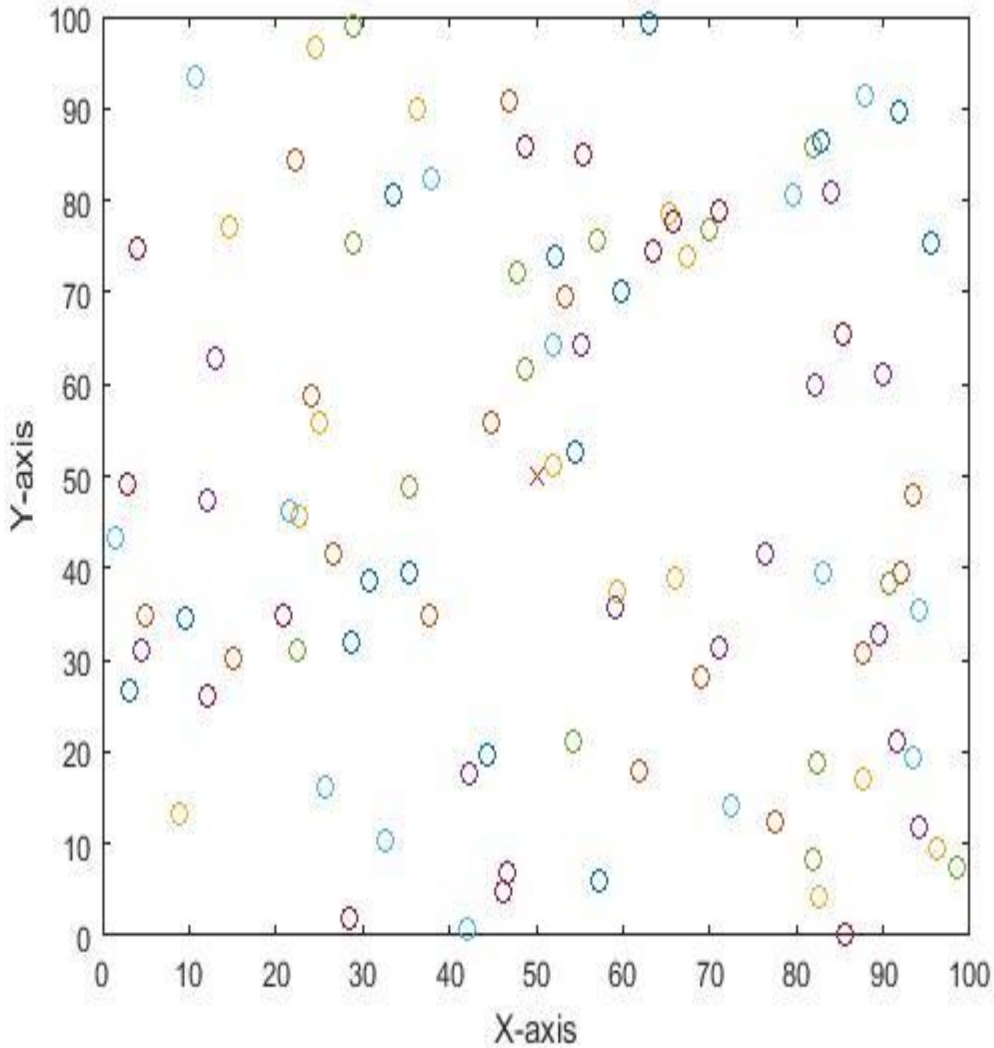

Fig 8: Show the graph of sensor node randomly deployment.

2.8.3: **Dead Node Vs Rounds**

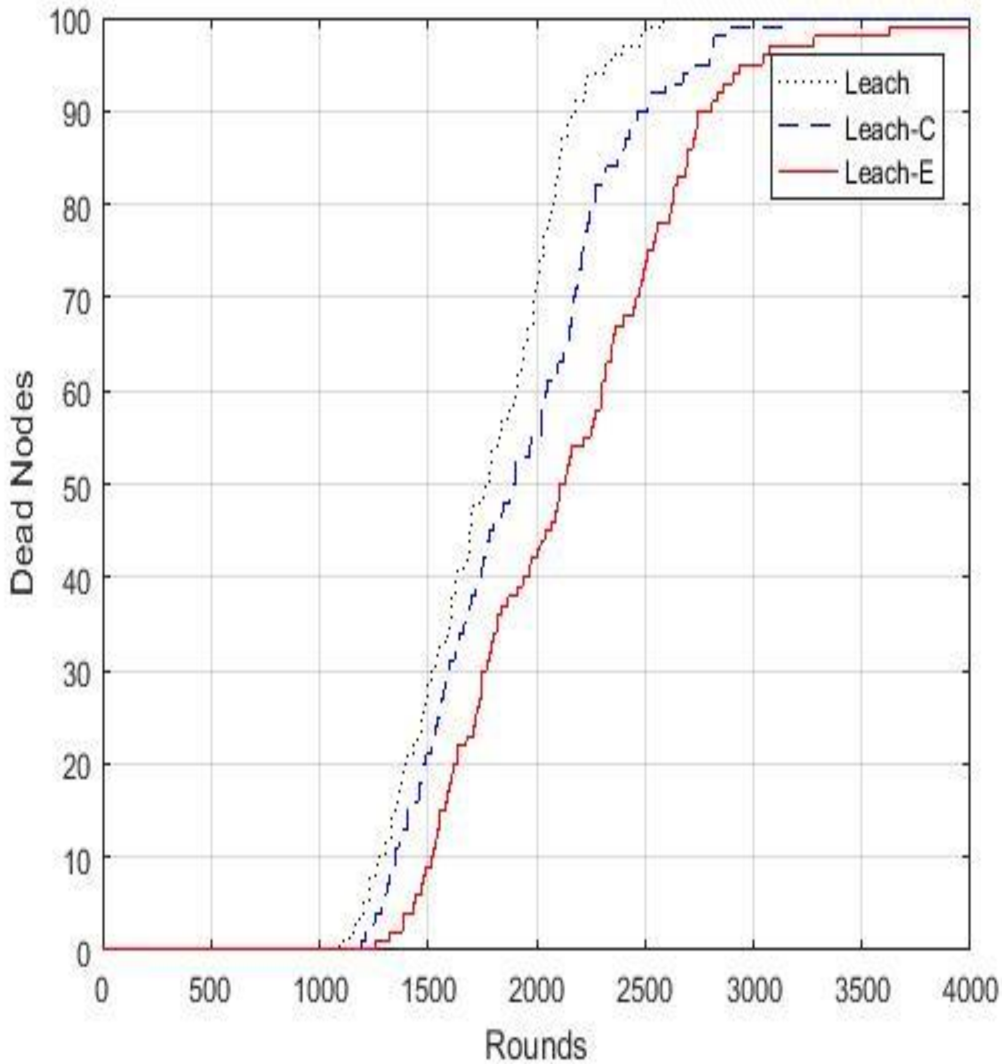

Fig 9: shows the network life time of whole sensor network. Plot is drawn between Dead Nodes in sensor network to Number of Rounds.

