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ENERGY EFFICIENT THREE TIER ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS

by

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A THESIS

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DEPARTMENTAL ACCEPTANCE

The thesis entitled "**Energy Efficient Three Tier Routing Protocol for Wireless Sensor Network**", submitted by **Bhim Chandra Gautam** in partial fulfillment of the requirement for the award of the degree of "**Master of Science in Information and Communication Engineering**" has been accepted as a bonafide record of work independently carried out by him in the department.

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ABSTRACT

Wireless Sensor Network will enable the reliable monitoring of a variety of environments. This thesis deal with proposed communication protocol, which can have significant improvement on energy of (Lifetime) of heterogeneous networks and increment in data packets transmission from the sensor members to the cluster heads. Currently DEEC, DDEEC, EDEEC protocols are used for data transmission in heterogeneous network where data transmitted to the sink, as a result the communication from the sensor nodes to the cluster heads is not efficient; which is improved by the proposed protocol . The nodes send data to BS and CHs only when the sensed attribute crosses a pre-defined threshold, and keep their transmitters off otherwise. Hard Threshold; in which each sensor nodes compare its sensed attribute when the sensor nodes cross the value, transmitter reports to CH. In the case of the Soft Threshold, it is used when sensor crosses hard threshold. Higher value of Soft Threshold lead to lower power consumption and higher network lifetime. 3-Tier communication architecture is introduced to minimize the communication distance. Purposed Protocol approach is 1.5, 1.38 and 1.08 times better than DEEC, DDEEC and EDEEC respectively, in terms of network lifetime. Which shows that the proposed protocol is much better than other routing protocols for Wireless sensor network.

Keywords: Wireless Sensor Networks (WSNs), Cluster heads, Routing Protocol, energy efficiency

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LIST OF ABBREVIATIONS

ADC	Analog to Digital Converter
AG	Automatic Gain
AGC	Automatic Gain Control
BS	Base Station
BER	Bit Error Rate
CSMA-CA	Carrier Sense Multiple Access- Collision Avoidance
C1WSNs	Category 1 Wireless Sensor Networks
C2WSNs	Category 2 Wireless Sensor Networks
CPU	Central Processing Unit
CCA	Clear Channel Assessment
CH	Cluster Head
CM	Cluster Members
DDEEC	Development Distributed Energy Efficient Clustering
DC	Direct Current
DSSS	Direct Sequence Spread Spectrum
DEEC	Distributed Energy Efficient Clustering
EETTRP	Efficient Energy Three Tier Routing Protocol
EECS	Energy Efficient Clustering Scheme
EDDEC	Enhanced Development Distributed Energy Efficient Clustering
FCS	Frame Control Signal
FHSS	Frequency Hopping Spread Spectrum
IT	Information Technology
I/Q	In-phase/ Quadrate-phase
IF	Intermediate Frequency
IEEE	International Electrical and Electronic Engineering
LQI	Link Quality Indication
LO	Low
LEACH	Low Energy Adaptive Clustering Hierarchy
LAN	Low Noise Amplifier
MPDU	MAC Protocol Data Unit
MAC	Media Access Control
MHz	Mega Hertz

O-QPSK	Offset-Quadrature Phase Shift Keying
PER	Packet Error Rate
PA	Power Amplifier
PEGASIS	Power Efficient Gathering in Sensor Information Systems
Q	Quadrature
RF	Radio-Frequency
RFID	Radio-Frequency Identification
RAM	Random Access Memory
RSSI	Receive Signal Strength Indicator
REECH-ME	Regional Energy Efficient Club Heads based on Maximum Energy
SN	Sensory Nodes
SNR	Signal to Noise Ratio
SFD	Start of Frame Delimiter
TH	Threshold
TDEEC	Threshold Distributed Energy Efficient Clustering
TSDDR	Threshold Sensitive Density Controlled Divide and Rule
T/R	Transmitter and Receiver
VGA	Variable Gain Amplifier
VCO	Voltage Control Oscillator
WNS	Wireless Sensor Network

CHAPTER ONE: INTRODUCTION

1.1 Background

Wireless Sensor Network (WSN) is an area of research that has various applications both for mass public and military [1]. A wireless sensor network is composed of many sensors which can be used to monitor physical or environmental conditions, such as temperature, sound, pressure. After collecting these data they should pass this data through the network to a main location. Wireless Sensor Networks (WSN) requires small size, large number, tether-less and low cost. They are constrained by energy, computation and communication. Small size implies small battery. Low cost & energy implies low power CPU, radio with minimum bandwidth and range. Its deployment implies no maintenance or battery replacement. Also to increase the network life time no raw data is transmitted. A Sensor Node in Wireless Sensor Network lacks resources such as processing capability, capability , memory , capacity, battery , power and communication capability .When we consider wireless connections the links are fragile, possibly asymmetric, connectivity depends on power levels and fading and interference is high for omnidirectional antennas. Because of the limited resources, on resources on sensor nodes, the use of conventional key management techniques in wireless sensor networks is limited [2]. This thesis is trying to provide energy efficient Routing Protocol for communication schemes in wireless sensor networks.

Due to the poor energy efficiency for routing packets in wireless sensor network, in practice most of our routing protocols do not give importance to the energy [3]. The objective of the study is to develop the energy efficient 3-tier routing algorithm for wireless sensor network.

1.2 Problem statement

The routing in the wireless sensor networks has major limitations on energy and uncontrolled environment .Role of routing protocol is to cope with these limitations. When we consider Wireless Sensor Network (WNS) in contrast to other ad hoc network it is seen that sensing and data processing are essential. WSNs have many more nodes and are more densely deployed. WSNs operate under very strict energy constraints and nodes are typically static. The communication scheme is many-to-one (data collected at a base station) rather than peer-to-peer communication. Nodes are battery-powered, nobody is going to change the batteries. So, each operation brings the node closer to death. Minimal usage of energy is key responsibility of routing protocol running on Wireless Sensor Network however, environment cannot be controlled fully .So we encounter with the problems as :-

i. Minimizing energy consumption of the nodes
ii. Enhancing network lifetime
iii. Enhancing stability period of the network

1.3 Objectives

Lifetime is crucial to save the energy nodes should be in sleep mode as much as possible. Nodes should acquire data only if indispensable and use data fusion and compression also transmit and receive only if necessary. Receiving is just as costly as sending. Clustering Mechanism can be used in Wireless sensor Network. WSNs should be self-configure and be robust to topology changes (e.g, death of a node). It also ensures coverage that are we able to observe all phenomena of interest? The clustering Algorithm is a kind of key technique used to reduce energy consumption which can increase the scalability and lifetime of the network. Energy efficient clustering protocols should be designed for the characteristic of heterogeneous wireless sensor networks. As we can find many algorithms for homogeneous wireless sensor networks, moreover homogeneous networks are not always useful.

1.3.1 Research Objectives

Firstly to assess the 3-tier communication design requirement for the wireless sensor Network. Then to obtain the variation in different parameters of the wireless sensor network. Finally to recommend the energy efficient routing protocol for the heterogeneous wireless sensor network for communication.

1.3.2 Main objective

The main objective of this thesis is to propose the efficient energy routing protocol for heterogeneous Wireless Sensor Networks.

1.4 Scope and Application

Energy efficient routing protocol is useful for the wireless sensor networks where there is need of the network for the longer duration of data transmission. This could be useful more for such types of environment where there is implementation of WSNs for longer period. Where we need to save more energy there we can use this protocol.

1.5 Thesis Outline

The thesis is developed into six chapters, each of which focuses on one different aspect of the thesis. This thesis states various techniques used in research, evaluates their performance and provides possible future enhancement.

Chapter-2 Introduces the relevant research and techniques that had been done previously and briefly discusses the limitations of their research. This research focuses mainly on the heterogeneous wireless sensor network. Which use the clustering mechanism as the key techniques.

Chapter-3 present the Wireless Sensor Network and related theory used in this thesis work. The general introduction to the wireless sensor networks and their types and different mechanism which are used later on this thesis are described in briefly here.

Chapter-4 discusses the overall process of this thesis. It starts with choosing the radio model used for the wireless sensor network along with the different parameters that are used in radio communication with the standard values and energy used in that radio model. It also explains about how this protocol is developed and what are the techniques used to make it energy efficient. Moreover it focuses on the hardware standards that are available for the sensory nodes.

Chapter-5 focuses on the simulation results and its analysis, and Discussions. Starting with the simulation standard parameters used to test the protocol. Mainly two things are done here. Firstly, the node deployment within certain area in different manners. Secondly, comparison of the proposed protocol to other different protocol which are used currently in the world.

Chapter-6 focuses on: present summary, limitations and conclusion of this thesis with its future enhancement and reference concludes the thesis.

This chapter gives the general introduction about thesis; the next chapter will give the literature review related to work.

CHAPTER TWO: LITERATURE REVIEW

2.1 Literature Review

Literature review focus on recent contributions related to Routing protocol for wireless sensor network and past efforts most closely related to the needs of the present work. Routing is very difficult in wireless sensor network due to a large number of sensor nodes. Routing algorithm at a router decides which output line an incoming packet should go, i.e. making a routing decision. It should process properties, like correctness, simplicity, robustness, stability, fairness, and optimality. There are two classes of routing algorithms: Non adaptive (static), routing decision are computed in advance, off line, downloaded to routers at booting time and fixed, e.g. shortest path, flooding, and flow-based where as in Adaptive routing decisions are adapted to reflect change in topology and traffic, e.g distance vector, link state, hierarchical, broadcast, multicast. In wireless sensor network, Routing can be divided into Flat Routing, Hierarchical Routing, Location-aware Routing. Hierarchical Routing can be further divided into two parts: Dynamic and Static Hierarchical Routing or Clustering-based Routing. Dynamic Clustering based protocols are those in which the clusters are formed and diminished dynamically. Static Clustering based Routing Protocols are those in which clusters once formed remain same throughout the network lifetime [4].

Like hosts, routers can come and go. In ad hoc one-dimensional distance vector, a distance relative of distance vector routing is used. Each node maintains, giving information about that destination, including which neighbor to send packets in order to reach the destination. In route discovery, flooding is used, so many measures are employed to keep flood in check, and to make sure the route discovered is a fresh (live) one. Route maintenance: nodes can move or be switched off, network topology can change periodically, each node broadcasts a Hello message, and each of its neighbours is expected to respond to it. If no response is forthcoming, broadcaster knows that the specific neighbor either has moved out of its range or no longer exists. Similarly, if a node sends a packet to a neighbor that does not respond, it learns that that neighbor is no longer available. When any of its neighbours becomes unreachable, the node checks its routing table to see which destinations have routes, using this now-gone neighbor. For each of these routes, the active neighbours, are informed that they must do purging too. The active neighbours that tell their active neighbours and so on.

LEACH (Low Energy Adaptive Clustering Hierarchy) is a routing protocol for wireless sensor networks in which, the base station (sink) is fixed and sensor nodes are homogenous. LEACH conserves energy through aggregation and adaptive clustering. LEACH is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensor in the network. In LEACH, the nodes organize themselves into local clusters, with one node acting as the local 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 sensor 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 dissipation and enhancing system lifetime. However, Leach doesn’t take account of residual energy of a node and also LEACH use same amplification energy for both kinds of transmissions i.e cluster heads (CH) to base station (BS) and cluster member (CM) to CH [4].

EECS (Energy Efficient Clustering Scheme): EECS is a LEACH-like clustering scheme, where the network is partitioned a set of clusters with one cluster head in each cluster. Communication between the cluster head and BS is direct (single-hop). In the cluster formation phase, it use distance to balance the load among cluster heads. In the cluster head election phase, well distributed cluster heads are elected with a little control overhead. And in the cluster formation phase, a novel weighted function is introduced to construct load balanced clusters. In the cluster head election phase, the cluster head is elected by localized competition which is unlike LEACH and with no iteration which differs from HEED. The optimal value of competition range produces a good distributed of cluster heads. Further in the cluster formation phase, plain nodes join clusters not only taking into account its intra-cluster communication, but also considering cluster heads to the BS [4].

