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On

Performance Evaluation of Threshold Sensitive Stable Election Reactive Protocol in Wireless Sensor Network

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CERTIFICATE

This is to certify that the dissertation titled **"Performance Evaluation of Threshold Sensitive Stable Election Reactive Protocol in Wireless Sensor Network"** is a bonafide record of work done by **Ram Kumar, Roll No. 2K13/CSE/20** at **Delhi Technological University** for partial fulfilment of the requirements for the degree of Master of Technology in Computer Science & Engineering. This project was carried out under my supervision and has not been submitted elsewhere, either in part or full, for the award of any other degree or diploma to the best of my knowledge and belief.

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Date: __ __ ___

ABSTRACT

Wireless sensor network refers to the collection of hundreds to thousands of geographically dispersed and distributed sensor node, where each node is connected to one or more sensors, for monitoring and recording conditions of environment at diverse locations and organizing the collected data at a central location. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance. Today wireless sensor networks are used in many industrial and consumer applications, such as industrial process control and monitoring, machine health monitoring, and so on. Commonly monitored parameters are temperature, pressure, wind direction and speed, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels and vital body functions.

Reactive networks as opposed to proactive networks responds immediately to the changes in required parameters of interest, due to continuous sensing nature of WSN. The efficiency and improvement in terms of energy in network's lifetime is one of the crucial issues in wireless sensor networks (WSNs) [36, 37]. WSNs are expected also to finds the wide applications and increasing deployments in near future. In this paper, we proposed an efficient version of TSEP Protocol, which prolongs the networks lifetime as we have simulated. We evaluated the performance of our protocol and compared the results with the TSEP. And from the results of simulation, it is observed that our protocol perform better in terms of lifetime.

Keywords - Wireless sensor network, Stable election protocol, Threshold sensitive stable election protocol.

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List of Abbreviations

WSNs	Wireless Sensor Networks
BS	Base Station
CHs	Cluster Heads
LEACH	Low Energy Adaptive Clustering Hierarchy
TEEN	Threshold sensitive Energy Efficient sensor Network Protocol
TSEP	Threshold sensitive Stable Election Protocol
ISO	International Organization for Standardization
SPIN	Sensor Protocols for Information via Negotiation
DD	Directed Diffusion
GAF	Geographic Adaptive Fidelity
GEAR	Geographic and Energy Aware Routing
SEP	Stable Election Protocol
TSEP	Threshold sensitive stable election protocol
APTEEN	Adaptive Periodic Threshold sensitive Energy Efficient sensor Network Protocol
FSPM	Free Space Propagation Model
TRPM	Two-Ray Propagation Model
SNR	Signal to Noise Ration
SV	Sense Value
CV	Current Value
TAG	Tiny Aggregation
GPS	Global Positioning System
ADC	Analog to Digital Convertors
TMP	Task management plane
MMP	Mobility management plane
HT	Hard Threshold
ST	Soft Threshold
EEHTSEP	Energy Efficient Heterogeneous TSEP

Recent advances in technology have led to the development of wireless domain from the wired domain. which results the introduction of wireless sensor network, which basically refers to the collection of a few to the thousands of geographically distributed sensor node, where each node is connected to one or more sensors, for monitoring and recording conditions of sensing environment at diverse location and organizing the collected relevant data at a central location as shown in Figure 1.1. The central location or authority is referred to as sink or base-station (BS), which is also a sensor node but has ample power supply unlike constrained power of sensor nodes.

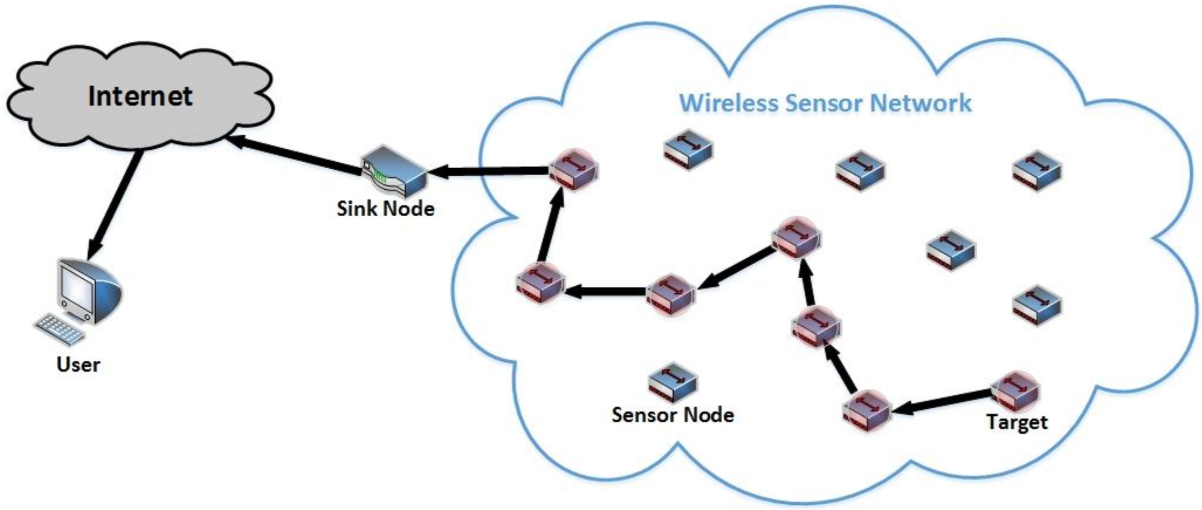

Figure 1.1: Fundamental Structure of Wireless Sensor Network.