2.8.4: Alive Nodes Vs Rounds

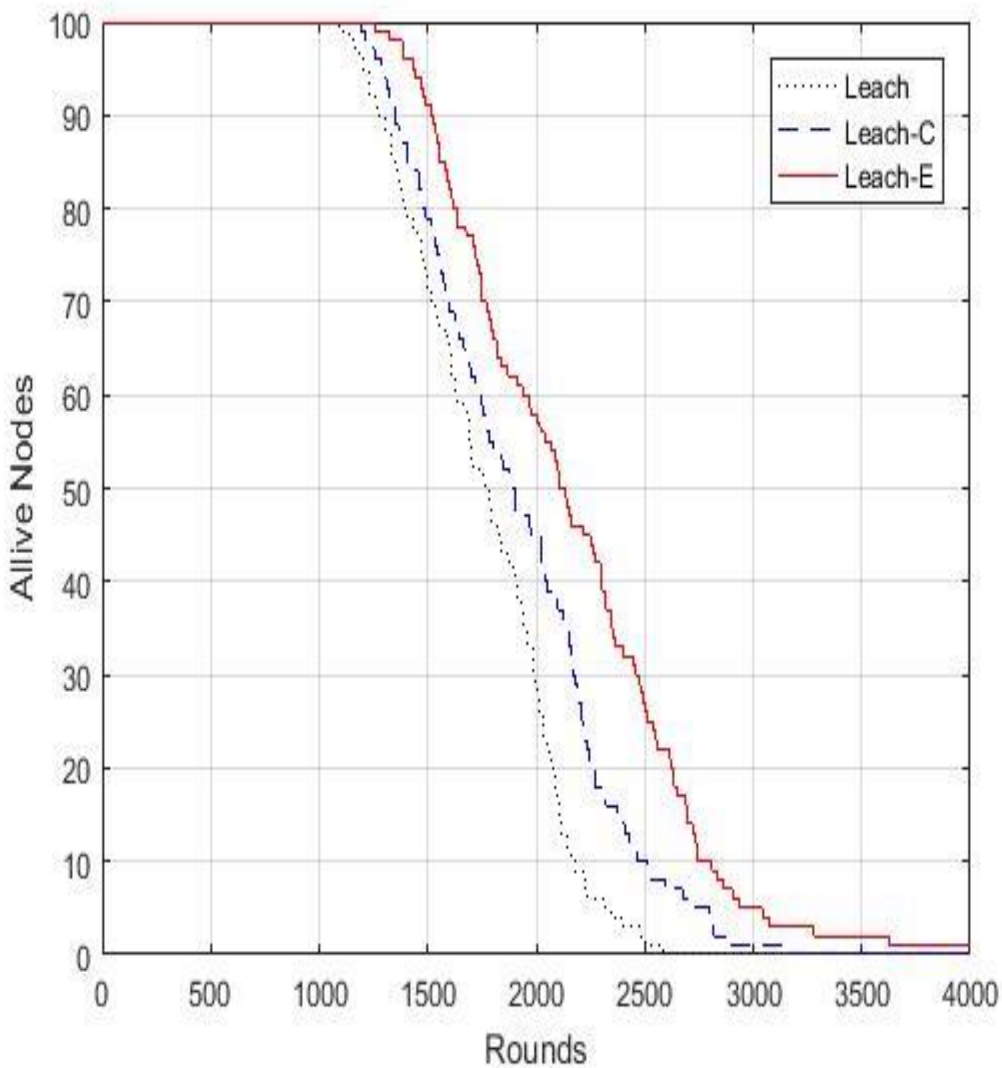

Fig 10: shows the network life time of whole sensor network. Plot is drawn between Alive Nodes in sensor network to Number of Rounds.

2.8.5: Packets to BS Vs Rounds

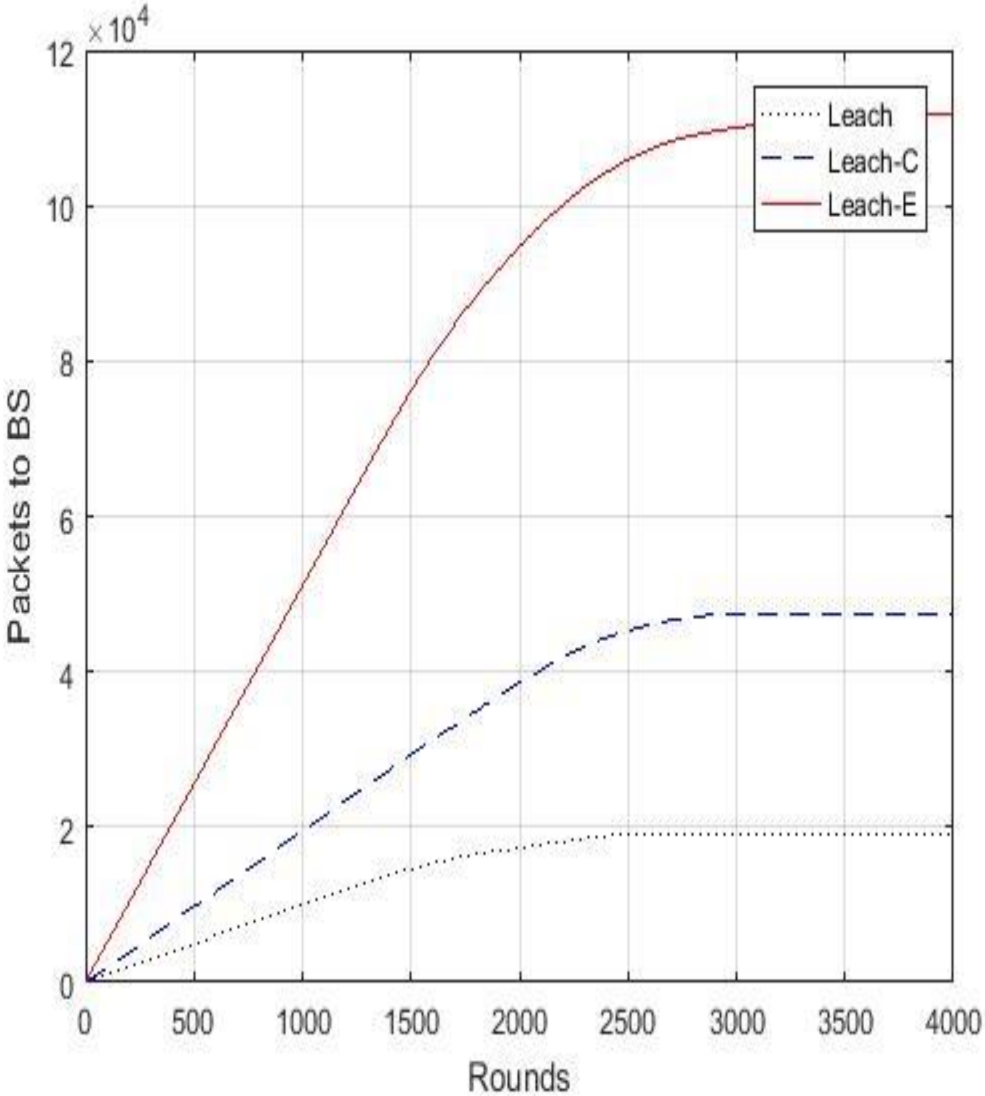

Fig 11: Plot is drawn between Packets to BS Vs Round.