PEGASIS- (Power Efficient Gathering in Sensor Information Systems) nodes will be organized to form a chain, which can be computed by each node or by the base station. The requirement of global knowledge of the network topology makes this method difficult to implement. In addition, PEGASIS introduce excessive delay for distance nodes on the chain. The single leader can become a bottleneck. Finally, although in most scenarios sensors will be fixed or immobile as assumed in PEGASIS, some sensor may allowed to move and hence affect the protocol functionality [4].

HEED- a distributed clustering algorithm, which selects the cluster-heads stochastically. The election probability of each node is correlative to the residual energy. But in heterogeneous environments, the low-energy nodes could own large election probability than the higher-energy nodes in HEED [5].

In Distributed Energy Efficient Clustering (DEEC), the cluster –heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The epochs of being cluster heads for nodes are different according to their initial and residual energy. The nodes with high initial and residual energy will have more chances to be the cluster heads than the nodes with low energy in heterogeneous environment [5].

LEACH-E, using the remaining energy level of a node for cluster head selection. It is proposed to elect the cluster heads according to the energy left in each node. But it requires the assistance of routing protocol, which should allow each node to know the total energy of network [5].

SEP- Developed for the two-level heterogeneous networks, which include two types of nodes according to the initial energy. The rotating epoch and election probability is directly correlated with the initial energy of nodes. But the problem with this is it performs poorly in multi-level heterogeneous networks [6].

In Threshold Sensitive Density Controlled Divide and Rule Routing Protocol for Wireless Sensor Networks paper, It propose a novel routing protocol; Threshold Sensitive Density Controlled Divide and Rule (TSDDR) to prolong network lifetime and stability period. Wireless sensor nodes are restricted to computational resources, and are always deployed in a harsh, unattended or unfriendly environment. Therefore, network security becomes a tough task and it involves the authorization of admittance to data in a network .The problem of authentication and pair wise key establishment in sensor networks with mobile sink is still not solved in the mobile sink replication attacks. To determine the above problem the system adduces the three –tier security framework for authentication and pair wise key establishment between mobile sinks and sensor nodes. In order to overcome this problem a random pair wise key pre distribution scheme is suggested and further it helps to improve the network resilience. In addition to this an identity Based encryption is used to encrypt the data and mutual authentication scheme is proposed for the identification and isolation of replicated mobile sink from the network [7].

Regional Energy Efficient Club heads based on Maximum Energy (REECH-ME) Routing protocol for wireless sensor networks (WSNs) was purposed in 2013 . The main purpose of this protocol is to improve the network lifetime and particularly the stability period of the network. In REECH-ME, the node with the maximum energy in a region becomes Cluster Head (CH) of that region for that particular round and the number of the cluster heads in each round remains the same [8].

DREMME which uses a unique technique for clustering to overcome the two problems with energy constraints and their finite lifetimes efficiently. DREEM-ME elects a fix number of cluster heads (CHs) in each round instead of probabilistic selection of CHs. In DREEM-ME confidence interval is also shown in each graph which helps in visualizing the maximum deviation from original course. Simulations and results show the DREEM-Me is much better that existing protocols of the same nature [9].

Reactive routing protocols are gaining popularity due to their event driven nature day by day. Route request, route reply and route transmission phases are modeled with respect to overhead. Control overhead varies with respect to change in various parameters. [10].

Tiered sensor networking architecture results in an agile surveillance system with a focus on improved operational flexibility and usability. Performance measurements using an in house simulator are provided using two different scenarios to demonstrate the system’s great ability and expandability, operating from possibly a small-scaled single cluster to a cluster to a network of many chained hop-to-hop connections offering a large covering area [11, 12, 13].

For the heterogeneous wireless sensor networks DDEEC (Development Distributed Energy Efficient Clustering) technique is used. This is based on technique of changing dynamically and with more efficiency the cluster head election probability. It’s an energy aware adaptive clustering protocol and with an adaptive approach which employ the average energy of the network as the reference energy [14].

EDDEC (Enhanced Development Distributed Energy Efficient Clustering) adds heterogeneity in the network by introducing the super nodes having energy more than normal and advanced nodes and respective probabilities [15].TDEEC (Threshold Distributed Energy Efficient Clustering), for heterogeneous wireless sensor networks: by modifying the threshold value of a node based on which it decides to be a cluster head or not [16].

CHAPTER THREE: RELATED THEORY

3.1 Wireless Sensor Network

A sensor network is an infrastructure comprised of sensing (measuring), computing, and communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment. The administrator typically is a civil, governmental, commercial, or industrial entity. The environment can be the physical world, a biological system, or an information technology (IT) framework. Network sensor systems are seen by observers as an important technology that will experience major deployment in the next few years for a plethora of applications, not the least being national security. Typical application include, but are not limited to, data collection, monitoring, surveillance, and medical telemetry. In addition to sensing, one is often also interested in control and activation.

There are four basic components in a sensor network: (1) an assembly of distributed or localized sensor; (2) an interconnecting network (usually, but not always, wireless-based); (3) a central point of information clustering; and (4) a set of computing resources at the central point (or beyond) to handle data correlation, event trending, status quering, and data mining. In this context, the sensing and computation nodes are considered part of the sensor network; in fact, some of the computing may be done in the network itself. Because of the potentially large quality of data collected, algorithm methods for data management play an important role in sensor network. The computation and communication infrastructure associated with sensor networks is often specific to this environmental and rooted in the device and application-based nature of these networks. For example, unlike most other settings, in-network processing is desirable in sensor networks; furthermore, node power (and/or battery life) is a key design consideration.

Wireless Sensor Networks can be considered as a special case of ad hoc networks with reduced or no mobility. WSNs enable reliable monitoring and analysis of unknown and untested environments. These networks are “data centric”, i.e., unlike traditional ad hoc networks where data is requested from a specific node, data is requested based on certain attributes such as, “which area has temperature over 35ºC or 95ºF”. A typical sensor consists of a transducer to sense a given physical quantity, an embedded processor, small memory and a wireless transceiver to transmit or receive data and an attached battery.

A wireless sensor network (WSN) consists of a large number of sensor nodes (SNs). Adequate density of sensors is required so as to void any un sensed area. Transmission between adjacent SNs is feasible if there is at least one SN within the communication range of each SN. Not just the sensing coverage, but the communication connectivity is equally important. The wireless communication coverage of a sensor must be at least twice the sensing distance. Data from a single SN is not adequate to make any useful decision and need to be collected from a set of SNs.

Ease of deployment – Can be dropped from a plane or placed in a factory, without any prior organization, thus reducing the installation cost and time, and increasing the flexibility of deployment.

Extended range – One huge wired sensor (macro-sensor) can be replaced by many smaller wireless sensors for the same cost

Fault tolerant – With wireless sensors, failure of one node does not affect the network operation.

Mobility – Since these wireless sensors are equipped with battery, they can possess limited mobility (e.g., if placed on robots).

Traditional routing protocols defined for MANETs are not well suited for wireless sensor networks due to the following reasons:

i. Wireless sensor networks are “data centric”, where data is requested based on particular criteria such as “which area has temperature 35ºC”

ii. In traditional wired and wireless networks, each node is given a unique identification and cannot be effectively used in sensor networks

iii. Adjacent nodes may have similar data and rather than sending data separately from each sensor node, it is desirable to aggregate similar data before sending it

iv. The requirements of the network change with the application and hence, it is application-specific

Attribute-based addressing: This is typically employed in sensor networks where addresses are composed of a group of attribute-value pairs.

Location awareness: Since most data collection is based on location, it is desirable that the nodes know their position.

Query Handling: Users should be able to request data from the network through some base station (also known as a sink) or through any of the nodes, whichever is closer.

Power efficiency in WSNs is generally accomplished in three ways:

1. Low-duty-cycle operation
2. Local/in-network processing to reduce data volume (and hence transmission time)
3. Multihop networking reduces the requirement for long-range transmission since signal path loss is an inverse exponent with range or distance. Each node in the sensor network can act as a repeater, thereby reducing the link range coverage required and, in turn, the transmission power.

Conventional wireless sensor networks are generally designed with link ranges on the orders of tens, hundreds, or thousands of miles. The reduce link rage and the compressed data payload in WSNs results in characteristics link budgets that differ from those of conventional systems. However, the power restrictions, along with the desire for low node cost, give rise to what developers call “profound design challenges”. Mainly two categories of WSNs:

Category 1 WSNs (C1WSNs):almost invariably mesh-based system with multihop radio connectivity among or between WNs, utilizing dynamic routing in both the wireless and wireline portions of the network. Military-threaten system typically belong to this category.

Category 2 WSNs (C2WSNs): point-to-point or multipoint-to-point (star-based) systems generally with single-hop-radio connectivity to WNs, utilizing static routing over the wireless network; typically, there will be only one route from the WNs to the companion terrestrial or wire line forwarding node (WNs are pendent nodes). Residential control systems typically belong to this category.

C1WSNs support highly distributed high-node-count applications (e.g environmental monitoring, national security systems); C2WSNs typically support confined short-range spaces such as a home, a factory, a building, or the human body. C1WSNs are different in scope and/or reach from evolving wireless C2WSN technology for short-range low-data-rate wireless applications such as RFID (radio-frequency identification) systems, light switches, fire and smoke detectors, thermostats, and home appliances. C1WSNs tend to deal with large-scale multipoint-to-point, systems with massive data flows, whereas C2WSNs tend to focus on short-range point-to-point, source-to-link applications with uniquely defined transaction-based data flows.

Routing protocol design is heavily influenced by many challenging factors. These challenges can be summarized as follows:

i. Ad hoc deployment – Sensor nodes are randomly deployed so that they form connections between the nodes

ii. Computational capabilities – Sensor nodes have limited computing power and therefore may run simple versions of routing protocols

iii. Energy consumption without losing accuracy – Sensor nodes can use up their limited energy supply carrying out computations and transmitting information

Data from SNs belonging to a single cluster can be combined together in an intelligent way (aggregation) using local transmissions. This can not only reduce the global data to be transferred and localized most traffic to within each individual cluster. A lot of research gone into testing coverage of areas by k-sensors clustering adjacent SNs and defining the size of the cluster so that the cluster heads (CHs) can communicate and get data from their own cluster members.