With the advancement, each wireless node in WSN [36, 37] is cost effective, very small sized electro-mechanical sensing device, and can be easily deployable with no fixed topology in the desired environment [2]. These features make the WSN to be used in many wide and significant applications like monitoring temperature, pressure, wind direction and speed, vibration intensity, power-line voltage, chemical concentrations, pollutant levels and vital body functions. There are Some restrictions with the Sensor nodes used in WSNs apart from the limited powered battery are like limited processing capability, low bandwidth for communication over the wireless media and less storage capacity. Although having the limited processing capabilities, combined efforts of wireless sensors have the potential to analyze the desired target environment in great details. While the wireless sensor nodes can be stationary or mobile depending on the application and can be deployed in the environment randomly or by using proper deployment mechanisms. If we consider the Sensor's Energy issues, partial energy of nodes gets consumed during sensing and some of it is reduced during the transmission and reception of data. It is not practically possible to replace or recharge sensors batteries once deployed. The advancements in technology have extends the applicability and Functionality of WSN, and major research is done to increase the network lifetime of wireless sensor network. Which have been achieved by introducing the Energy Efficient cluster based routing protocol, which reduces the number and amount of transmissions by the nodes, by transmitting only the non-redundant information out of all the data it has sensed and forwarding only the non repetitive data using the data aggregation techniques [5] in wireless sensor network, which technically saves a lot of transmission energy and increases the efficiency of the network. Data Compression or Data aggregation is a process of aggregating the sensor data using aggregation approaches as shown in Figure1.2.

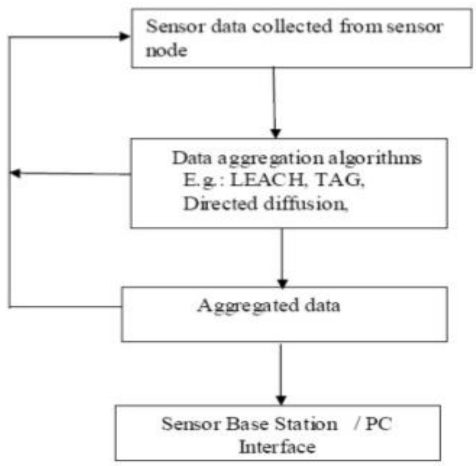

Figure 1.2: Basic block diagram of data aggregation process.

The algorithm uses the sensor data from the sensor node and then aggregates the data by using some aggregation algorithms such as centralized approach, LEACH (low energy adaptive clustering hierarchy), TAG (Tiny Aggregation) etc. shown in above Figure 1.2. This aggregated non-redundant required data is transmits along efficient path to the sink node. Data compression technique is employed by many routing protocols over the sensor nodes to further reduce the amount of transmissions and increasing the efficiency in the network [3].

The WSN must operate without human interruption, emphasizing to increase network life. We are purposing an improved version of TSEP and also evaluated the Performance with TSEP Protocol in WSN.

In WSN the sensor nodes are deployed in the desired target environment. Depending upon the WSN routing protocol the sensors senses the monitoring environment continuously or after every fixed quantum. Then the sensor node transmits the sensed information either periodically or on the occurrence of some event to the BS. The transmission of information to the sensor nodes to the BS can be done in various ways as proposed by many routing protocols to increase the efficiency of the network. Traditional way of transmitting the information directly from the sensor node to BS is very energy consuming and inefficient. It uses multi-hop transmissions to transmit the information to the BS which distributes the energy expended amongst many nodes and hence prolongs the lifetime of whole of the network. Use of such mechanisms and development of energy efficient routing protocol is a need for the proficient use of WSNs.

1.1 . Sensor Node Architecture

Sensors are limited powered small sized, integrated micro-electro-mechanical hardware systems, capable of operating in high volumetric densities and operate unattended, that generate responses to the changes in physical condition. A sensor node senses the physical parameter to be monitored in the target environment. The sensed information in the form of analog signal produced by the sensors node is converted into digitized signal by an analog-to-digital converter and then sent further to controllers chip for further processing. Figure 1.3 represents the basic component structure of a sensor node.