2.8.6: Packets to CH Vs Rounds

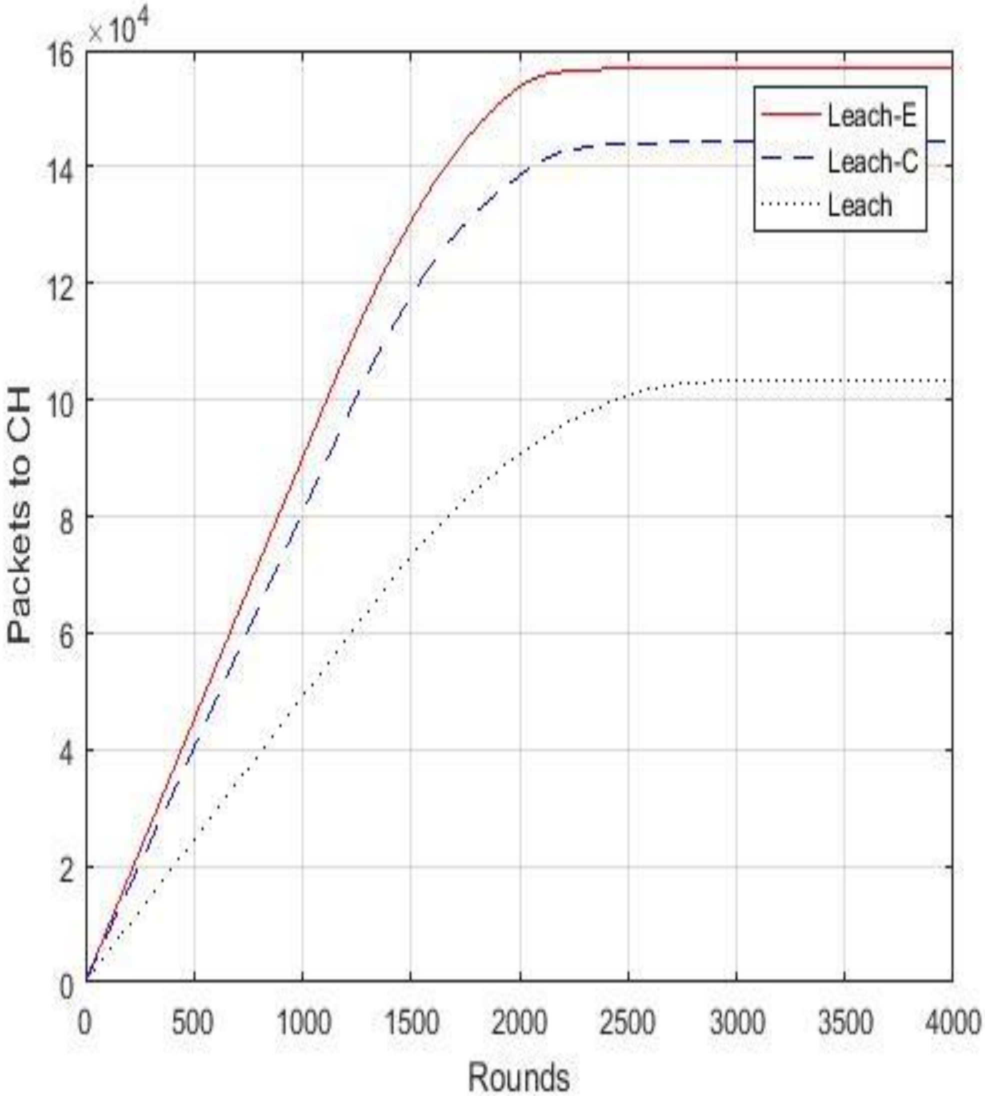

Fig 12: Plot is drawn between Packets to BS Vs Round.

2.9: COMPARISON OF CHARECTERISTICS OF LEACH, LEACH-C, AND LEACH-E

Parameters	**LEACH**	**LEACH-C**	**LEACH-E**
Classification	Cluster Based	Cluster Based	Cluster Based
Clustering Method	Distributed	Centralized	Distributed
No. of Clusters	Multiple	Multiple	Multiple
Data Transmitter	Cluster head	Cluster head	Cluster head
Data Aggregation	Yes	Yes	Yes
Energy Efficiency	Poor	Medium	Better
Choice of Cluster/Group Leader	Based on probabilistic approach	Based on energy level and distance from BS	Based on distance from CH to BS

Table 2

2.10: COMPARISON OF LEACH, LEACH-C, AND LEACH-E IN TERMS OF FIRST/LAST DEAD NODES, PACKETS TO BASE STATION AND PACKETS TO CLUSTER HEAD

Protocol	First dead node	All dead node	Packets to Base station	Packets to Cluster head
LEACH	1100	2583	1931	158891
LEACH-C	1197	2919	51426	144857
LEACH-E	1200	3825	114087	104925

Table: 3

2.11: CONCLUSION

From the simulation results and compare, we can say that LEACH-E is more energy-efficient than other LEACH and LEACH-C protocol with greater network lifetime.

CHAPTER 3

PROBLEM STATEMENT, PROPOSED PROTOCOL, PROBLEM FOMULATION AND SOLUTION APPROACH

3.1: PROBLEM STATEMENT

From previous chapter, we can see that many research work on advancement of LEACH. However they have not realized one drawback of leach related to a cluster head selection method. The decision which node becomes a cluster head depend on the energy level of each node. In traditional leach protocol the election of cluster head is depend upon the threshold level .All time this threshold level is defined as a random no. between 0 and 1. If assume that there is an optimal threshold value, that can improve the selection of cluster head method because in each cluster head selection process there may be loss some amount of energy. Further the location of base station is an important factor in a wireless sensor network as its effects its life time. If base station is deployed outer side of the sensor network field there are large energy is lost for data transmission.

3.2: THE PROPOSED PROTOCOL

A lot of experiments are going on in the research field of WSN to make routing protocols more and more energy efficient. Here, we proposed a modified version of LEACH called LEACH-EE (Energy Efficient) that can increase energy efficiency than original LEACH. The basic concept involved in increasing energy efficiency is to keep radio communication distance as possible as minimum [39]. The popular technique used to minimize communication distance is the formation of clusters between nodes rather than direct communication [39, 40]. The more we increase the number of clusters, the more communication distance decreases and as a result energy efficiency of the protocol increases. So, we can say that the number of clusters and communication distance are inversely proportional to each other. Keeping these concepts in mind, we proposed multilevel clustering technique in our proposed protocol. Here besides having a single layer of clusters formation between the nodes and Base station like LEACH, it involves two layers of clusters formation. In the first layer cluster heads are formed where the normal nodes transmit their own data to their respective cluster head and by using the data aggregation energy (E_{DA}) technique, cluster head aggregate the received data. Again in the second layer Master Cluster Heads (MCH) are formed. After the formation of MCHs, the cluster head search the nearest MCHs by calculating the distance between them and transmit their aggregate data to the respective MCHs. In the similar way, the MCHs receives data from their nearest CHs, aggregate all received data by using their master data aggregation energy, transform them into a compress format and forward them to the base station.