3.2 Routing Protocols

In general, Routing in WSNs can be divide into Flat-based Routing, hierarchical-based routing, and location-based routing depending on the network structure. In flat-based routing, all the nodes are typically assigned equals roles. In hierarchical-based routing nodes have different roles like low energy nodes sense the environment and high energy nodes used to transmit it. Figure (3.1) depicts the taxonomy of the routing protocols:

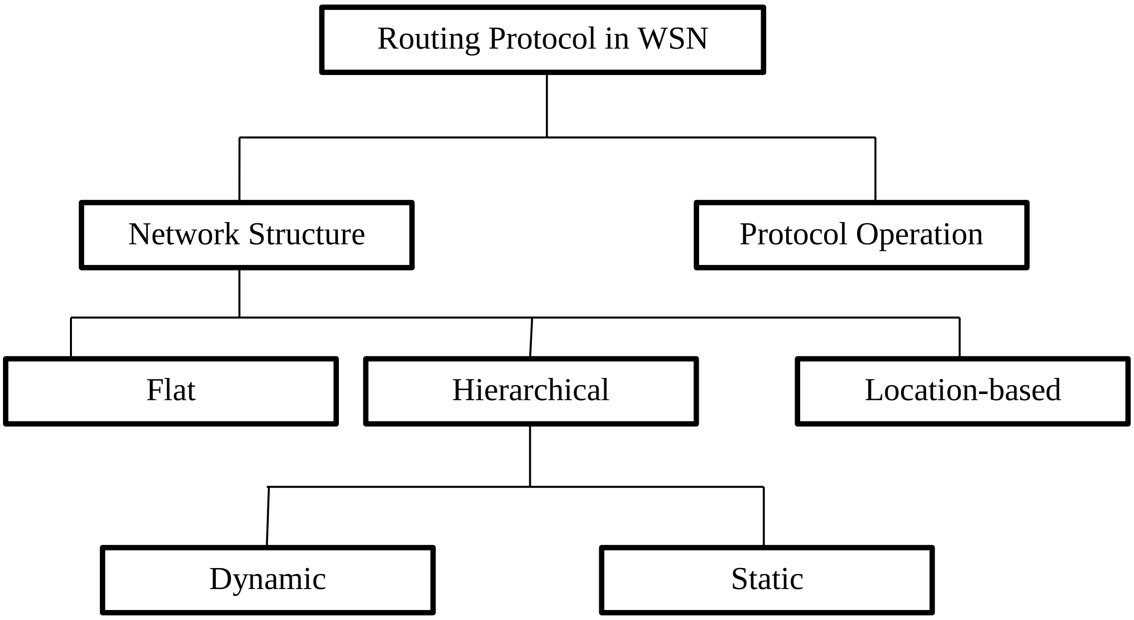

Figure: 3.1 Taxonomy of routing protocol

3.3 Hierarchical Routing

In Hierarchical routing, higher energy nodes can be used to process and send the information, while low-energy nodes can be used to preform the sensing in the targeted area. The creation of cluster can help to achieve scalability, network lifetime, and energy efficiency. Hierarchical routing is two layer routing where one layer is used to select cluster heads and the other for routing. It can be further divided into two parts Dynamic and Static. In Dynamic, cluster are changed with the rounds but in static, once the clusters are created remain same throughout network lifetime.

3.4 Cluster Based Routing

In clustering, whole network is divided into fixed or variable size cluster containing sensor nodes in it. Each cluster is represented by a cluster head that is responsible for communication between base station/sink and other non-cluster head nodes. Non-cluster head nodes of cluster communicates only with cluster head hence minimizing energy utilization. Here nodes are organized into clusters that communicate with a local BS (CH) and these local Base Stations transmit the data to the global BS, where it is accessed by the end user. Reduced distance of data transmission as the local BS (CH) is typically close to all nodes in the Cluster but BS becomes energy constrained. As soon as cluster – heads node lies, all nodes form that cluster effectively die since there is no way to get their data to the base station.

In Adaptive clustering, cluster heads changes as nodes move in order to keep the network fully connected. Cluster based routing has proven itself as efficient routing strategy in WSNs. Many routing protocols are derived using clustering mechanism that gives efficient wireless sensor network.

3.5 Applications

i. Unattendability and some degree of fault tolerance in these networks are desirable in those applications where the sensors may be embedded in the structure or places in an inhospitable terrain and could be inaccessible for any service

ii. Undoubtedly, wireless sensor networks have been conceived with military applications in mind, including battlefield surveillance and tracking of enemy activities

iii. However, civil applications considerably outnumber the military ones and are applicable to many practical situations

iv. Judging by the interest shown by military, academia, and the media, innumerable applications do exist for sensor networks

v. Examples include weather monitoring, security and tactical surveillance, distributed computing, fault detection and diagnosis in machinery, large bridges and tall structures, detecting ambient conditions such as temperature, movement, biological and chemical objects

vi. Under the civil category, envisioned applications can be classified into environment observation and forecast system, habitat monitoring equipment and human health, large structures and other commercial applications

CHAPTER FOUR: METHODOLOGY

4.1 Research Methodology

Wireless distributed sensor network consists of randomly deployed sensors having low energy assets. These networks can be used for monitoring a variety of environments. Major problems of these networks are energy constraints and their finite lifetime. To overcome these problem different routing protocols and clustering techniques are introduced.

To accomplish the objective of this thesis work, following procedure were adopted;

i. Preliminary study
    a. Survey and Review of various papers and research those are available to the related works.
    b. Communication Architecture and the selection of different architecture for the analysis having different physical shapes as mention earlier.

ii. Analysis stage
    a. Preparation od 3-tier communication model frames using sensor in different structure and Cluster Head properties.
    b. Perform energy efficient analysis
    c. Identification of deficient parameters if any
    d. From the analysis obtained the relationship of different parameter and their role in energy consumption in Wireless Sensor Networks for different configuration.

iii. Writing protocol and verification stage
    a. Development of suitable protocol techniques to verify the deficiencies
    b. Re-analysis of the protocols to confirm the adequacy with the proposed energy efficient 3-tire routing protocol.

iv. Results
    a. By using all the above methodologies the energy efficient 3-tier routing protocol for wireless sensor network will be developed.

4.2 Radio Model

In the today contest, there is a great deal of research in the area of low-energy radios. Different characteristics, including energy dissipations in the transmit and receive modes. In this work, a simple model where the radio dissipates $E_{elec} = 50\, nJ/bit$ to run the transmitter or receiver circuitry and $\epsilon_{amp} = 100\, pJ/bit/\, m^2$ to run the transmit amplifier to achieve an acceptable $\frac{E_b}{N_o}$ (for Figre 1 and Table 1). These parameters are better than current state of the art in radio design. Assumption is made that d^2 energy loss due to channel transmission. Thus, to transmit a k bit message a distance d using this radio model, the mathematical expressions are:-

$$ifd < d_o\ E_{Tx(l.d)} = E_{elec} \times k\ + \epsilon_{fs} \times k \times d^2 \tag{4.1}$$

$$ifd \geq d_o\ E_{Tx(l.d)} = E_{elec} \times k\ + \epsilon_{mp} \times k \times d^2 \tag{4.2}$$

Reception Energy: $E_{R_x}(l) = E_{elec} \times k$ (4.3)

For these parameter values, receiving a message is not a low cost operation; the protocols try to minimize not only the transmit distances but also the number of transmit and receive operations for each message

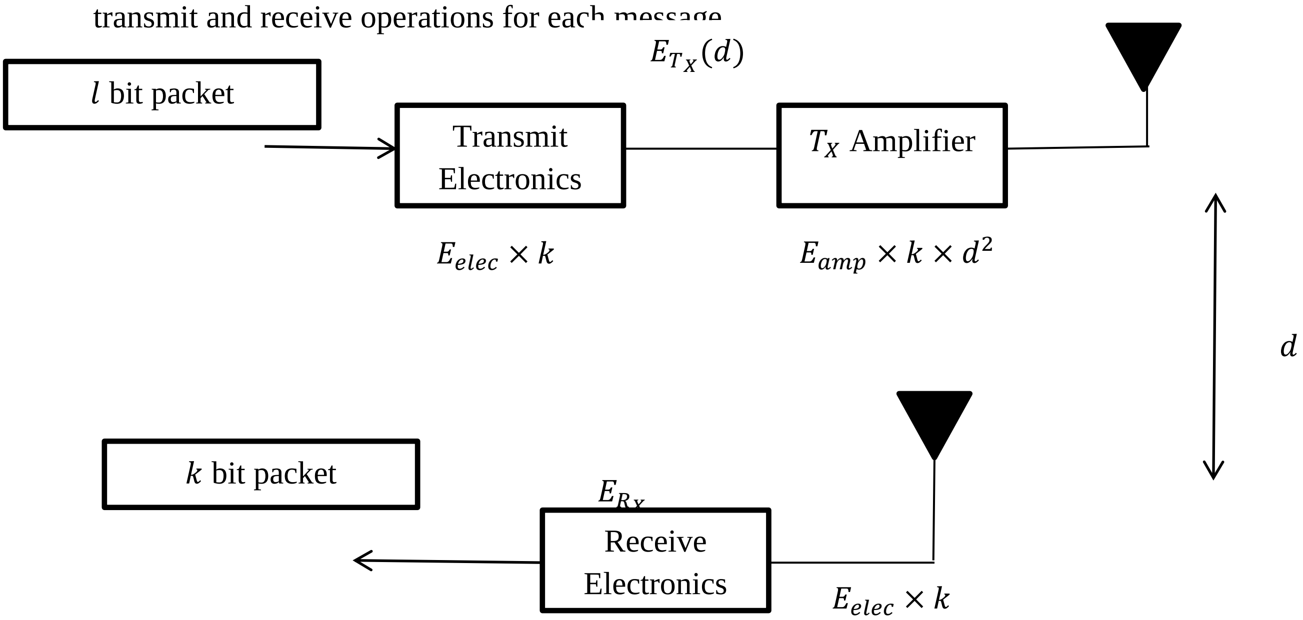

Figure 4.1 Radio model diagram

The separate distance, $d_o$is the threshold for swapping amplification model, which can be calculated as $d_o = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$. In the reception module, to receive l- bit message, Eq.(4.4) is used.

4.3 Heterogeneous Network Model

It is assume that there are N sensor nodes, which are uniformly dispersed within a $M \times M$ square region. The nodes have data to transmit to a base station, which is often far from the sending area. It is assume that the base station is located at the center of the square region. The network is organized into a clustering hierarchy, and the cluster heads execute function to reduce correlated data produced by the sensor nodes within the cluster. The cluster heads transmit the aggregated data to the base station directly. To avoid the frequent change of the topology, it is assume that the nodes are micro mobile or stationary.

In the two-level heterogeneous networks, there are two types of sensor nodes, i.e the advance nodes and normal nodes. Note E_o the initial energy of the normal nodes , and m the fraction of the advanced nodes, which own a times more energy than the normal nodes. Thus there are mN advance nodes equipped with initial energy of $E_o(1+a)$, and $(1-m)N$ normal nodes equipped with initial energy of E_o. The total initial energy of the two-level heterogeneous networks is given by:

$$E_{total} = N(1-m)E_o + NmE_o(1+a) = NE_o(1+am) \tag{4.4}$$

Therefore, the two level heterogeneous networks have am times more energy and virtually am more nodes. It is also consider that the multi level heterogeneous networks, initial energy of sensor nodes is randomly distributed over the close set $[E_o, E_0(1+a_{max})]$, where E_o is the lower bound and a_{max} determine the value of the maximum energy. Initially, the node S_i is equipped with initial energy of $E_o(1+a_i)$, which is a_i times more energy than the lower bound E_o. The total intial energy of the multi level heterogeneous networks is given by:-

$$E_{total} = \sum_{i=1}^{N} E_o(1+a_i) = E_o(N + \sum_{i=1}^{N} a_i) \tag{4.5}$$

As in two level heterogeneous networks, the clustering algorithm should consider the discrepancy of initial energy in multi level heterogeneous networks.

4.4 The EETTRP Protocol

This section present the details of proposed EETTRP Protocol. EETRP uses the initial and residual energy level of the nodes to select the cluster heads. To avoid that each node needs to know the global knowledge of the networks, EETTR estimates the ideal value of network life-time, which is use to compute the reference energy that each node should expend during a round this technique is same that have been used by DDEC. The choosing of the threshold which get the election threshold, which is used to decide if node should be a cluster-head in the current round is different. It also different from that of EDEEC and TDEEC which uses the super node and its energy for the increment of the data packets to receive at the base station. In the proposed protocol it use intermediate nodes which need less amount of energy than that of the super node which were used before.