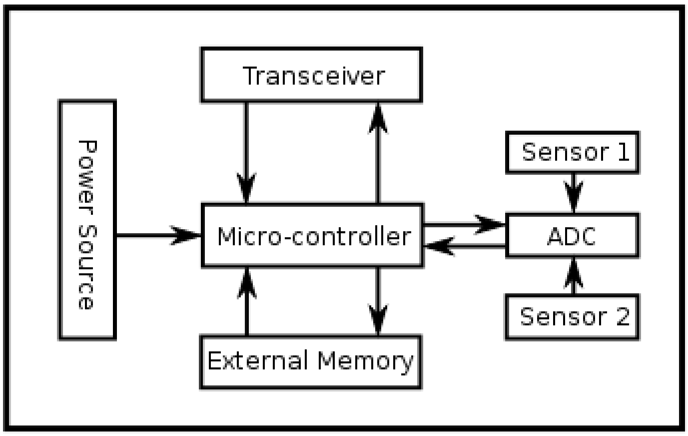

Figure 1.3: Sensor Node Structure

The main components of a sensor device are a microcontroller system, transceiver system, external memory component, power source and one or more sensors [4]. Some of the additional components which can be found in the sensor device depends applications are mobilize, location finding system (like GPS System) and power generator. The sensing unit comprised of two subunits as shown in the figure. The two units are sensors and ADC (Analog to Digital Convertors). Sensors produces the analog signals based on the desired phenomenon and are digitized by using ADC. The converted digitized signals are then given to the processing unit as input, which is associated with a small storage unit and handles the collaboration of the sensor nodes with other nodes to accomplish desired sensing tasks. Transceiver connects the node to the network. The most essential unit of a sensor is its power unit, as the power is consumed at every step for sensor node, like for sensing, communicating, data processing and also it derives all the other units to accomplish their respective tasks. Location finding system is another optional but essential unit in sensor nodes as location of the respective node is generally required time to time to accomplish the routing efficiently. Thus because of limited transmission and power capabilities major research is done to reduce the number of transmission without sacrificing the essential information and efficient use of power unit to prolong the lifetime of the nodes and hence the network.

1.2. Sensor Network Protocol Stack

The Protocol stack for Wireless sensor network is different from the standard TCP/IP as along with the layers used in traditional protocols it has additional planes to handle the issues in the sensor nodes.

The front plane has five layers as shown in Figure 1.4, works as traditional protocols suit. The application layer includes a variety of application such as node localization, time synchronization, and network security and also involved development of application software(s) based on the specified sensing tasks. The transport layer is responsible for data flow or end–to–end data delivery between sensor nodes and the sink(s) in WSN. Due to the energy, computation, and storage constraints of sensor nodes, traditional transport protocols cannot be applied directly to sensor networks without modification.

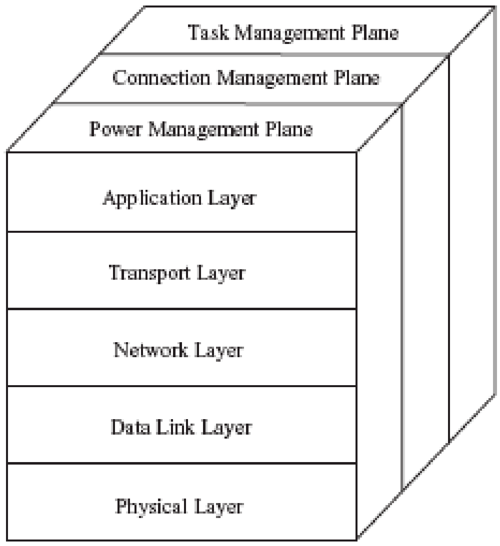

Figure 1.4: Sensor Network Protocol Stack

Data link layer also handles the noise and mobility of the nodes in the network and are power aware. The physical layer is responsible for converting bit streams from the data link layer to signals that are suitable for transmission over the communication medium. For this purpose, it must deal with various related issues, for example, transmission medium and frequency selection, carrier frequency generation, signal modulation and detection, and data encryption. In addition, it must also deal with the design of the underlying hardware, and various electrical and mechanical interfaces. The objective of these planes is to carry out the collaborative sensing task as desired with least power consumption. The power management plane (PMP) has the responsibility to decide how a node will use its power like when it has to switch on their sensors and when they have to switch off them. Power management plane also takes care of when to transmit the information and when not to. Mobility management plane (MMP) is responsible to know the route back to the BS in case of movement of the sensor nodes from their initial positions and inform neighbours about the newly moved sensor node. With the updated knowledge of neighbours now they can contribute and use the power of the nodes efficiently. Task management plane (TMP) performs the balancing of sensing tasks amongst the sensor nodes. It is not necessary that all the sensor nodes in the vicinity should sense and transmit the information. Thus TMP takes such decisions as per the application used in WSNs. So the additional planes are very essential for the objective of WSNs as without them a node will have no capability and will act as an individual transmitting the unwanted information and wasting the constrained power of the sensor node. These planes are essential for simple computations at the sensor nodes as per the changes in power, mobility and required tasks efficiently by the sensor nodes.

1.3. WSN Characteristics

Wireless Sensor Network consists of hundreds to the thousands of randomly scattered sensors in the target environment. There are many operational characteristics of WSNs, few can be listed as:

- Self Configuration: The node organization in WSNs is very dynamic and is supposedly changed with non-traceable patterns (topology). So the sensor nodes of the WSN have to be very adaptable to such a frequent changing environment, while keeping the power efficiency intact. Self configuration also has to handle the situations like node failures and node additions to the network or any other obstacles.
- Efficient Energy Usage: Power is very crucial issue in increasing the performance and lifetime of the network. So energy in a WSN should be expended in optimal manner like sensor nodes can switch off and switch on their sensors for a particular period of time and transmits the sensed data only when any event occurs or after every frame time.
- Mobility of nodes: sensor nodes in sensor network are highly mobiles as the media of communication is wireless, the nodes needs to be very adaptive in nature. So, this is a big challenge to synchronize the sink and sensor nodes, so that the data can be transmits with accuracy and timely.
- Heterogeneity of nodes: Heterogeneity may be in terms of nodes structure or sensor node's initial power in the sensor network, so this is also a big challenge to lets the sensor nodes to works collaboratively altogether in the sensor network despite of different node structure and initial power.
- Single-Hop communication: Traditional Sensor Network protocols used the single hop mechanism to send the sensed information to the BS. In this mode of communication all the sensor nodes transmits all the sensed information directly to the base station (Sink Node) without the involvement of other sensor nodes on its own. This mode of communication is very inefficient and power consuming with lots of redundant information to the BS. Thus introduced the modern protocols that rely on the multi hop mode of communication for better efficiency.
- Multi-Hop communication: While in case of Multi-hop, the sensor nodes senses the information and send it to the head node, may be named as Cluster Head (CH), which

filters the data i.e. removes the redundant data and send the aggregated data to the Sink Node.