3.3: PROBLEM FORMULATION

The whole problems are formulated in following points:

- All sensor motes in the sensor field are homogeneous and power limited.
- No mobility of sensor nodes.
- The position of base station is fixed and located at center of the sensor field.
- Data are transmitted periodically from sensor network (nodes-cluster head-master cluster head) to the base station.

3.4. SOLUTION APPROACH

The work follows as:

I. Positioning of base station.
II. Selection of cluster head.
III. Selection of master cluster head.
IV. Radio communication distance.

3.5: NETWORK ARCHITECTURE OF PROPOSED PROTOCOL

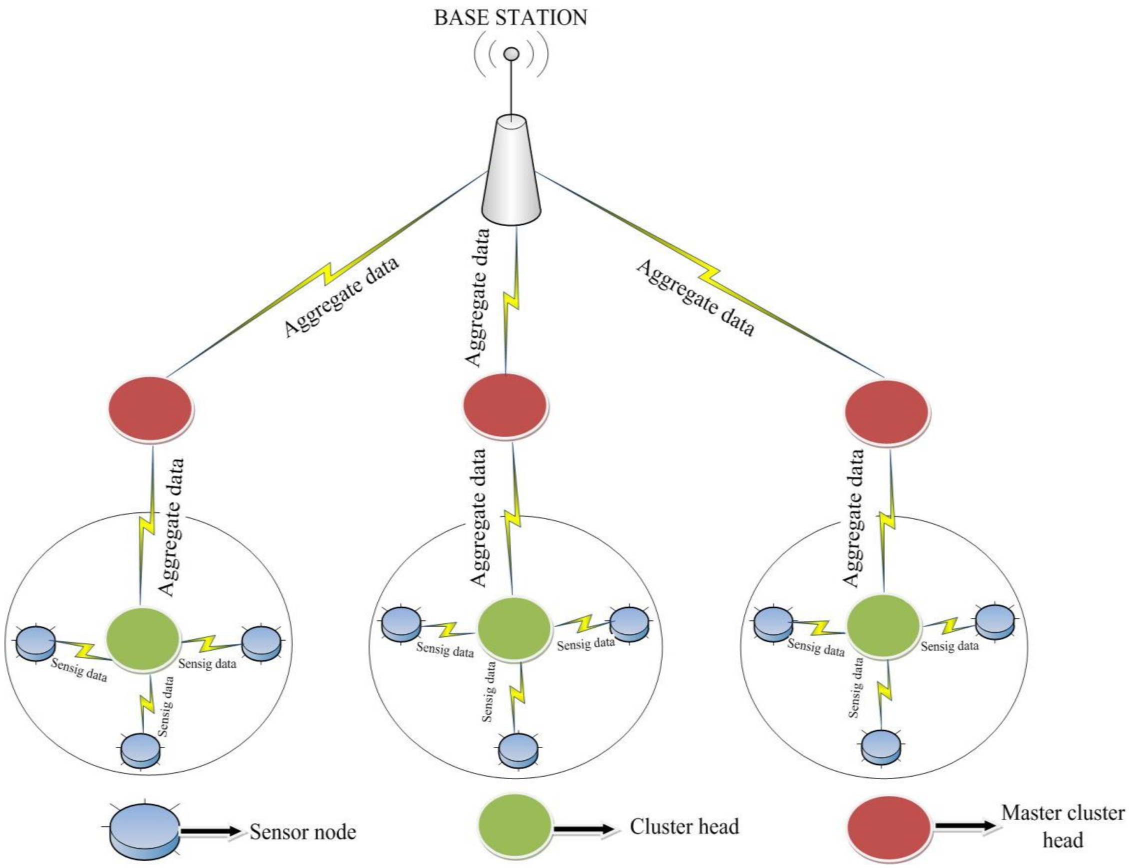

Fig 13: Network Architecture of Proposed Protocol LEACH-EE

In first go the cluster head are selected. Out of selected cluster head considering the position of sink the master cluster head are selected. The function of cluster head is to aggregate the sensory data and the function of master cluster head is to aggregate the data collected from the cluster head. In this way the data will be aggregated, number of packet shall be reduced. This reduction in no of packet shall be save energy.

CHAPTER 4
SIMULATION AND RESULT ANALYSIS

4.1: SIMULATION TOOL

MATLAB

MATLAB (matrix laboratory) is a multi paradigm numerical computing environment and proprietary programming language developed by Math Works. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, FORTRAN and Python.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

4.2: SIMULATION RESULT

4.2.1: Master Cluster Head

The function of the master cluster head is to aggregate the data collected from the cluster head in this way it will aggregate the data and reduce the number of packets to be transmitted to the sink. The selection of the master cluster head is based on the position of the sink node. First of all we calculate the distance between cluster head and sink, and then we will calculate the average distance between cluster head and sink as:

$$\text{Average distance between cluster head to sink} = \frac{\text{Distance between cluster head to sink}}{\text{Number of cluster head}}$$

The cluster head having the distance, less than average distance to sink has the more probability to be selected as master cluster head.

4.2.2: Radio Communication Distance

Let the distance from the sensor field to the base station be x, distance between nodes be y, distance between CHs is z, the number of normal nodes is n1, the number of CHs is n2, and the number of MCHs is n3.

For example, Let there are total 100 nodes in both existing LEACH and proposed LEACH-EE. Using LEACH algorithm, the nodes are grouped into 34 numbers of clusters. Therefore the numbers of CHs are 34 and normal nodes are 66. Similarly let, using EE LEACH algorithm 100 nodes are divided into 30 numbers of CHs, 4 numbers of MCHs and 66 numbers of normal nodes.

The radio communication distance of an existing LEACH model is calculated as [39]:

d=(n1*y)+(n2*x) (10)

The radio communication distance of a proposed LEACH-EE model is calculated as:

d'=(n1*y)+(n2*z)+(n3*x) (11)

Let, x=15, y=2, z=3

Now in LEACH, d = 66*y + 34*x = 642 unit.

And in LEACH-EE, d' = 66*y + 30*z + 4*x = 282 unit.

In this way we can observe that there is huge difference between d and d' as d' is very minimum in comparison of d. Thus, multilevel clustering greatly minimizes transmission distances which in turn conserve energy consumption.