4.4.1 Cluster Head selection algorithm based on residual energy

Let $n_i$denote the number of rounds to be a cluster head for the node S_i, and refer to it as the rotating epoch. In homogeneous networks, to guarantee that there are average $p_{opt}N$ cluster heads every rounds., LEACH let each node $S_i(i = 1,2,3, \dots \dots N)$ becomes a cluster head once every $n_i = \frac{1}{p_{opt}}$ rounds. Note that all the nodes cannot own the same residual energy when the network evolves. If the rotating epoch n_i is the same for all the nodes as proposed in LEACH, the energy will be not well distributed and the low energy nodes will die more quickly than the high energy nodes. In TTRP protocol, choose different n_i based on the residual energy $E_i(r)$ of node S_i at round . Let $p_i = \frac{1}{n_i}$, which can be also regarded as average probability to be a cluster head during n_i rounds. When nodes have the same amount of energy at each epoch, choosing the average probability p_i to be p_{pot}can ensure that there are $p_{opt}N$ cluster heads every rounds and all nodes die approximately at the same time. If nodes have different amount of energy, p_i of the nodes with more energy should be larger than p_{opt}.Let $\bar{E}(r)$ denote the average energy at round r of the network, which can be denoted by:-

$$\bar{E}(r) = \frac{1}{N}\sum_{i=1}^{N} E_i(r) \qquad (4.6)$$

To compute $\bar{E}(r)$ by Eq.(4.6), each node should have the knowledge of the total energy of all nodes in the network. Using $\bar{E}(r)$ to be the reference energy, we have,

$$p_{i=p_{opt}\left[1-\frac{\bar{E}(r)-E_i(r)}{\bar{E}(r)}\right]} \tag{4.7}$$

i.e $$p_i = p_{opt}\frac{E_i(r)}{\bar{E}(r)} \tag{4.8}$$

This guarantees that the average total number of cluster heads per round per epoch is equal to:

$$\sum_{i=1}^{N} p_i = Np_{opt} \tag{4.9}$$

It is the optimal cluster head number to achieve. We get the probability threshold, that each node S_i use to determine whether itself to become a cluster head in each round. As follows

$$T(S_i) = \left\{\begin{array}{ll} \frac{p_i}{1-p_i\left(r mod \frac{1}{p_i}\right)} & if\ S_i\ \in G \\ 0 & Otherwise \end{array}\right\} \tag{4.10}$$

Where $G$is the set of nodes that are eligible to be cluster heads at round r. If node S_i has not been a cluster head during the most recent $n_i$rounds, we have $S_i \in G$. In each round r, when node S_i finds it is eligible to be a cluster head, it will choose a random number between 0 and 1. If the number is less than threshold $T(S_i)$, the node S_i becomes a cluster head during the current round. The epoch n_i is the inverse of p_i , n_i is chosen based on the residual energy $E_i(r)$ at round r of node S_i . The nodes with high residual energy take more turns to be cluster heads than lower ones.

4.4.2 Coping with heterogeneous nodes

From Eq. (4.7) and (4.8) we can see that p_{opt} is the reference value of the average probability p_i, which determine the rotating epoch n_i and threshold $T(S_i)$ of node S_i. In homogenous networks, all the nodes are equipped with same initial energy, thus nodes use the same value p_{opt} to be the reference point of p_i. When the networks are heterogeneous, the reference value of each node should be different according to the initial energy. In the two-level heterogeneous networks, we replace the reference value $p_{opt}$with the weighted probabilities in Eq. (4.11) for normal and advance nodes [17].

$$p_{adv} = \frac{p_{opt}}{1+am}, \qquad p_{nrm} = \frac{p_{opt}(1+a)}{(1+am)} \tag{4.11}$$

Therefore, p_i changed into

$$p_i = \begin{cases} \dfrac{p_{opt\,E_i(r)}}{(1+am)\bar{E}(r)} & for\ Normal\ nodes\ \bar{E}(r) > TH_{REV} \\ \dfrac{(1+a)p_{opt}E_i(r)}{(1+am)\bar{E}(r)} & for\ Advance\ nodes\ \bar{E}(r) < TH_{REV} \end{cases} \tag{4.12}$$

Now we get the probability threshold used to select the cluster-heads. Thus the threshold is correlated with the initial energy and residual energy of each node directly.

This model can be easily extended to multi-level heterogeneous networks. We use the weighted probability shown in Eq. (4.13)

$$p(S_i) = \frac{p_{opt}N(1+a_i)}{(N+\sum_{i=1}^{N} a_i)} \tag{4.13}$$

When we use Eq.(4.11, 4.12 ,4.13) in Eq. (4.10) then,

The change is based on the using a threshold residual energy value TH_{REV}, which is equal to;

$$TH_{REV} = E_o\left(1 + \frac{a\,E_{dis}NN}{E_{dis}NN - E_{dis}AN}\right) \tag{4.14}$$

The idea is that under this TH_{REV} all nodes, the advanced and normal ones, must have the same probability to be cluster head. Therefore, the cluster head election is balanced and more equitable.

Let, $TH_{REV} = bE_0$ where $b = \left(1 + \frac{a\,E_{dis}NN}{E_{dis}NN - E_{dis}AN}\right)$ Where the value of $b\ \in [0,1]$ if b=o then this is same as that of the DEEC.

4.4.3 Estimating average energy of networks

It is difficult to realize such scheme, which presumes that each node knows the average energy of the network. The average energy is just used to be the reference energy for each node. It is the ideal energy that each node should own in current round to keep the network alive to the greater extent. In such ideal situation, the energy of the network and nodes are uniformly distributed, and all the nodes die at the same time. Thus we can estimate the average energy $\bar{E}(r)$ of r^{th}round as follow

$$\bar{E}(r) = \frac{1}{N} E_{total} \left(1 - \frac{r}{R}\right) \tag{4.15}$$

Where R denote the total rounds of the network lifetime. It means that every node consumes the same amount of energy in each round, which is also the target that energy-efficient algorithms trying to achieve. TTRP controls the rotating epoch n_i of each node according to its current energy, thus controls the energy expenditure of each round.

To compute $\bar{E}(r)$ by Eq. (4.15) , the network lifetime R is needed, which is also the value in an ideal state. Assuming that all nodes die at the same time, R is the total of rounds from the network begins to all the nodes die. Let E_{round} denote the energy consumed by all the network in each round.

$$R = \frac{E_{total}}{E_{round}} \tag{4.16}$$

In the process of transmitting an $l - bit$message over a distance d, the energy expended by radio is given by:

$$E_{T_x}(l, d) = \left\{ \begin{matrix} lE_{elec} + l \in_{f_s} d^2, & d < d_o \\ lE_{elec} + l \in_{mp} d^4, & d \geq d_o \end{matrix} \right\} \tag{4.17}$$

Where E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, and $\in_{f_s} d^2$ or $\in_{mp} d^4$ is the amplifier energy that depend on the transmitter amplifier model.

We assume that the N nodes are distributed uniformly in an $M \times M$ region, and the base station is located in the center of the filed for simplicity. Each non cluster head send L bit data to the cluster head a round. Thus the total energy dissipated in the network during a round is equal to:

$$E_{round} = L\left(2NE_{elec} + NE_{DA} + k \in_{mp} d_{toBS}^4 + N \in_{f_s} d_{toCH}^2\right), \tag{4.18}$$

Where k is the number of clusters, $E_{DA}$is the data aggregation cost expended in the cluster heads, $d_{toBS}$is the average distance between the cluster head and the base station, and d_{toCH} is the average distance between the cluster members and the cluster head. Assuming that the nodes are uniformly distributed [16, 17] , we get

$$d_{toCH} = \frac{M}{\sqrt{2\pi K}}, \qquad d_{toBS} = 0.765\frac{M}{2} \tag{4.19}$$

By setting the derivative of E_{round} with respect to k to Zero, we have the optimal number of cluster as:

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{\epsilon_{f_s}}{\epsilon_{mp}}}\frac{M}{d_{toBS}^2} \tag{4.20}$$

4.4.4 Communication Architecture

In our proposed model, data from the sensor reach BS by using multi-hop scheme. It consists of 3-Tier communication architecture. In tier-1, all the non CH nodes forward their sensed data to their respective CHs. In tier-2, CHs of the local will send data to the nearest CHs in the middle part. To achieve energy efficiency, CHs find their distance to the next level CHs and send the data to the nearest CHs. In Tier-3, nodes near and CHs of all regions communicate with BS/sink.

4.4.5 Protocol Operation

In proposed protocol, a WSN is being implemented. The nodes send their data to BS and CHs only when the sensed attribute crosses a pre-define threshold, and keep their transmitters off otherwise. Centralized algorithm need to operate with global knowledge of the whole network, and an error in transmission or a failure of a critical node will potentially causes a serious protocol failure. So distributed algorithm only executed locally within partial nodes, thus can prevent the failure caused by a single node. Localized algorithm; more scalable and robust than centralized algorithm [18].

As each sensor node is tightly power constrained and one-off, the life time of WSN is limited. Here localized can efficiently operate within clusters and need not to wait for control messages propagation across the whole network. Therefore localization bring better scalability to large network than centralized, which executed in global structure.

To avoid that each node needs to know the global knowledge of the networks the proposed protocol use the estimates the ideal value of network life-time, which is use to compute the reference energy that each node should expend during a round. In previous developed algorithm the rotating epoch n_i, is the same for all the nodes as proposed in LEACH, the energy will be not well distributed and the low energy nodes will die more quickly than the high energy nodes. So proposed protocol choose different n_i,based on the residual energy $E_i(r)$ of node S_i, at round r.

In proposed protocol change is based on the using a threshold residual energy value , TH_{REV} . The idea is that under this TH_{REV} all nodes, the advance node and normal ones, must have the same probability to be cluster head. Therefore, the cluster head election will be balanced and more equitable. But the reality is that all the advanced nodes can not be a cluster heads. The same case for the normal ones, it’s probable that some of them will be a cluster heads.

The reveived RF signal is amplified by the low-noise amplifier (LNA) and down-converted in quadrate (I and Q) to the intermediate frequency (IF). At IF (2MHZ), the complex I/Q signal is filtered and amplified, and then digitized by the ADCs. Automatic gain control, final channel filtering, de-spreading, symbol correlation and byte synchronization are performed digitally.

When the SFD is high, this indicates that a start of frame delimiter has been detected. Buffer receive data and the transmitter is based on direct up-conversion. The preamble and start of frame delimiter are generated. The preamble and start of frame delimiter are generated. Each symbol is spread and output to the digital-to-analog converters (ADCs). An analog lowpass filter passes the signal to the quadrature (I and Q) upconversion mixers. The RF signal is amplified in the power amplifier (PA) and fed to the antenna. The internal T/R switch circuitry makes the antenna interface and matching easy. The biasing of the PA and LNA is done by connecting TXRX_SWITCH to RF_P and RF_N through an external DC path. The frequency synthesizer includes LC VCO and a 90 degrees phase splitter for generating the I and Q LO signals to the down-conversion mixers in transmit mode. The VCO operates in the frequency range 4800-4966 MHz, and the frequency is divided by two when split in I and Q.

Application circuit for Wireless sensor network have input/output matching, bias resistor, crystal, voltage regulator, power supply decoupling and filtering.

The 2.4GHz direct sequence spread spectrum (DSSS) RF modulation format defined in IEEE 802.15.4. For a complete description, please refer to [19]. Each byte is divided into two symbols, 4 bits each. The least significant symbol is transmitted first. Ffor multi-byte fields, the least significant byte is transmitted first, except for security related fields where the most significant byte is transmitted first. Each symbol is mapped to one out of 16 pseudo-random sequences, 32 chips each. The chip sequence is then transmitted at 2 MChips/s, with the least significant chip transmitted first for each symbol. The modulation format is offset-Quadrature Phase Shift Keying (O-QPSK) with half-sine chip shapping. This is equivalent to MSK modulation. Each chip is shaped as a half-sine, transmitted alternately in the I and Q channels with one half chip period offset.

In receive mode, the SFD goes high after the start of frame delimiter (SFD) field has been completely received. If address recognition is disabled or is successful, the SEF goes low again only after the last byte of the MPDU has been received. If the received frame fails address recognition, the SFD goes low immediately. The length will be 8 bytes, RSSI will contain the average RSSI level during receiving of the packet and FCS/corr contain information of FCS check result and the correlation levels. The MAC layer must read the source address of the received frame before it can decide which key to use to decrypt or authenticate. The SFD is however active during transmission of a data frame. The SFD goes high when the SFD field has been completely transmitted. It goes low again when the complete MPDU (as defined by the length field) has been transmitted or if an overflow is detected. The SFD can be used to extract the timing information of transmitted and received data frames. The SFD will go high when a start of frame delimiter has been completely detected/ transmitted. The SFD should preferably be connected to a timer. The frame type subfield shall not contain an illegal frame type.