- Automatic Load Balancing: Automatic load balancing is dynamic in nature as any number of sensor nodes can run out of power anytime in between the network lifetime, so we can let different node to become the cluster head in different iterations. So that the load can be balanced among all the nodes in the sensor network.

1.4 Motivation

In hierarchical based routing protocols, the sensors nodes interacts each other to set up a communication network system such as multi-hop network or a hierarchical organization with many clusters and associated cluster heads (CHs) [1]. Cluster formation increases the performances of the WSNs by making efficient use of energy of sensor nodes [10, 13, 14]. The CH selection is done on the basis of probability of nodes to become the CH or on the basis of remaining energy of the nodes. After CH selection nodes near to CH are associated with CH and transmit data to CH instead of base station (BS) to reduce transmission energy. CH then transmits only non-redundant necessary information to the BS which increases the network lifetime of the network [5].

LEACH proposed in [13] is a clustered protocol where the nodes elects their CH and transmit the packets to the CH which than performs computations and forwards the non redundant information to the BS. LEACH was then used as the base protocol for hierarchical clustering and family of protocols were proposed as improvements over LEACH. First reactive protocol for homogeneous network, TEEN as proposed in [7] improved the performance of WSNs for time critical applications. Heterogeneity was introduced in WSNs with the implementation of SEP as proposed in [14]. [10] Proposed TSEP, a reactive protocol for the heterogeneous WSNs. TSEP improved the network lifetime and throughput of the network but has some drawbacks which are the same as with other threshold sensitive networks.

Thus lots of active research is done in the area of reactive networks. Although reactive network provide great flexibility and efficiency but there are some shortcomings associated with these networks. Some of the application specific networks do not rely on reactive network because of its drawbacks in terms of status of the network and priority in information. We in this dissertation have worked on addressing these drawbacks of the reactive protocols in WSNs to increase the use and applicability of such networks and making it more efficient and reliable for time critical applications.

1.5. Research Objective

With the motivational points we have explained in the previous section, the objective of our research work can be identified as:

- Development of a mechanism to keep the BS aware of the status of the network dynamically in situations when the network is idle. This will assist the BS to analyze and use the network structure efficiently.
- To improvise the transmission of critical information(s) to BS with highest priority, almost instantaneously.
- To transmit the information using greedy hops instead of regular hops to increase the lifetime of the network.
- To give control to the user to monitor the introduced features after each round of CH selection so that the user can decide which information is critical to the network and optimally evaluate the degree of awareness needed by the BS.
- Compare our protocol which takes into consideration all the above characteristics with the conventional routing protocols in terms of energy efficiency and performance metrics.

1.6. Thesis Organization

We start with introduction in chapter 1. A detailed background description is presented in chapter 2 which includes applications, issues and characteristics of WSNs. Chapter 3 describes the routing protocols in detail which are related to our research problem. Chapter 4 gives a brief about the network model we have used in our simulation. Chapter 4 also explains in detail about our proposed protocol EEHTSEP. The description of the proposed work is explained in phases of cluster head selection, cluster formation and data transmission phase in chapter 4. We evaluate the performance of the proposed routing protocol and technique with conventional routing protocols in chapter 5. We conclude about the work done and observations in chapter 6.

2.1 WSNs Classification

Wireless Sensor networks can be used beneficiary in a variety of applications. Depending on the applications, sensor node differs greatly in technical requirements. Such network requires development and deployment of application oriented sensor devices. Although there are some application specific properties of the sensors, some are common in these networks even for some very discrete applications, independent of application. Like group of some sensors in one application can be deployed and distributed randomly in the target monitoring area and the remaining group of sensors in another applications may use strategic static deployment and development methodology. Hence a network can be classified on the basis of deployment strategy. Some of the most prominent properties of WSNs can be listed as [6, 7, 10, 11].

2.1.1 Proactive and reactive networks

The classification of Proactive and reactive networks can be derived based on the target application environment. In the time-sensitive applications where periodic data is required by the Base Station to analyze the desired task (target environment) proactive networks are employed. The working of sensor in Proactive network is time-sensitive. After every fixed time period each sensor switches-on their transmitter-circuit to transmit the sensed relevant information to the intermediate node or Base Station. Thus, the amount of energy dissipated in each round of such a network can calculate and the life time of the network can be estimated, so the final Network life can be estimated. While in some time-sensitive or time critical applications periodic transmission of information is not necessary and hence using periodic networks is wastage of resources in such situations and here we can employee the reactive networks. In reactive networks, sensor node transmits the information only when any specified event occurs, while sense the target environment continuously. Thus reactive network are more efficient than proactive in terms of network lifetime, throughput and energy efficiency and are used actively for specific event driven applications, as transmission requires most of the energy of sensor nodes.