4.2.3: Simulation parameters

Sl.No.	Description	Symbol	Value
1	The Sensing Area	M×M	100m×100m
2	Number of Nodes	N	100
3	The Initial Node Energy	$E_{INITIAL}$	0.5J
4	Energy Consumed by the Amplifier to Transmit at a Short Distance	E_{FS}	10pJ/bit/m2
5	Energy Consumed by the Amplifier to Transmit at a Longer Distance	E_{MP}	0.0013pJ/bit/m4
6	Energy Consumed in the Electronics Circuit to Transmit or Receive the Signal	E_{ELEC}	50pJ/bit
7	Data Aggregation Energy	E_{DA}	5pJ/bit/report

8	The Cluster Probability of LEACH,LEACH-C	P	0.1
9	The Cluster Probability of LEACH-E	P	0.5
10	No. of Round	R_{MAX}	4000

Table: 4

4.3: SIMULATION ANALYSIS

4.3.1: SENSOR NODES DEPLOYMENT

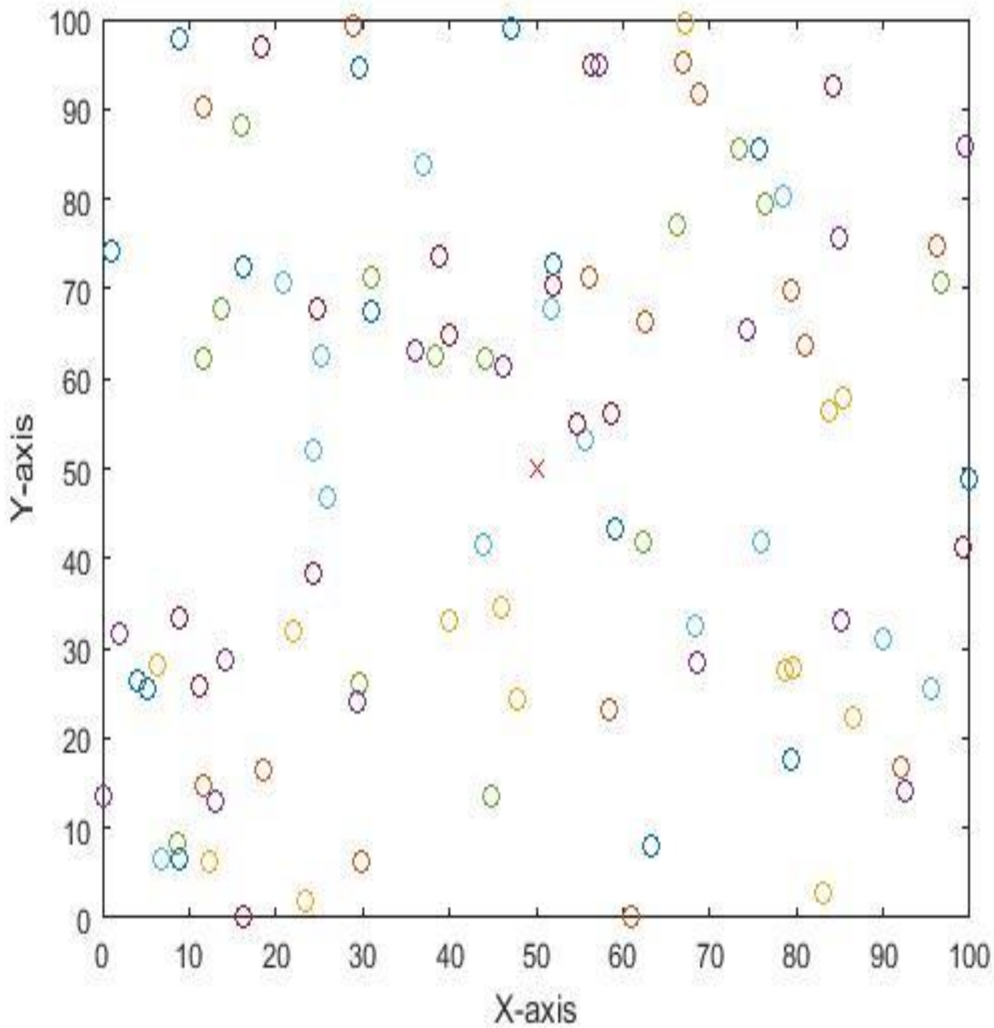

Fig 14: Show the fig Sensor Node Randomly Deployment

4.3.2: DEAD NODES Vs ROUNDS

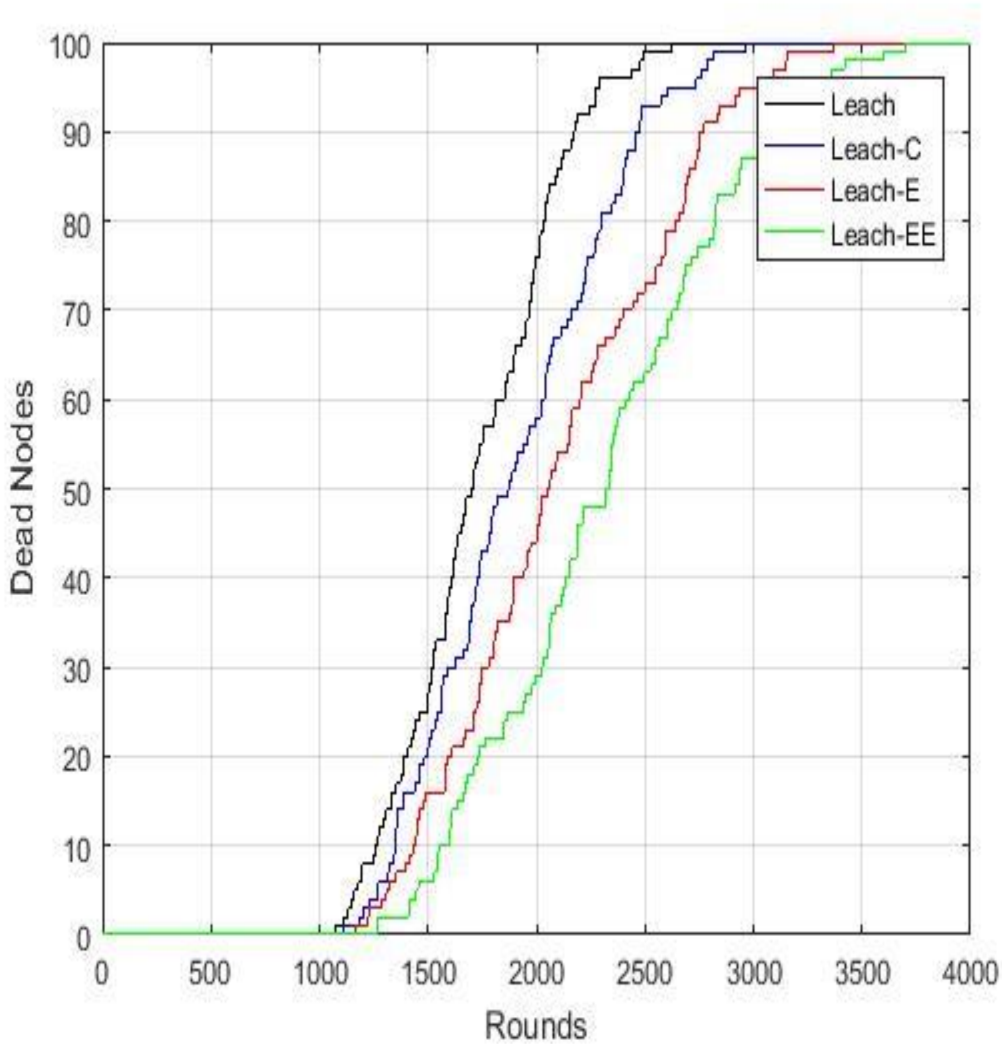

Figure 15**:** Shows the network life time of whole sensor network. Plot is drawn between Dead nodes in sensor network to number of rounds.