If the frame type indicates that the frame is a beacon frame, the source PAN identifier shall match macPANId unless macPANId is equal to 0XFFFF, in which case the beacon frame shall be accepted regardless of the source PAN identifier. If a destination PAN identifier is included in the frame, it shall match macPANId or shall be the broadcast PAN identifier (OXFFFF). If a short destination address is included in the frame, it shall match either macShortAddress or the broadcast address (0XFFFF). Otherwise if an extended destination address is included in the frame, it shall match a ExtendedAddress. If only source addressing fields are included in a data or MAC command frame, the frame shall only be accepted if the device is a PAN coordinator and the source PAN identifier matches macPANId. If any of the above requirements are not satisfied and address recognition is enable, this will disregard the incoming frame and flush the data from the RX. Only data from the rejected frame is flushed, data from previously accepted frames may still be in the RX. The control bit must be set when the PAN identifier programmed into RAM is equal to 0XFFFF and cleared otherwise. This particularly applies to active and passive scans as defined by which requires all received beacons to be processed by the MAC sublayer. Incoming frames with reserved frame is however accepted if the control bit is set. In this case, no further address recognition is prefermod on these frames. If the frame is rejected, then device will only start searching for a new frame after the rejected frame has been completely received (as defined by the length field) to avoid detecting false SFDs within the frame. The control bit must be correctly set, since parts of the address recognition procedure requires knowledge about wheather the current device is a PAN coordinate or not.

If auto acknowledge frame is transmitted for all incoming frames accepted by the address recognition with the acknowledge request flag set and a valid CRC. Auto acknowledge therefore does not make sense unless two command strobes, SACK and SACKPEND are defined to transmit acknowledge frame with the frame pending field cleared or set, respectively. The acknowledge frame is only transmitted if the CRC is valid. For systems using beacons, there is an additional timing requirement that the acknowledge frame transmission should be started on the forst back0ff-slot boundary at least 12 symbol periods after the last symbol of the incoming frame. This timing must be controlled by issuing the SACK and SACKPEND command strobe symbol periods before the following backoff-slot boundary. The sequence number is copied from the incoming frame. Auto acknowledge may be used for non-beacon system as long as the frame pending field is cleared. The acknowledge frame is then transmitted symbol periods after the last symbol of the incoming frame. This is as specified by for non-beacon networks. If a SACK or SACKPEND command strobe is issued while receiving an incoming frame, the acknowledge frame is transmitted symbol periods after the last symbol of the incoming frame. This should be used to transmit acknowledge frames in non-beacon networks. Using SACKPEND will set the pending data flag for automatically transmitted acknowledge frame using auto acknowledge. The pending flag will then be set also for future acknowledge frames, until a SACK command strobe is issued. Acknowledge frame may be manually transmitted using normal data transmission if desired.

This wireless sensor network use a built in state machine that is used to switch between different operation states (modes). The change of state is done either by using command strobes or by internal events such as SFD detected in receive mode. Before using the radio in either RX or TX mode, the voltage regulator and crystal oscillator must be turned on and become stable. Turning off RF can be accomplished by using one of the command strobe registers. After reset in power down mode. All configuration registers can then be programmed in order to make the chip ready to operate at the correct frequency and mode. Due to the very fast start-up time, sensor node can remain in power down until a transmission session is requested. Sensor nodes are based on a liner IF chain where the signal amplification is done in an analog VGA (Variable gain amplifier). The gain of the VGA is digitally controlled. The AGC (Automatic Gain Control) loop ensures that the ADC operates inside its dynamic range by using an analog/digital feedback loop. The AGC characteristics are set through the registers. The reset values should be used for all AGC control and registers. The link quality indication (LQI) measurement is a characterization of the strength and quality of a received packet. The RSSI value is used by the MAC software to produce the LQI value. The LQI value is required by to be limited to the range 0 through 255, with at least 8 unique values. Software is responsible for generating the appropriate scaling of the LQI value for the given application. Using the RSSI value directly to calculate the LQI value has the disadvantage that e.g. a narrowband interferer inside the channel bandwidth will increase the LQI value although it actually reduces the true link quality.

Sensory nodes therefore also provides an average correlation value for each incoming packets, based on the 8 first symbols following the SFD. This unsigned 7-bit value can be looked upon as a measurement of the “chip error rate,” although sensor nodes does not do chip decision. As described in the frame check sequence , the average correlation value for the 8 first symbols is appended to each received frame together with the RSSI and CRC OK/not OK. A correlation value of 110 indicates a maximum quality frame while a value of 50 is typically the lowest quality frames detectable by sensor node. So protocol should convert the correlation value to the range 0-255 define by calculating

$$LQI = (CORR - a).b \tag{4.21}$$

Limited to the rage 0-255, Where a and b are found empirically based on PER measurement as a function of the correlation value. A combination of RSSI and correlation values may also be used to generate the LQI value.

The clear channel assessment signal is based on the measured RSSI value and a programmable threshold. The clear channel assessment function is used to implement the CSMA-CA functionality. Carrier sense threshold level is programmed. The threshold value can be programmed in steps of 1dB. A CCA hysteresis can also be programmed in the control bits. All 3 CCA modes are implemented in sensor nodes. They are set in as can be seen in the register description. The different modes are: (1) Clear channel when received energy is below threshold; (2) Clear channel when not receiving valid IEEE 802.15.4 data; (3) Clear channel when energy is below threshold and not receiving valid IEEE 802.15.4 data. Clear channel assessment is available on the CCA output. CCA is active high, but the polarity may be changed by setting the control bit. Implementing CSMA-CA is done using command strobe as in radio control. Transmission will then only start if the channel is clear.

The operating frequency is set by programming the 10 bit frequency word. The operating frequency Fc in MHz is given by

$$Fc = 2048 + FREQ[9:0]MHz \tag{4.22}$$

In receive mode the actual LO frequency is Fc- 2 MHz, since a 2MHz IF is used. Direct conversation is used for transmission, so here the LO frequency equals Fc. The 2 MHz IF is automatically set by sensor node, so the frequency programming is equal for RX and TX. IEEE 802.15.4 Specifics 16 channels within the 2.4 GHz band, numbered 11 through 26. The VCO operates at 4800-4966 MHz. The VCO frequency is divided by 2 to generate frequencies in the desired ban (2400-2483.5 MHz). The VCO's characteristics vary with temperature, change in supply voltages, and the desired operating frequency. In order to ensure operation the VCOs bias current and tuning range are automatically calibrated every time the RX mode or TX mode is enabled.

Sensor node includes a low drop-out voltage regulator. Which is used to provide a 1.8V power supply to the sensor node power supply. The voltage regulator should not be used to provide power because of limited power sourcing capability and noise considerations. The voltage regulator input is connected to the unregulated 2.1 to 3.6V power supply. The voltage regulator is enable/ disabled using the active high voltage regulator. The regulated 1.8V voltage is available in output. When disabling the voltage regulator, note that register and RAM programming will be lost as leakage current reduces the output voltage below 1.6V. Note that the battery monitor will not work when the voltage regulator is not used. Battery monitor gives status information on the voltage being above or below a programmable threshold. The battery monitor can be enable and disabled using the control bit. The voltage regulator must also be enabled when using the battery monitor.

An crystal oscillator can be used as main frequency reference. The reference frequency must be 16MHz. Because the crystal frequency is used as reference for the data rate as well as other internal signal processing functions, other frequencies cannot be used. The oscillator is designed for parallel mode operations of the crystal. The crystal oscillator os amplitude regulated. This means that a high current is used to start up the oscillations. When the amplitude builds up, the current is reduced to what is necessary to maintain a stable oscillation. This ensures a fast start-up and keeps the drive level to a minimum. The ESR of the crystal must be within the specification in order to ensure a reliable start-up.

International regulations and national laws regulate the use of radio receivers and transmitters. SRDs (Short Range Devices) for license free operation are allowed to operate in the 2.4 GHz band worldwide. The 2.4 GHz band is shared by many systems both in industrial, office and home environments. Sensor nodes uses direct sequence spread spectrum (DSSS) as to spread the output power, thereby making the communication link more robust even in a noisy environment. With wireless sensor nodes it is also possible to combine both DSSS and FHSS (Frequency hopping spread spectrum) in a proprietary non-IEEE 802.15.4 system. This is achieved by reprogramming the operating frequency before enabling RX or TX. A frequency synchronization scheme must then be implemented within the proprietary MAC layer to make the transmitter and receiver operate on the same RF channel.

The data buffering in sensor node lets the user have a lower data rate link, which allows to reduce the workload and timing requirements. The relatively high data rate of sensor node also reduces the average power consumption compared to the 868/915 MHz bands, where only 20/40 kbps are available. Sensor nodes may be powered up a smaller portion of the time, so that the average power consumption is reduced for a given amount of data to be transferred. Sensor node provides very good adjacent, alternate and co channel rejection, image frequency suppression and blocking properties. These are highly important parameters for reliable operations in the 2.4Ghz band, since an increasing number of device/system are using this license free frequency band. As the sensor node provides 250kbps multi-channel performance without any external filters, a very low cost system can be made. A differential antenna will eliminate the need for a balun, and the DC biasing can be achieved in the antenna topology. The sensor nodes are powered down when not being active. Extremely low power consumption is achieved when disabling the voltage regulator by programming of the register and RAM configuration by changing frequency.

In an IEEE 802.15.4 system, all communication is based on packets. The sensitivity limit is based on Packet Error Rate (PER) measurement instead of BER. This is a more accurate measurement of the true RF performance since it mirrors the way the actual system operates. So the transmission of the packets is used in EETTRP . The sensitivity limit specified the RF level resulting in a 1% PER. The packet sample space for a given measurement must then be >> 100 to have a sufficient large sample space. So more than 10000 packets are used in the network.

In the previous developed protocols the network scheme used to be direct communication because all nodes will be cluster heads and transmit directly here information to the base station, in those case the network performance use to be increase , in those cases packet transmitted to BS used to be larger than those packets that are transmitted to the CHs. In this protocol this is minimized and the solution to this is to increase the number of static cluster heads; because when the number of static cluster heads increases in network than it distribute the energy load among high power sensor nodes, thus extends network lifetime.

CHAPTER FIVE: RESULTS AND ANALYSIS

5.1 Simulation Parameters

The performance of Energy Efficient Three Tier Routing Protocol (EETTRP) protocol using MATLAB. We consider a wireless sensor network with N=100 nodes randomly distributed in a $100m \times 100m$ field. It is assume that the base station is in the center of the sensing region.

Assumption is also made that the radio channel is symmetric such that the energy required to transmit a message from node A to node B is the same as the energy required to transmit a message from node B to node A for a given SNR. It is also assume that, all sensors are sensing the environment at a fixed rate and thus always have data to send to the end user. Further more the threshold will play its role to transmit data if some event occurs in the networks.

The simulation is carried out in MATLAB with the radio model parameters as shown in Table.1.

Table 5.1 Parameters of the radio model

Parameters	**Value**
Initial Energy, E_o	$0.05J$
Packet Size, k	$4000bit$
Energy of transceiver, E_{elec}	$50nJ/bit$
Energy of data aggregate, E_{DA}	$5nJ/bit/message$
Transmit amplifier (Free space), $\epsilon_{fs}(d_{BS} < d_o)$	$10pJ/bit/m^2$
Transmit amplifier (multi path), $\epsilon_{mp}(d_{BS} \geq d_o)$	$0.0013pJ/bit/m^4$

5.2 Node Deployment

Node deployment in WSN is done in $100m \times 100m$ field with the base station at the center of the field. All others nodes are uniformly distributed in the filed, all together there are 100 nodes deployed in the network. The optimal election probability of node to become cluster head is 0.1. All the energy model have values in joules. The amplification energy for the intra cluster communication is taken as 0.1 of the total transmit amplifier taken for free space. In the contest 20% of the nodes are taken as advance nodes and 30% as the intermediate nodes. The maximum number of rounds taken were 6000 rounds where in each round protocol performs its function.