2.1.2 Single-hop and multi-hop networks

Based on the way by which the node transmits the sensed information to BS or depending upon the hop count, networks can be divided into single hop network or multi hop network. In single hop sensed network, all the sensor node will directly transmits the sensed information to BS, without involvement or interruption of any other intermediate node. While, in case of multi hop network, all sensors node sense the information and transmits the data indirectly to the BS via intermediate nodes of the network. It can be seen if some simple computation responsibility is given to the senor nodes then we can reduce in the network traffic and increase the efficiency with multi hop networks.

2.1.3 Self-configurable and non-self-configurable networks

This classification is derived from the control aspect of the network. Mostly sensors network works based on the self-configurable schemes to handle the complex tasks for the correct working of the network. As the topology of sensor network is very dynamic, by using self–configurable behaviour, the sensor network can manage themselves. Inclusion and exclusion of a sensor node in a wireless sensor network is quite often and self-configuration is needed to handle changes in the number of nodes in the network. While the non-self-configurable networks are none of use in present era of technology, but can be employed in small-scale static networks with usually a static deployment of the sensor nodes.

2.1.4 Aggregating and non-aggregating networks

This classification of network is based on the aggregation ability of the sensor nodes of network. Aggregating networks do not transmit the information directly to the BS but use packet forwarding mechanism, and while forwarding the packet each and every intermediate node aggregates or filters the data and transmits further to the next level node toward the BS. While in the case of non-aggregating networks, every node just senses the information and sends it further to the next upper level nodes toward the BS without aggregating and filtering the redundant or repeated data. Aggregation process makes the data packets more compact by reducing the amount of redundant or repeated data. So the number of data packet can be reduced, which reduced the number of data transmission to the Base Station. Data Aggregation is also very efficient in the larger target environment which is most common situation in WSNs. Aggregating network reduces a lot of network traffic by balancing the amount of data and reducing the number of transmissions to the BS. The network load traffic is proportional to the size and density of the network and as the size of the network increase preference for aggregating networks also increase over non aggregating networks for a better efficiency of the limited energy of the sensor nodes.

2.2 WSNs Application

With the advancements in technology and increased feasibility of WSNs, there are enormous applications which now use WSNs. Different kinds of sensors are used for such different applications. The various kinds of sensors are capable of monitoring variety of diversified environmental conditions like pressure, temperature, noise levels, soil makeup, vehicular movement etc. Sensors can also employed for the object detection and localisation kinds of application, also for mechanical or chemical evaluation of objects i.e. to measure the mechanical stress levels on attached sample objects and to measure some kinds of the dynamics properties of the object like speed of the object along with its direction of propagation and size of object [12]. As the enormous applications of WSNs are there, briefly some of them can be categorize in military, health, home, environment and commercial applications.

2.2.1 Military applications

Most typical and significant use of WSNs has done in military applications, since the introduction of WSN. The category of military applications can be in remote areas and force protection, computing, intelligence, surveillance, military command, etc [15]. The features provided by WSNs like ease and rapid deployment, cheap sensors devices, self-configuration and fault tolerance makes WSNs the most appropriate option in the field of military operations as in the battlefield there is a need to quick deployment of the nodes so as to setup a wireless sensor network as quick as possible in high intension areas. The number of nodes depends upon the subject to frequent changes due to intrusions in the target network field and hence self-configuration and self-management is necessary to keep the network active.

Some military tasks involving WSNs for targeting, battle damage assessment, battlefield surveillance, monitoring friendly forces, equipment and ammunition etc. Apart from these, military can always use WSNs for monitoring of the troops area of the target friendly forces to keep a tight or close watch on them. WSNs can also manage the information related to the availability and conditions of the military equipments used in the target battlefield before and after the battles.

2.2.2 Health applications

As the most favourable characteristics of Sensor network are like easy deployment and cheap sensor makes the Health industry to adopted the use of advanced WSNs for enormous applications, from the very simple diagnostics to providing advance technology interfaces for the disabled. Some other applications of WSNs are like monitoring of patients, drugs administration, Monitoring in Mass-Casualty Disasters, Vital Sign Monitoring in Hospitals, Large-scale In-field Medical and behavioural Studies, tele-monitoring of the physiological human data and also tracking of the doctors in the hospital using WSNs [12]. In tele-monitoring of the physiological human data sensors give more freedom to the humans. Use of WSNs in tele-monitoring provides greater flexibility and comfort to the patient. In WSNs, doctors and patients can be tracked by attaching sensor nodes to them. The sensor nodes attached to the patient and doctors may has some application specific tasks which maybe checking blood pressure, heart beat, body temperature etc.

2.2.3 Environmental applications

Wireless sensor networks play a vital role in environmental applications. They save a vast amount of time also where traditional methods required setting up a lot of equipment, or monitoring a site demanded one to be physically present. Some of the applications using WSNs are in natural calamities and disasters, monitoring environmental conditions can affects the agriculture, tracking the movements of small animals, biological factors of insects and birds, marine and other atmospheric factors, bio-complexity and pollution factors [17]. By using the WSNs, Flood detection can be achieved and one of the examples of such sensors is ALERT which is used by US and also the agricultural precision can be maintained as it can monitor the level of erosions in soil, the level of pesticides in water and the amount of air pollution [19]. The data gathered by the sensors can be used to generate maps of ecosystem distribution. This will reveal the distribution and diversity of ecosystem types. The sensor network can be a major part of conducting remote sensing of ecosystems.