4.3.3: ALIVE NODES Vs ROUNDS

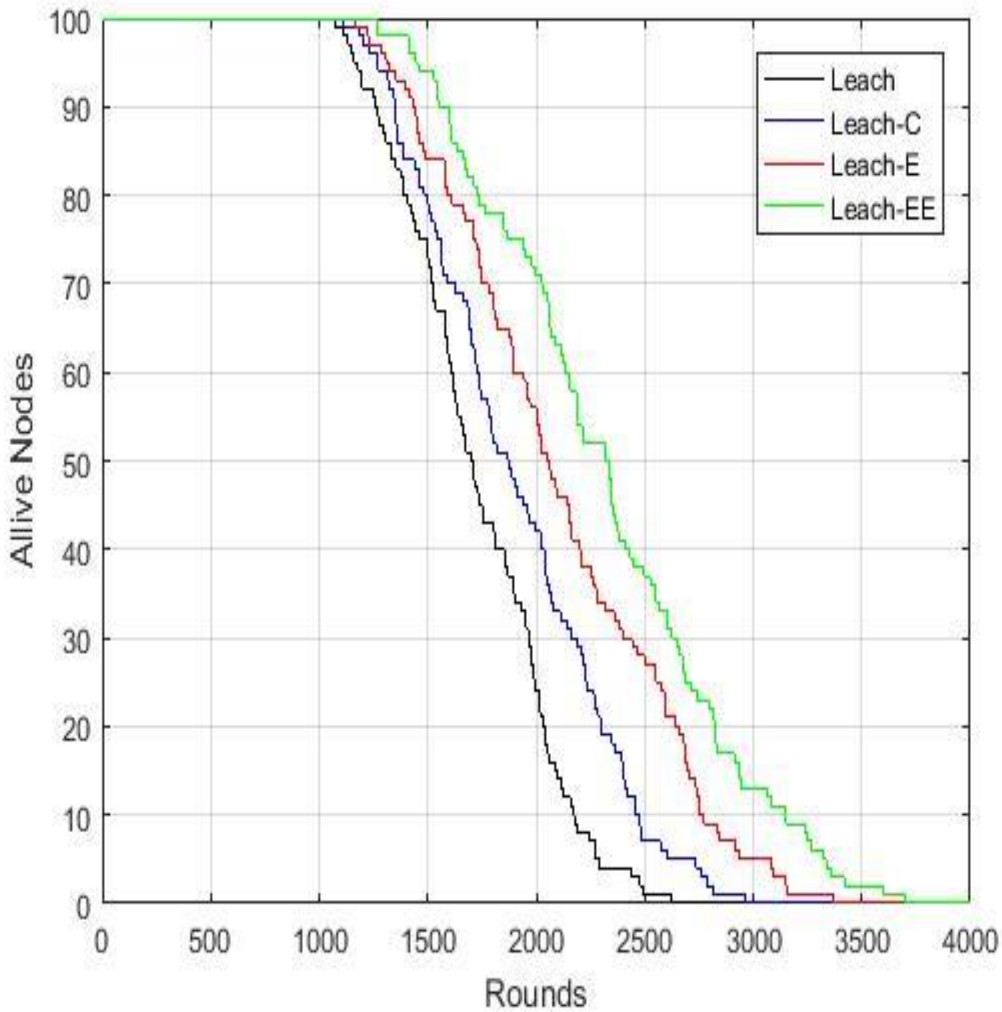

Figure 16: shows the network life time of whole sensor network. Plot is drawn between alive nodes in sensor network to number of rounds.