5.3 Results

CASE I

In this case node are scattered randomly in the area with sensor members, cluster heads (Intermediate nodes and advance nodes) together with sink at the center of the area.

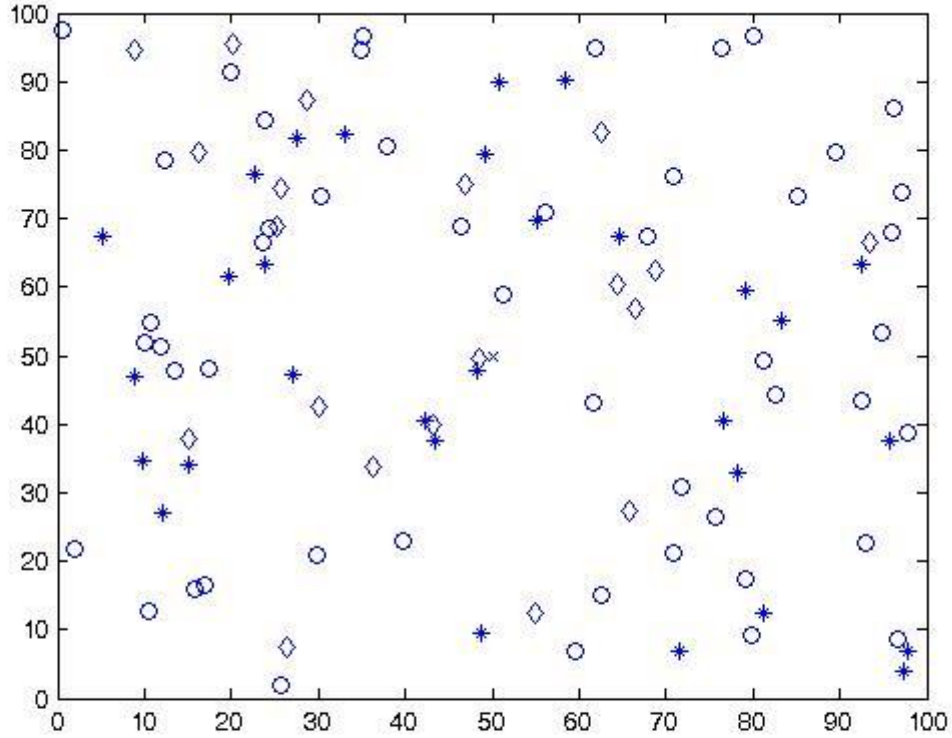

Figure 5.1 Node deployment in WSN of $100m^2$ area

Initially there is random seeding of the normal nodes in the network. Then Random election of intermediate and advance node is made. Then distance between cluster head and base station is calculated then the first cluster is selected. Then the communication stat and the number of packets that are transmitted to the Cluster Heads from nodes are calculated and similarly the number of packets that are transmitted to the Base station is also calculated in each round or operation. Then in next round the nodes that have not been assign to cluster head are chosen for the cluster head and then the communication begins as above.

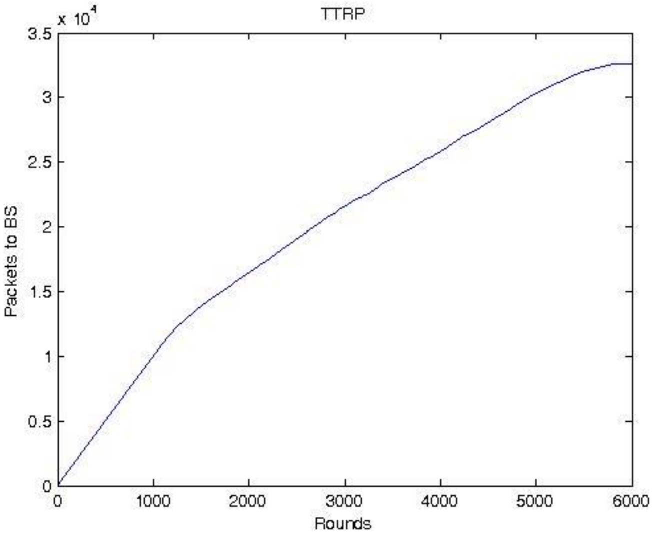

Figure 5.2 Graph for packets transmitted to BS

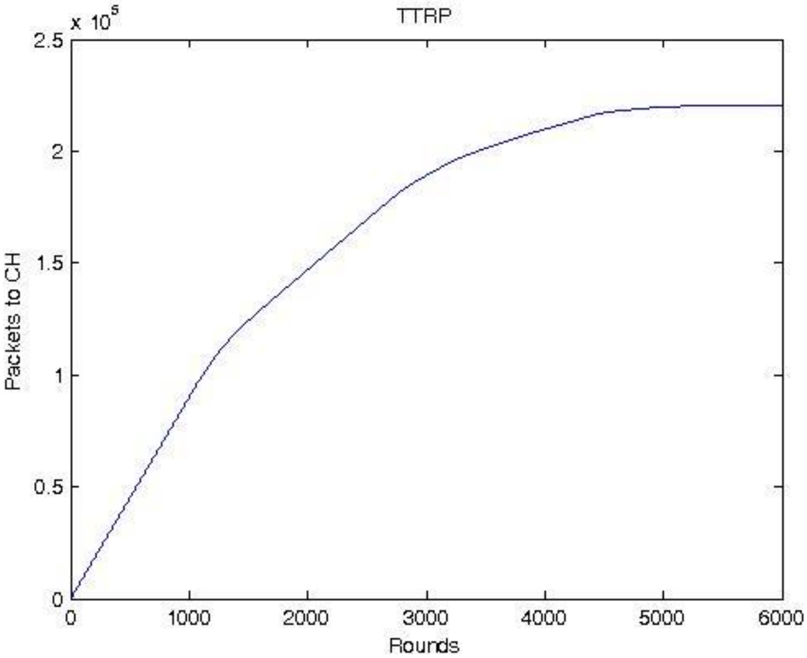

Figure 5.3 Graph for packets transmitted to CH

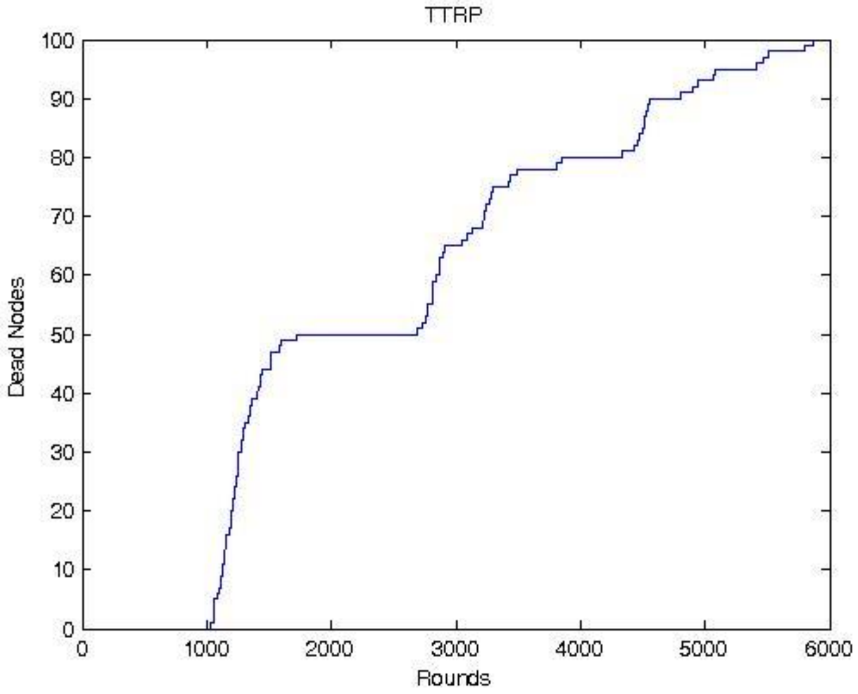

Figure 5.4 Graph to show number of dead nodes

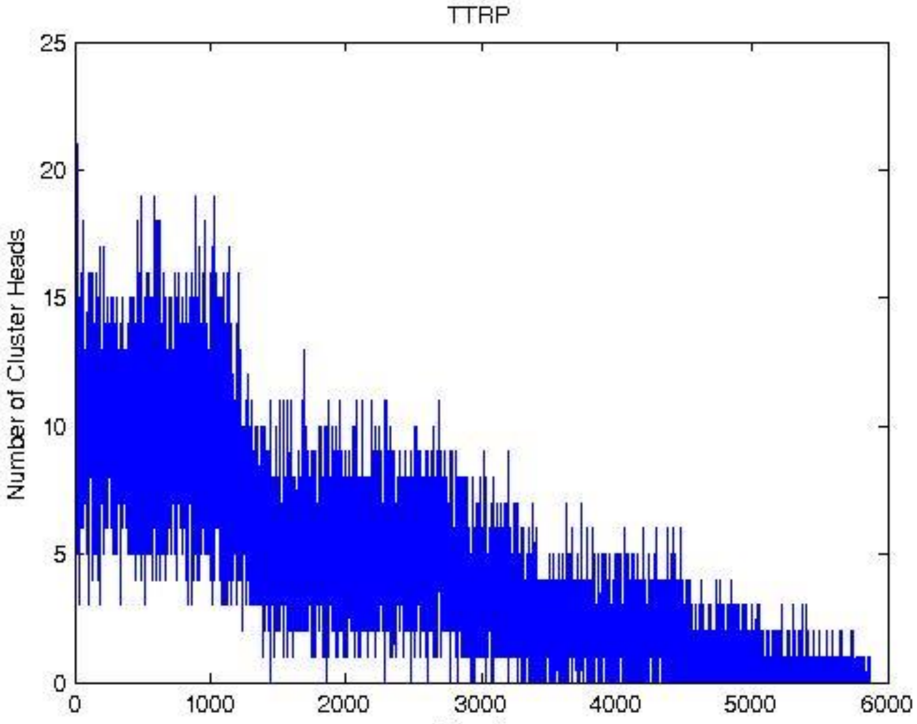

Figure 5.5 Number of cluster heads

CASE II

In this case the sensor nodes are deployed randomly in the same area as in the case I . In this case the deployment of the sensor nodes are in random pattern than the location of the sensor member is change along with the location of the advance node and intermediate node. But the sink is at the same position in the center of the area. The different sensory nodes are deployed randomly in the area. There is no fixed pattern of distribution of the sensory nodes in the network. These sensory nodes can be deployed in any manner. The important this for the considerations is that the distribution of the energy in the network area. So there are two different cases in this part for the comparison to be made about the distribution of the sensory nodes in the network.