Another very critical environmental application of WSNs is detection of forest fire. There are situations when forest fire can broke large and can cause a lot of disaster. Monitoring for environmental purposes which focuses on the effects of climate change entails monitoring biological diversity and ecosystem functioning, or biogeochemical cycles. Also chemical vapours, gas concentrations, relative humidity, and barometric pressure need to be detected.

2.2.4 Commercial applications

Commercially WSNs are used for better ease of deployment, flexibility, ease of management and versatility. Some of the commercial applications of WSNs are monitoring Products quality, construction of smart office places, robot control in target environment, automation and control in factories, machine transportation. WSNs can also be deployed in security services in target monitoring area also like monitoring and detecting thefts, theft alarm, tracking of vehicles. Various factory applications are modelled using WSNs like factory instrumentation, instrumentation of semiconductor processing chambers, rotating machinery and wind tunnels.

2.2.5 WSN Characteristics

Wireless Sensor Network consists of hundreds to the thousands of randomly scattered sensors in the target environment. There are many operational characteristics of WSNs, few can be listed as:

- Self-configuration: The node organization in WSNs is very dynamic and is supposedly changed with non-traceable patterns (topology). So the sensor nodes of the WSN have to be very adaptable to such a frequent changing environment, while keeping the power efficiency intact. Self configuration also has to handle the situations like node failures and node additions to the network or any other obstacles.
- Efficient Energy Usage: Power is very crucial issue in increasing the performance and lifetime of the network. So energy in a WSN should be expended in optimal manner like sensor nodes can switch off and switch on their sensors for a particular period of time and transmits the sensed data only when any event occurs or after every frame time.
- Mobility of nodes: sensor nodes in sensor network are highly mobiles as the media of communication is wireless, the nodes needs to be very adaptive in nature. So, this is a big challenge to synchronize the sink and sensor nodes, so that the data can be transmits with accuracy and timely.
- Heterogeneity of nodes: Heterogeneity may be in terms of nodes structure or sensor node's initial power in the sensor network, so this is also a big challenge to lets the sensor nodes to works collaboratively altogether in the sensor network despite of different node structure and initial power.

- Single-Hop communication: Traditional Sensor Network protocols used the single hop mechanism to send the sensed information to the BS. In this mode of communication all the sensor nodes transmits all the sensed information directly to the base station (Sink Node) without the involvement of other sensor nodes on its own. This mode of communication is very inefficient and power consuming with lots of redundant information to the BS. Thus introduced the modern protocols that rely on the multi hop mode of communication for better efficiency.
- Multi-Hop communication: While in case of Multi-hop, the sensor nodes senses the information and send it to the a head node, may be named as Cluster Head (CH), which filters the data i.e. removes the redundant data and send the aggregated data to the base station (Sink Node).Which is very efficient and power utilizing way of sensing and transmitting the data to the base station.
- Automatic Load Balancing: Automatic load balancing is dynamic in nature as the number of nodes in the network can run out of power anytime in between the network lifetime, so we can let different node to become the cluster head in different iterations. So that the load can be balanced among all the nodes in the sensor network.

2.3 Design metrics

With the advancements in technology and growth in sensor network's scope, now a days WSNs are used in enormous applications. To address these various applications some of the significant design issues a sensor network must possess are [18, 20]

- Fault tolerance: The Fault tolerance is an ability of the network to work as expected even after node failures. The wireless sensor nodes are very prone to failure or getting blocked from the network. Circumstances like lack in power, natural interruption like raining or flooding, environmental interference and physical damages can affects the sensor nodes. Thus the wireless sensor network should be tolerant to such a real-world faults scenarios and the accurate and efficient working of network should not be affected even after reduction of the sensor nodes.
- Scalability: As few hundred to the thousands number of sensor nodes may compose the sensor network, so the scalability of network is an important issue. Thus the schemes of wireless sensor nodes should be such a scalable to respond to such a certain events.

- Coverage: In WSNs, each sensor has a certain view of its environment. The view of sensors is very limited in both the cases i.e. in range and in accuracy of sensors; it only covers a limited physical area of the target environment.
- Power consumption: The most energy conservative task in the WSNs is transmission of information, proportional to the square of the distance or even four times, while in some cases when the distance between the source and target nodes is greater than a particular distance. By employing the Multi-hoping mechanism in WSNs energy consumption have been reduced.
- Data Aggregation: Since sensors may generate redundant sensed data as thousands of nodes deployed in the target limited environment, similar data packets with the same sensed information from multiple sensor nodes can be aggregated, into the compact data packets to control the number of transmissions, to achieve the energy efficient data transfer routing protocols.