4.3.4: PACKETS TO BS Vs ROUNDS

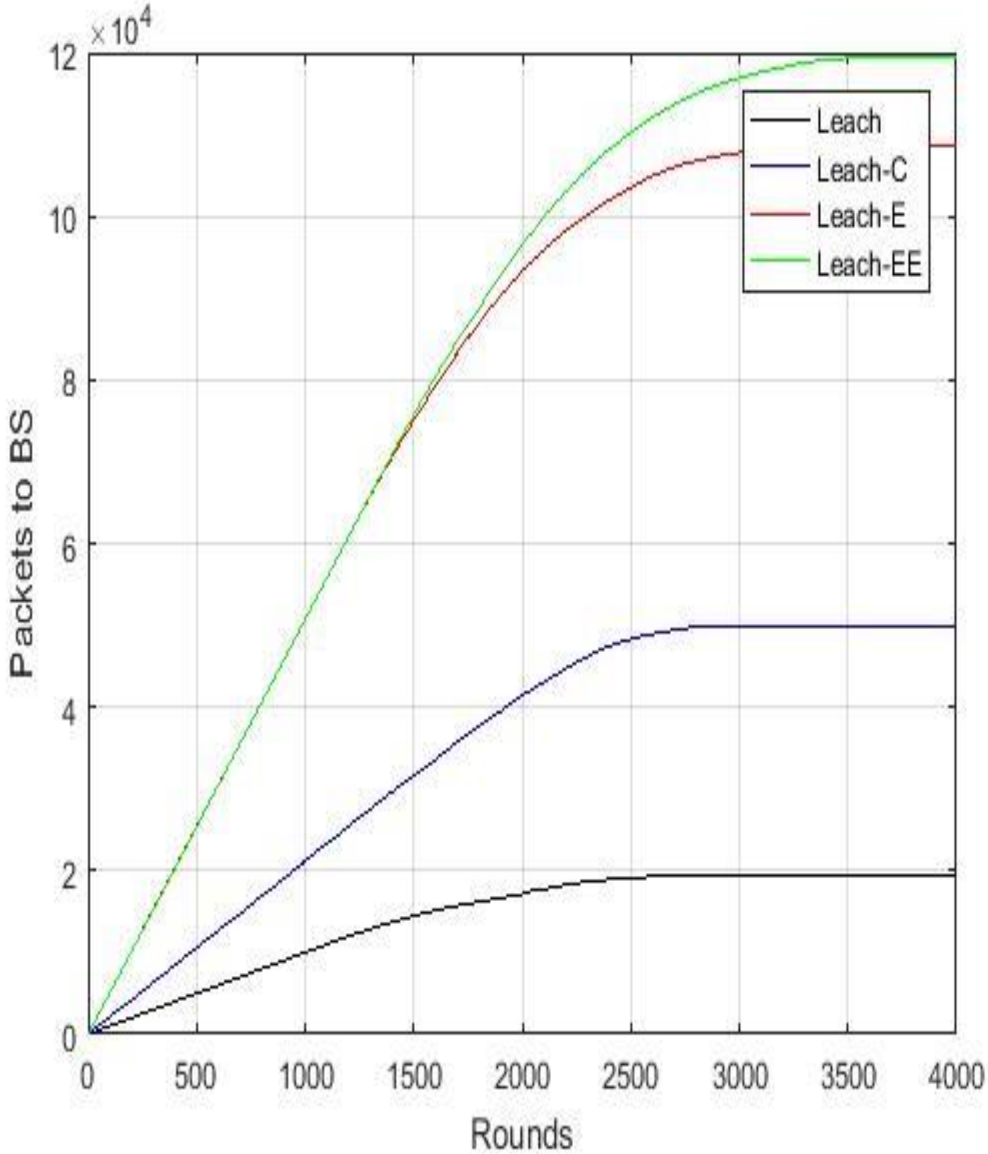

Figure 17: Plot is drawn between Packets to BS Vs Rounds

4.3.5: PACKETS TO CH Vs ROUNDS

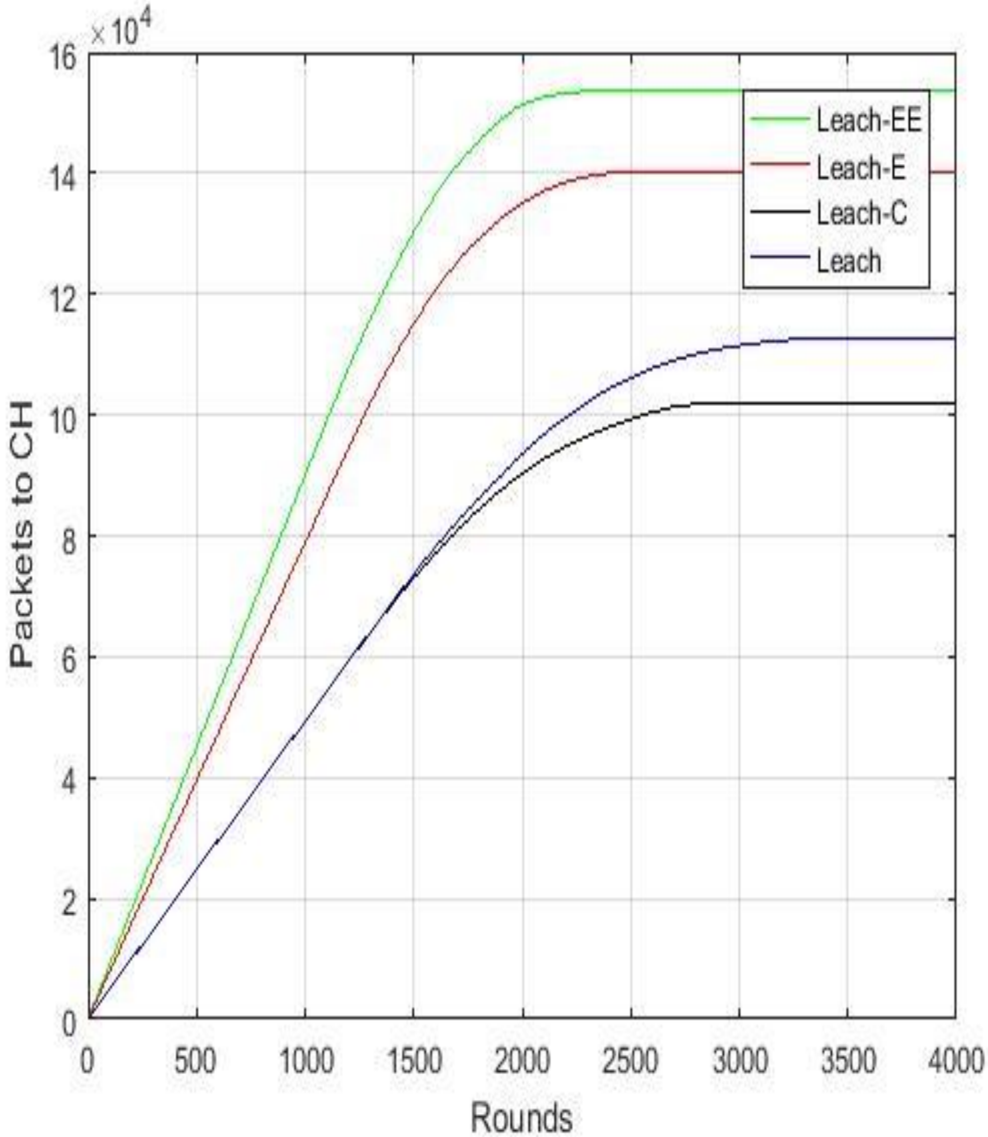

Figure 18: Plot is drawn between Packets to CH Vs Rounds

4.4: COMPARISON OF CHARACTERISTICS OF LEACH, LEACH-C, LEACH-E AND PROPOSED LEACH-EE

Parameters	LEACH	LEACH-C	LEACH-E	LEACH-EE

Classification	Cluster Based	Cluster Based	Cluster Based	Cluster Based
Clustering Method	Distributed	Centralized	Distributed	Distributed
No. of Clusters	Multiple	Multiple	Multiple	Multiple
Data Transmitter	Cluster head	Cluster head	Cluster head	Cluster head
Data Aggregation	Yes	Yes	Yes	Yes
Energy Efficiency	Poor	Medium	Better	Excellent
Choice of Cluster/Group Leader	Based on probabilistic approach	Based on energy level and distance from BS	Based on distance from CH to BS	Based on distance from CH to MCH to BS

Table: 5

4.5: COMPARISON OF LEACH, LEACH-C, LEACH-E AND LEACH-EE IN TERMS OF FIRST/LAST DEAD NODES, PACKETS TO BASE STATION AND PACKETS TO CLUSTER HEAD

Protocol	First dead node	All dead node	Packets to Base station	Packets to Cluster head
LEACH	1100	2583	1931	158891
LEACH-C	1197	2919	51426	144857
LEACH-E	1200	3825	114087	104925
LEACH-EE	1447	3836	124967	95221

Table: 6

4.6: CONCLUSION

From the simulation results and compare, we can say that LEACH-EE (Energy Efficient) is more energy-efficient than other LEACH, LEACH-C, and LEACH-E protocol with greater network lifetime.

CHAPTER 5
CONCLUSION AND FUTURE SCOPE

5.1: CONCLUSION

In this paper we considered a well known wireless sensor network routing protocol called

LEACH and proposed a new version of LEACH protocol called LEACH-EE. Then LEACH-EE protocol is successfully simulated and compared with LEACH protocol. From the simulation results we can draw the conclusion that LEACH-EE is more energy-efficient than other LEACH protocol with greater network lifetime.

5.2: FUTURE SCOPE

The proposed algorithm is for the homogeneous network, fixed base station and master cluster head. Using this algorithm we optimized the energy consumption. The future work can include some more level of hierarchy and mobility in the network.

REFERENCES

Artificial Retina project. Available at http://artificialretina.energy.gov.

Boomerang shooter detection system. http://bbn.com/boomerang.

Center for Coastal Margin Observation and Prediction. http://www.ccalmr.ogi.edu/corie.

Dust Networks Inc. http://www.dust-inc.com.

J. Agre and L. Clare. An integrated architecture for cooperative sensing networks. IEEE Computer Magazine, 33(5):106–108, May 2000.

F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci. Wireless sensor networks: a survey. Computer Networks, 38(4):393–422, March 2002.

Y. Kim, T. Schmid, Z. M. Charbiwala, J. Friedman, and M. B. Srivastava. NAWMS: Nonintrusive Autonomous Water Monitoring System. In Proceedings of ACM SenSys'08, pp. 309–322, Raleigh, NC, USA, November 2008.