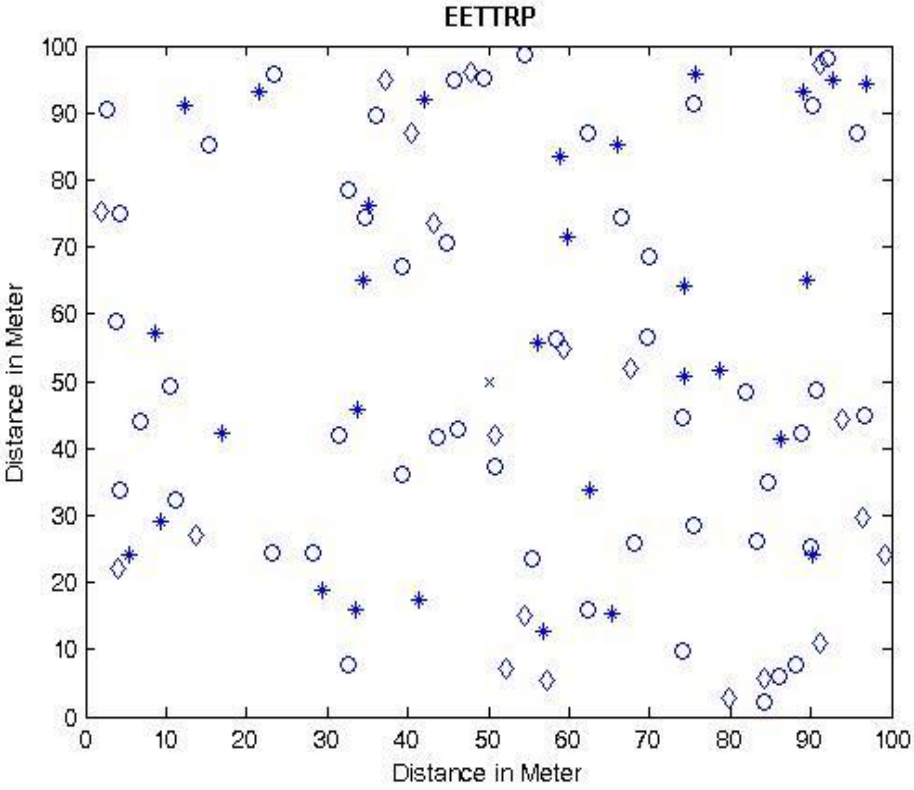

Figure 5.6 Situation one

Figure 5.6 shows the node deployment made for the wireless sensor network for the situation one. Where nodes are deployed randomly with equal energy distribution.

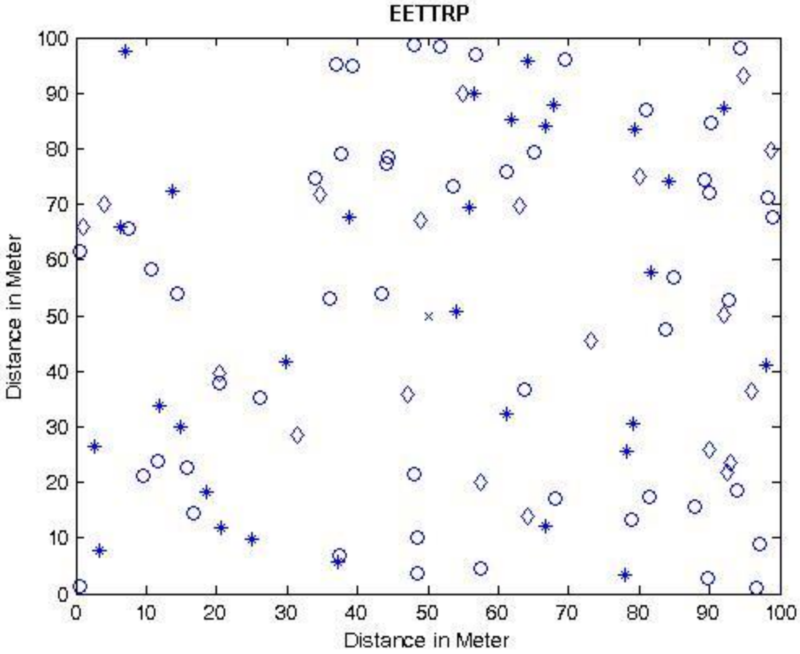

Figure 5.7 Situation two

Figure 5.6 and Figure5.7 show the random deployment of the sensor nodes and cluster heads where the sink is in the same position of the network area. Figure 5.6 and Figure 5.7 show the different deployment of the nodes in the wireless sensor network.

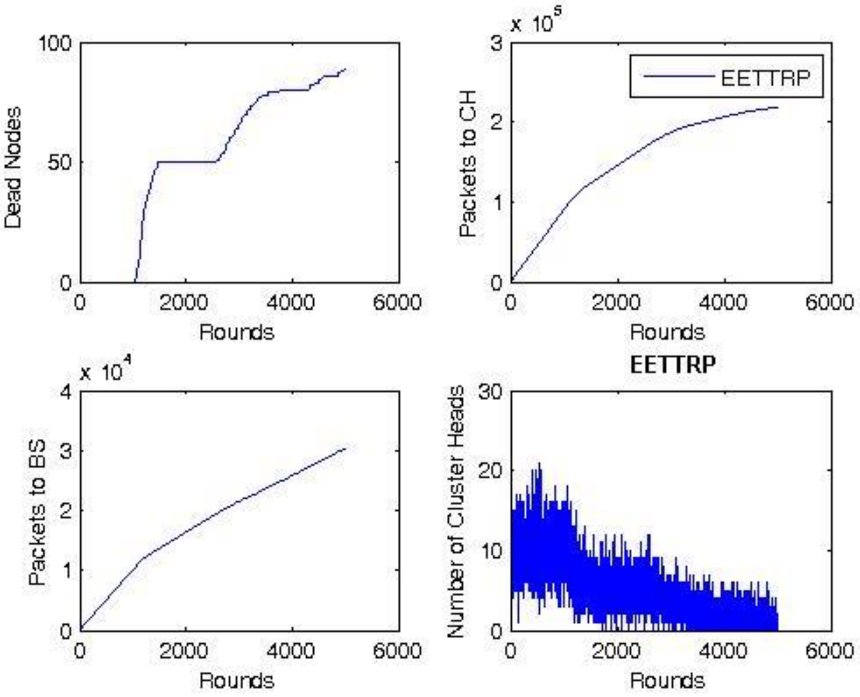

Figure 5.8 Result of situation one

From the figure 5.8 result of situation one and figure 5.9 result of situation two shows that they are all most similar. Which we can observe from Figure 5.8 and Figure 5.9. In which Figure 5.8 show the result of the situation one and Figure 5.9 shows the result of the situation two.

In the Case I it was found that number of packets deliver to the Cluster Heads is 219,429 packets and number of packets deliver to the base station is 30,079 packets. In the Case II it was tested in two different situation situation-one and situation-two. In situation-one it was found that number of packets deliver to the Cluster Heads is 218,058 packets and number of packets deliver to the base station is 30,298 packets. Where as in the situation-two it was found that packets deliver to the Cluster Heads is 219,715 packets and number of packets deliver to the base station was 29,842 packets. This shows that in whatever pattern the nodes are deployed in the area the output doesn't very.

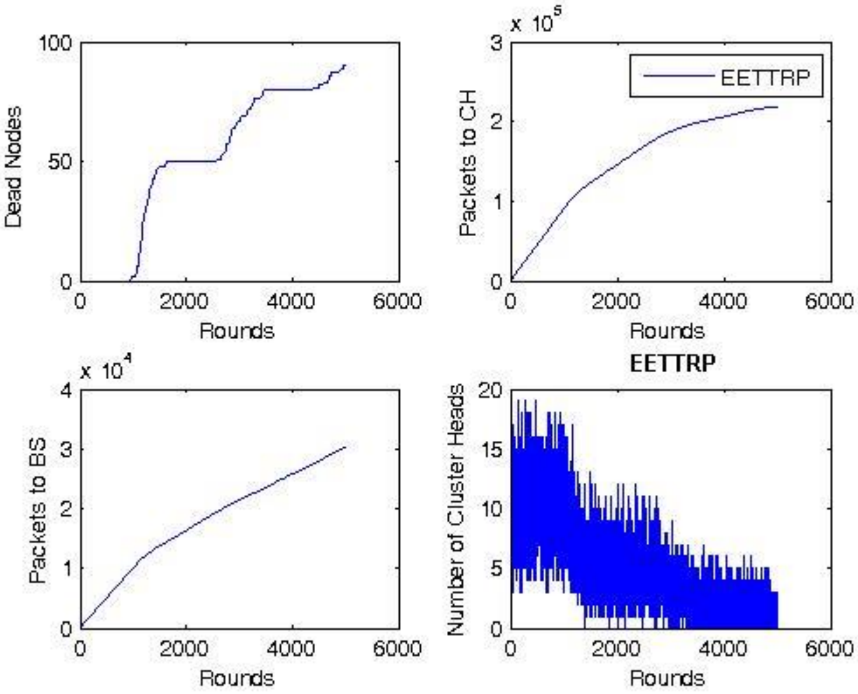

Figure 5.9 Result of situation two

It shows that in the heterogeneous network nodes are deployed on the basis of uniformly distributed energy pattern. So, the random distribution of sensor is always based on the uniform distribution of energy level in the cluster of the network.

5.4 Comparison with other developed protocols

In this section the proposed protocol is compared with the other developed protocol for the heterogeneous network of the wireless sensor network. In which we compare the proposed protocol with DEEC, DDEEC and EDEEC which were developed before. So compare these protocols it is necessary that they are tested in the same environment so that the difference could be seen. So for that the network is equal. Figure 5.10 shows the comparison of the protocols in the same environment A. where first figure shows the numbers of nodes dead during operation, where in the second figure alive nodes are shown. In the third part of figure shows the number of packets delivers to the base station. Where the fourth part of the figure 5.10 show number of cluster heads used. Similarly in the same way these parameters are tested in different environment. Figure 5.11 shows the comparison in environment B whereas the Figure 5.12 show the comparison in environment C.

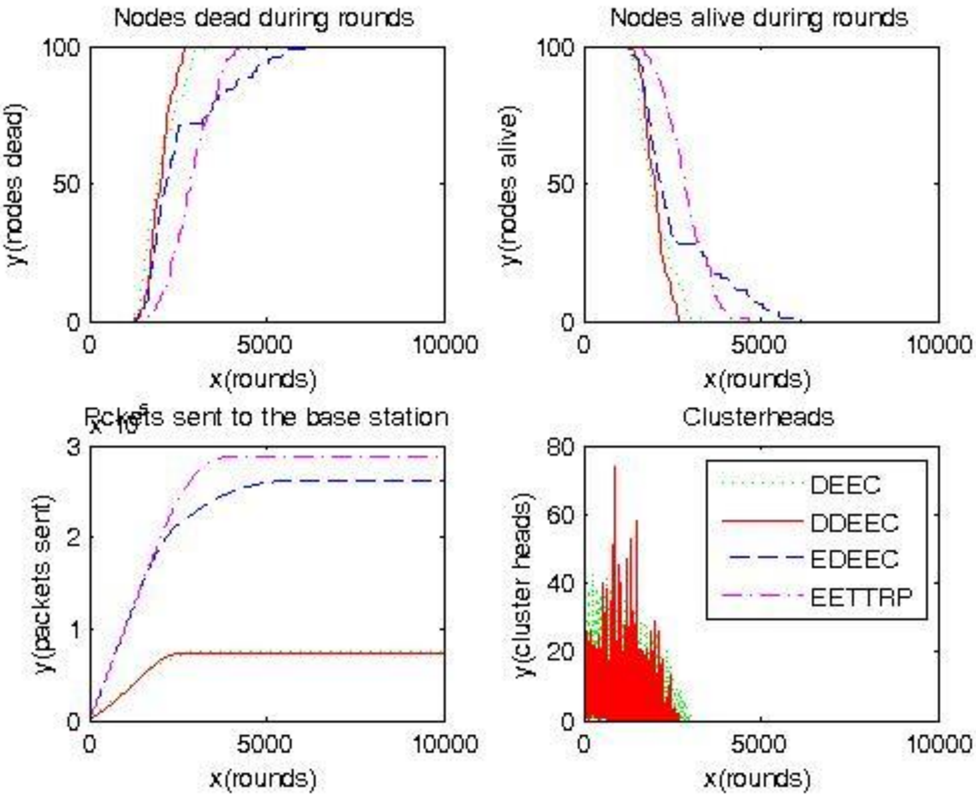

Figure 5.10 Comparison on environment A

From these comparison it is seen that the proposed protocol EETTRP is much better than previous developed protocol DEEC and DDEEC. Whereas in the case of the EDEEC protocol show that it has after certain thousands of rounds the rate of nodes to die decreases due to which in the later stage of the network nodes are alive for a little longer duration than the proposed one but this situation is due to the use of super node in EDEEC. But in the others environment it is nearly equals to that of the proposed one.