2.4 Network Layer Routing Protocol

According to ISO model routing protocols are defined as network layer protocol [21]. Wireless Sensors have limited capabilities like limited energy, restricted communication bandwidth and computational ability. These are some of the significant feature of Sensor Network which makes it distinguishable from wireless ad-hoc networks and traditional wired networks. But the advancements in micro-electro-mechanical systems and very large integrated digital electronics circuits have introduced the micro-sensors. Such sensor nodes generally have limited data processing and communication capabilities. Almost every WSNs application requires the information to be sensed from multiple sensors and send to a particular sink node. So they share a very high probability that some of the sensors may sense the redundant information or same information. This redundant value increases a lot of traffic in the network as well as the number of transmission between the sensors and Base Station. Increase in traffic for redundant information causes inefficiency in the network. Therefore some data aggregation algorithms are required in protocols of WSNs. Energy constraint is the biggest challenge to create a routing protocol in WSN. Also it is non-feasible and impossible to recharge or replace the batteries of a sensor node. Thus we cannot use traditional routing protocols available to address the needs of a WSN. Now the classifications of WSNs Routing Protocol are shown below.....

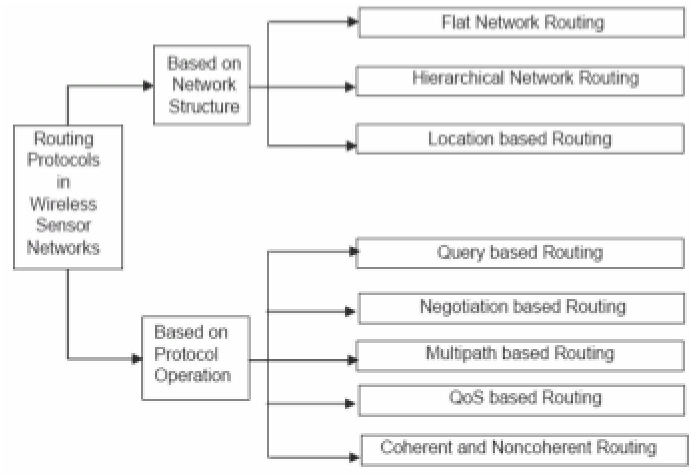

Figure 2.1: Classification of the WSNs Routing Protocols

2.4.1 Flat-based routing protocol

The first classifications of routing protocols are the multi-hop flat routing protocols. In flat-based networks, each and every node plays a similar role and sensor works altogether to accomplish the sensing tasks for the target environment. Due to the large number sensor nodes, it non-feasible to assigns a global identifiers to each sensor node. This consideration introduces a data centric routing approach in WSN, where the Base Station sends queries to sensor node located in some another regions and waits for data from that sensors. Since data is being requested as queries, so an attribute-based naming mechanism is quite necessary for the specification of the properties of requested data. Previous work on the data centric routing algorithms, e.g., SPIN [23] and directed diffusion [24] are described below.

SPIN: SPIN [23] is one of an early work done to pursue a data-centric routing mechanism. The core idea behind SPIN protocol is to name the data packets using meta-data that itself describes the particular characteristics of the data packets, which is an important feature of this routing protocol. SPIN has three types of messages, that is ADV, REQ, and DATA.

- ADV- When a node wants to send data; it advertises this message containing meta-data.
- REQ- A node has to send this message, if its will is to receive some data packets.
- DATA- Its a data message containing the data with its meta-data header.

Before a transmitting a DATA message, the sensors sends an ADV message to the neighbour nodes containing the meta-data of the DATA. If a neighbour node is interested in receiving the data, it acknowledges a REQ message for the interested DATA, and then DATA is transmitted to that neighbour node. Respectively, the neighbour iterates the same process until data is sent to the sink node. One of the significant improvements of SPIN is localization of topological changes since each sensor needs to know about only its immediate single-hop neighbours. However, there are also some disadvantages of SPIN like, First of all, it is not a scalable. Secondly, the sensors close to the sink node could disseminate their own energy if the Base Station will be busy in too many events. Lastly, data advertisement mechanism in SPIN's doesn't guarantee the data delivery. For example, if the sensors interested in the getting the data packets are very far-away from source node and the nodes between source sensor and destination sensor are not interested in getting that data, such a data packet will not be delivered further to the destination sensor at all.

Directed Diffusion [24]: It is a data-centric protocol with applications awareness which uses name schemes for the data to introduces data diffusion among the sensors. To create an information query, interests have to be defined using the list of attribute-value pairs such as interval and the name of the object. Then the interest is broadcasted by the sink via its neighbours. When the nodes receive interest from the BS they perform catching. Then the interests in the catches will be used to compare the received sensed data packet with the values in the interest received by the BS. The interests also contain gradients which contains back link to the neighbour from which the interests were received. Gradients are characterized by time stamp of the interest, data rate and duration. Hence with the help of interests and the gradient path between the node and the BS can be derived. Thus then the sink can send the original interest message through the selected pat with smaller time interval to get the data packets of interest frequently. The main objective of DD is to combine the data it receives from the various nodes using in-network data aggregation based on the list of attributes of the form attribute-value pairs. DD differs from SPIN in terms of the on demand data querying mechanism. In DD the sink will query the sensor node only if a particular data of interest is available while in SPIN it advertises the availability of data to the sensor nodes.

Some advantages of DD are that the nodes are capability of data aggregation and caching which is a great plus to save the energy of the nodes. No need to maintain global identity of the nodes and it is an on demand protocol so is highly energy efficient. However it should not be used in the situation where continuous monitoring of the data is required like environmental monitoring as it a query driven protocol.