L. Krishnamurthy, R. Adler, P. Buonadonna, J. Chhabra, M. Flanigan, N. Kushalnagar, L. Nachman, and M. Yarvis. Design and deployment of industrial sensor networks: experiences from a semiconductor plant and the North Sea. In Proceedings of SenSys'05, pp. 64–75, San Diego, CA, USA, 2005.

E. M. Petriu, N. D. Georganas, D. C. Petriu, D. Makrakis, and V. Z. Groza. Sensor-based information appliances. Instrumentation & Measurement Magazine, 3(4):31–35, December

2000.
).Crossbow MicaZ mote specifications. http://www.xbow.com.
..S. Cho and A. P. Chandrakasan. Energy efficient protocols for low duty cycle wireless microsensor networks. In Proceedings of IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP'01), volume 4, pp. 2041–2044, Salt Lake City, UT, USA, January 2001.
:.J. Rabaey, J. Ammer, J. L. da Silva Jr., and D. Patel. Picoradio: ad-hoc wireless networking of ubiquitous low-energy sensor/monitor nodes. In Proceedings of the IEEE Computer Society Annual Workshop on VLSI (WVLSI'00), pp. 9–12, Orlando, FL, USA, April 2000.
;.S. Roundy, P. K. Wright, and J. M. Rabaey. Energy Scavenging for Wireless Sensor Networks: with Special Focus on Vibrations. Springer, 2003.
..W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS '00), January 2000.
;.C. Intanagonwiwat, R. Govindan, and D. Estrin, "Directed diffusion: a scalable and robust communication paradigm for sensor networks," Proceedings of ACM MobiCom '00, Boston, MA, 2000, pp. 56-67.
;.W. Heinzelman, J. Kulik, and H. Balakrishnan, "Adaptive Protocols for Information Dissemination in Wireless Sensor Networks," Proc. 5th ACM/IEEE Mobicom Conference (MobiCom '99), Seattle, WA, August, 1999. pp. 174-85.
'.J. Kulik, W. R. Heinzelman, and H. Balakrishnan, "Negotiation-based protocols for disseminating information in wireless sensor networks," Wireless Networks, Volume: 8, pp. 169-185, 2002.
;.K. Sohrabi, J. Pottie, "Protocols for self-organization of a wireless sensor network", IEEE Personal Communications, Volume 7, Issue 5, pp 16-27, 2000.
).Y. Yao and J. Gehrke, "The cougar approach to in-network query processing in sensor networks", in SIGMOD Record, September 2002.
).F. Ye, A. Chen, S. Liu, L. Zhang, "A scalable solution to minimum cost forwarding in large sensor networks", Proceedings of the tenth International Conference on Computer Communications and Networks (ICCCN), pp. 304-309, 2001.
..F. Ye, H. Luo, J. Cheng, S. Lu, L. Zhang, "A Two-tier data dissemination model for large-scale wireless sensor networks", proceedings of ACM/IEEE MOBICOM, 2002.
:.N. Bulusu, J. Heidemann, D. Estrin,"GPS-less low cost outdoor localization for very small devices", Technical report 00-729, Computer science department, University of Southern California, Apr. 2000.
;.Savvides, C-C Han, aind M. Srivastava,"Dynamic fine-grained localization in Ad-Hoc networks of sensors," Proceedings of the Seventh ACM Annual International Conference on Mobile Computing and Networking (MobiCom), July 2001. pp. 166-179.
..Y. Xu, J. Heidemann, D. Estrin,"Geography-informed Energy Conservation for Ad-hoc Routing," In Proceedings of the Seventh Annual ACM/IEEE International Conference on

Mobile Computing and Networking 2001, pp. 70-84.
5.S. Capkun, M. Hamdi, J. Hubaux,"GPS-free positioning in mobile ad-hoc networks", Proceedings of the 34th Annual Hawaii International Conference on System Sciences, 2001 pp. 3481-3490.
6. http://www.ieee802.org/15/
7.B. Chen, K. Jamieson, H. Balakrishnan, R. Morris, "SPAN: an energy-efficient coordination algorithm for topology maintenance in ad hoc wireless networks", Wireless Networks, Vol. 8, No. 5, Page(s): 481-494, September 2002.
8.T. Rappaport, Wireless Communications: Principles & Practice. Englewood Cliffs, NJ: Prentice-Hall, 1996.
9.W.Heinzelman, A.Chandrakasan, and H.Balakrishnan, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks," IEEE Transaction on Wireless Communications, vol. 1, no. 4, pp. 660–670, 2002.
0.Depedri, A. Zanella and R. Verdone, "An Energy Efficient Protocol for Wireless Sensor Networks" in Proc. AINS, 2003, pp. 1-6.
1.E.Abdellah, S. Benalla, A.B.Hsaane, and M. Lahcen, "Advanced Low Energy Adaptive Clustering Hierarchy," (IJCSE) International Journal on Computer Science and Engineering, vol. 02, no. 07, pp. 2491-2497, 2010.
2.V.Kumar, S.Jain, and S. Tiwari, "Energy Efficient Clustering Algorithms in Wireless Sensor Networks: A Survey," International Journal of Computer Science Issues (IJCSI), vol. 8, issue 5, no. 2, pp. 259-268, September 2011.
3.J.Gnanambigai, Dr.N.Rengarajan, and K.Anbukkarasi, "Leach and Its Descendant Protocols: A Survey," International Journal of Communication and Computer Technologies (IJCCT), vol. 01, issue 02, no.3, pp. 15-21, September 2012.
4.M.Ahmad Jan and M.Khan, "A Survey of Cluster-based Hierarchical Routing Protocols," IRACST – International Journal of Computer Networks and Wireless Communications (IJCNWC),vol.3, no.2, pp. 138-143, April 2013.
5.P.Manimala and R.Senthamil selvi, "A Survey on LeachEnergy Based Routing Protocol," International Journal of Emerging Technology and Advanced Engineering (IJETAE), vol.3, issue 12, pp. 657-660, December 2013.
6.R.Kaur, D.Sharma, and N.Kaur, "Comparative Analysis Of Leach And Its Descendant Protocols In Wireless Sensor Network," International Journal of P2P Network Trends and Technology (IJPNTT), vol. 3, issue 1, pp. 51- 55, 2013.
7.A.Braman and Umapathi G.R, "A Comparative Study on Advances in LEACH Routing Protocol for Wireless Sensor Networks: A survey," International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE), vol. 3, issue 2, pp. 5683-5690, February 2014.
8.M.Usha and Dr.N.Sankarram, "A Survey on Energy Efficient Hierarchical (Leach) Clustering Algorithms in Wireless Sensor Network," International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE), Proceedings of International

Conference On Global Innovations In Computing Technology (ICGICT’14), vol.2, special issue 1, pp. 601- 609, March 2014.

Wairagu G. Richard, “Extending LEACH routing algorithm for Wireless Sensor Network,” Data Communications Engineering, Makerere University, 2009.

Nidhi Barta, Anuj Jain, Surender Dhiman, “An Optimized Energy Efficient Routing Algorithm For Wireless Sensor Network,” International Journal of Innovative Technology and Creative Engineering (ISSS:2045-8711) Vol 1 No.5 May 2011.