In the case of comparison when we run the protocols then we found that the number of packets deliver to the cluster are obtained for DEEC is 135,487 packets, for DDEEC is 120,289 packets, for EDEEC is 90,097 packets, and in the case of proposed EETTRP it is found that the number of packets transmitted to the cluster heads is 187,740 packets. Which shows that the rate of transmission of data to the cluster heads from the sensor members is high in the purposed EETTRP protocols. Which is much efficient than other developed protocols.

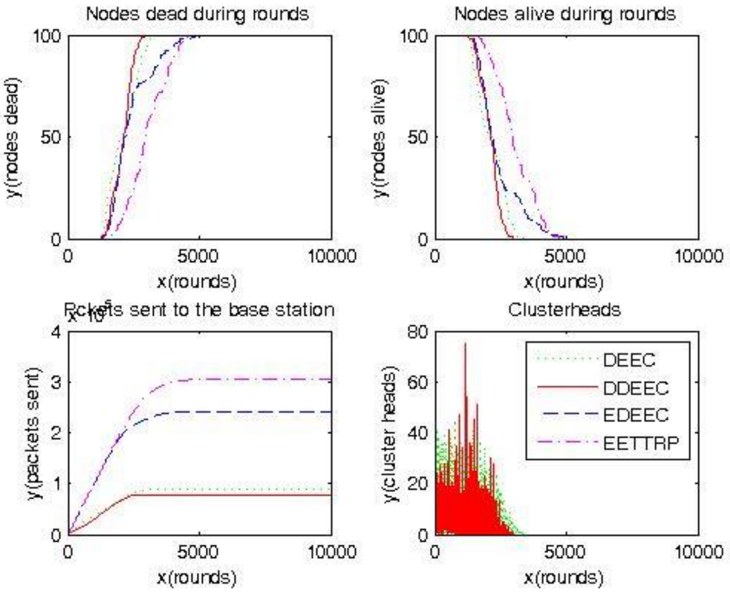

Figure 5.11Comparision in environment B

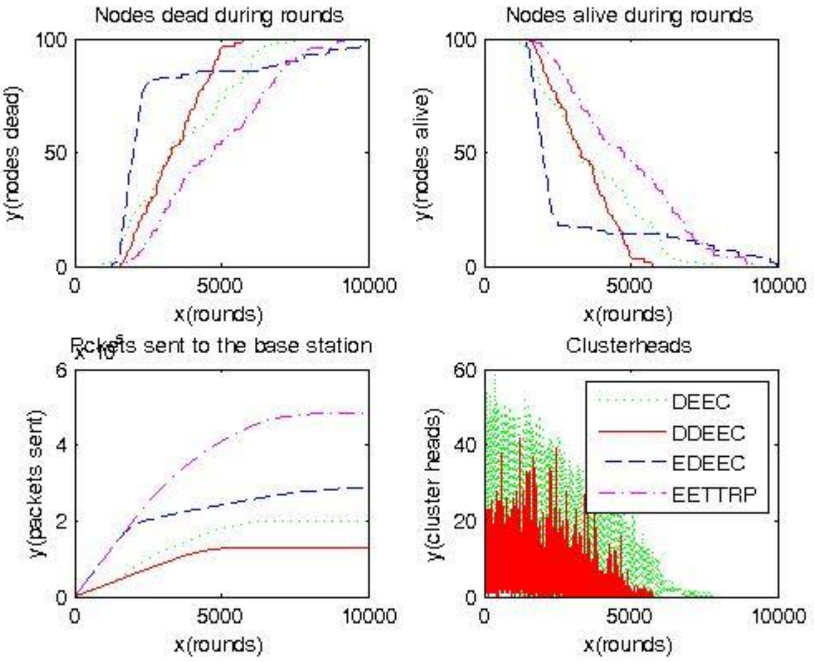

Figure 5.12 Comparison on environment C

Table 5.2 Comparison table of different protocols used in wireless sensor networks

	ALGORITHMS			
NODES	**DEEC**	**DDEEC**	**EDEEC**	**EETTRP**
First node dead	1127	1636	1316	1894
Tenth node dead	1784	1986	1582	2601
All node dead	7125	5227	8260	8407
First node dead	969	1459	1319	1926
Tenth node dead	1653	1891	1538	2392
All node dead	7885	5460	8556	9305
First node dead	808	1459	1306	1684
Tenth node dead	1537	1790	1519	2196
All node dead	7328	5884	8845	9299
First node dead	774	1484	1378	1384
Tenth node dead	1489	1815	1556	2343
All node dead	6960	5064	9510	9063
First node dead	958	1522	1311	1554
Tenth node dead	1694	1859	1599	2219

All node dead	7001	5598	8959	9306
First node dead	768	1438	1376	1866
Tenth node dead	1515	1773	1560	2319
All node dead	7540	5309	9938	8864
First node dead	840	1473	1298	1759
Tenth node dead	1909	2070	1587	2473
All node dead	7237	5420	9652	8456
First node dead	957	1476	1378	1485
Tenth node dead	1565	1728	1510	2246
All node dead	7075	5792	9758	9866
First node dead	780	1531	1304	1824
Tenth node dead	1600	1812	1602	2280
All node dead	6738	6208	9978	9620
First node dead	837	1648	1369	1832
Tenth node dead	1707	1990	1626	2565
All node dead	7211	5474	9889	9000

From Table 5.2 we can see that the difference in the different protocols functioning. The death of the first node in the network could be seen in terms of the number of rounds of the operation. Above experiment has been performed in same environment condition for all the protocols. We can observe that the death of the first node in the network which uses the Distributed Energy Efficient Clustering (DEEC) is 957 rounds but in the same environment condition Development Distributed Energy Efficient Clustering (DDEEC) first nodes dies at 1476 rounds; similarly in the case of the Enhanced Development Distributed Energy Efficient Clustering (EDDEC) first nodes dies at 1378 rounds and in the case of the purposed protocol Efficient Energy Three Tier Routing Protocol (EETTRP) the first nodes dies at 1485 rounds which is much longer periods than previously developed algorithms. It also shows that the proposed protocol has much stability period than previously developed algorithms.

From Table 5.2 we can also see that the death of the tenth node in the network could be seen in terms of the number of rounds of the operation in the same environmental condition for all the protocols. We can observe that the death of the tenth node in the network which using the Distributed Energy Efficient Clustering (DEEC) is 1565 rounds but in the same environment condition Development Distributed Energy Efficient Clustering (DDEEC) tenth nodes dies at 1728 rounds; similarly in the case of the Enhanced Development Distributed Energy Efficient Clustering (EDDEC) tenth nodes dies at 1510 rounds and in the case of the purposed protocol Efficient Energy Three Tier Routing Protocol (EETTRP) the first nodes dies at 2246 rounds which is much longer periods than previously developed algorithms. From which we can observe that the period for death of tenth node in the network which is using EDDEC protocol is much faster compare to all others. In the case of DDEEC it seems much better than EDDEC and DEEC. But in the case of the purposed EETTRP protocol it is much longer period than all of the others protocols. It shows that the uniformity of the network is maintained.

The death of the all node in the network could be seen in terms of the number of rounds of the operation. Which is also the death of the network it self. We can observe that the death of the all nodes in the network which is using the Distributed Energy Efficient Clustering (DEEC) is 7057 rounds but in the same environment condition Development Distributed Energy Efficient Clustering (DDEEC) all nodes dies at 5420 rounds; similarly in the case of the Enhanced Development Distributed Energy Efficient Clustering (EDDEC) first nodes dies at 9758 rounds and in the case of the purposed protocol Efficient Energy Three Tier Routing Protocol (EETTRP) the all nodes dies at 9866 rounds which is much longer periods than previously developed algorithms. It shows that the purposed EETTRP protocol has longer life time than previously developed protocols for the wireless sensory networks. In previous developed protocols we can see that EDEEC has the longer network life time which signifies the energy efficient clustering. But the DDEEC has much more stability period than others protocols. But now we can see that the proposed protocol has both more stability than DDEEC and much longer network life time than EDEEC protocol. Therefore we can say that the proposed protocol is the better energy efficient protocol for wireless sensory network.

5.5 Discussion

When the simulation was performed it is found that the last node to die in the Wireless Sensor Network was in 5101 rounds by the proposed protocol. Where as in the case of the other algorithm that are developed recently has much less. In the case of EDDEC the last nodes to die is at 4100 round and in the case of DEEC it is at 4500 rounds. Therefor the proposed protocol is energy efficient than developed before.

The number of data packets transmitted to the cluster heads by EDEEC is 39,093 similarly that of the DEEC is 22, 460 where as in the case of the EETTRP it has been increase upto 219,700 data packets. Which increase the efficiency of the network when the network is fully run in their best proposed environment.

In the case of the case of the static cluster heads EDEEC and TDEEC has not any alive static cluster head in 5000 rounds where as proposed protocol has more 2 alive static cluster left for the transmission of the data. When the number of static cluster heads increases in network then it distribute the energy load among high power sensor nodes, thus extends network life time.

In order to verify about EETTRP, currently extending the network were simulated to simulate EETTRP, DEEC, DDEEC and EDEEC. This will verify and give us a more accurate picture of the advantages and disadvantages of the different protocols. Based on our MATLAB simulations described above, it is sure that EETTRP outperform conventional communication protocols, in term of energy dissipation, ease of configuration, and system lifetime/quality of the network. Providing such a low-energy will help pave the way for future microsensor networks.

CHAPTER SIX: EPILOGUE

6.1 Conclusion

In this thesis proposed Energy Efficient Three Tier Routing Protocol (EETTRP), describe a clustering based routing protocol that minimizes global energy usage by distributing the load to all nodes at different points in time. EETTRP outperforms clustering algorithms by requiring nodes to volunteer to be high-energy cluster heads and adapting the corresponding cluster based on the nodes that choose to be cluster-heads at a given time. At different times, each node has the burden of acquiring data from the nodes in the cluster, fusing the data to obtain an aggregate signal, and transmitting this aggregate signal to the base station. Distributing the energy among the nodes in the network is effective in reducing dissipation from a global perspective and enhancing system lifetime. Specifically, simulations shows that: EETTRP reduces communication energy compared with other protocols as DEEC, DDEEC and EDEEC direct communication and minimum transmission-energy routing. The first node death in EETTRP occurs over 1.5 times later than the first node death in other communication, direct transmission and minimum-transmission-energy routing, and the last node death in EETTRP occurs over 1.389 times later than the last node death in the other protocols. This shows that the purposed is much better than other routing protocols for Wireless sensor network.

6.2 Limitations and Future Work

When operating at below the sensitivity limit, sensor node may lose symbol synchronization in infinite receive mode. A new SFD and restart of the receiver may be required to re-gain synchronization. This thesis work deals with only network life time of the wireless sensor networks. For in depth analysis of the increment in the overall data transmission in the network more better results may be obtained by transmitting all the data received by the sensor nodes to the base station without any loss. This thesis focus on the minimum energy required by the sensor nodes to sense the data and also the minimum energy required to transmit the received data to the cluster heads in the network. All the results are for a single transmit and signal receive antenna, so future extensions can be done in multiple input multiple output antenna.

Similarly, this thesis totally assume the different parameters of standard for trans receiver used in wireless sensor network. Further improvement in EETTRP can be made by canceling the same data received by the cluster heads from the different sensor nodes which are around its area, as there is always high probability of receiving the same data from different sensor nodes which are spread around the cluster heads to receive the change in the environment. If we are able to identify the same information is being received by the cluster heads then we can only transmit the one data to the base station as a result we can save more energy during the transmission period.

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