2.4.2 Hierarchical based routing protocol

Hierarchical or cluster-based routing [25, 26, 27], originally introduced in traditional networks i.e. wired networks, these techniques are well-known with the advantages like scalable network and efficient communication. In a hierarchical based routing architecture, we can use the nodes having higher energy to process and transmitting the sensed information further while the nodes with lower energy can be used to sensing task in the target sensing environment. i.e. the clusters formation and assigning the special tasks to CH can significantly contribute to the overall scalability and lifetime of system and energy efficiency. Hierarchical based routing is an efficient way to manage the energy consumption within a cluster and by employing data aggregation mechanism, we can decrease the number of transmission to the BS. Hierarchical based routing mainly comprises of two-layer, where one layer is used to elect the CH and the other layer is used for transmitting the sensed information to the base station.

The transmission phase varies according to the protocol. It may use single hop for the communication of data packets or multiple hops can be used with any number of levels deepening on the area and density of the network. Different computational capabilities can be assigned to the sensor nodes or the CHs in the hierarchical networks like data aggregation, data compression to achieve optimality as per the needs of the applications.

2.4.3 Location based routing protocol

In this classification of routing protocol, sensor nodes are addressed based on their locations. The distance of a neighbour sensor node can be calculated based on the strength of the received signal. Exchanging such information between neighbours can gives the relative coordinates of that node. Also, we can get the location information of sensor node directly by communicating with a satellite, using Global Positioning System (GPS), if nodes have a small low powered GPS receiver [28, 29].We can enable the sensor nodes to go to sleep, if there is no activity to do, for saving the energy of the sensor node.

GAF proposed in [28] is one of the energy aware location based routing protocol which was developed for the mobile ad-hoc networks but works for sensor networks too. It aims at conservation of energy by switching off unnecessary nodes keeping the routing fidelity intact. In GAF, the sensor nodes are divided in fixed regions/zones and form a virtual grid. In each of the zones nodes synchronize and take different roles. Every node uses its GPS to locate itself and associate itself in virtual grid by using that GPS point. Nodes which are associated with the same point, the grids considered as equivalent in terms of data packet routing cost. This equivalence is used to keep some nodes in the sleeping state to save the energy.

The states defined in GAF are *discovery, active* and *sleep*. The discovery state determines the neighbours in the grid. Active state represents the participation of the node in the transmission and sleep state refers to the nodes which have their transmitter switched off to save energy. To handle the routing fidelity, sleeping time of nodes is broadcasted to the neighbours. The neighbours in the sleeping state adjust their sleeping time so that before the active nodes go to sleep, the nodes that are in the sleeping state should wake up. Although it is location based protocol, it also uses clustering as it breaks the sensor nodes into clusters/grids based on the location. In each grid there is a leader node however in GAF no data aggregation or data compression is performed.

GEAR is another location based energy aware routing protocol proposed in [29]. To route a data packet to a particular destination GEAR uses heuristic based neighbour selection and energy awareness. The main objective of GEAR is to reduce the number of interests in the diffusion by sending the interest message only to specific nodes along the path in the desired region rather than broadcasting the interest message. Each node in GEAR knows an estimation cost and learned cost. Estimated cost is based on the remaining energy of the node and the distance towards the destination. Learned cost is the more accurate version of the estimated cost which takes into account the holes in the network to reach the destinations. Hole is the situation when there is no neighbour closer to the target node in its sensing region than itself. If no holes are there in the path to the destination node the learned cost is same as the estimated cost.

GEAR works in two phases. First is forwarding data packets towards the target region and the second is to forward the data packet within the region. In the first phase, node with the data packet/interest checks if there is any sensor node which is near to the target sensing region than itself. If many node are there which are closer to the target region then the closest neighbour is selected as the next hop to reach the target region. In situation when no neighbour is close to the target region than itself, one of the neighbours is selected based on the learning cost to transmit the data/interest to the target region. In the second phase the interest has reached in the target region. The packet can be diffused in the region using restrictive flooding or recursive geographic flooding. In sparse deployment restrictive flooding is better and in densely deployed networks recursive geographic flooding performs better.

2.4.4 Operation based routing protocols

Some routing protocols incorporate with the additional computation capabilities in order to access variety of issues, we can call them as operation Based routing protocol. Some adds certain feature to an existing protocol to improve the design issues and enhance the performance of routing protocol. Some of such operation based protocols are discussed:

- Multipath routing protocols: Multipath routing protocols ensures stable network. It maintains alternate path list between the nodes and the BS. There also can be multi paths between the source node and the destination node. It purely depends on the application and trade-off between energy efficiency and fault tolerance ability on how many paths are to be stored by the protocol. The alternate paths are cross checked on regular basis and kept alive by transmission of periodic messages. It increases traffic in the network and costs energy also. Although multi path protocols increases the reliability of a network but are inefficient in terms of lifetime of the network.
- Query based: In such a protocol, destination node generates a query in the network. This query reaches the desired node or destination node or the region of interest with the help of a particular mechanism like broadcasting, communication in neighbours etc. Then the particular group of nodes, which matches the area of interest of the query sense the information and sends it back to the destination via a path which is established when the query has reached from destination to source. The queries can be sent in normal or encoded forms.
- Negotiation based: Negotiation based routing protocol reduce the redundancy of data by the usage of data advertisements which are high-level data descriptors containing meta-data. One such routing protocol SPIN we have discussed. The three stats in these protocols are used to broadcast the data only to those neighbours which are interested for that particular data. As the node receives some data ADV message is sent to all the neighbours which then checks if they need this data or not. If they need the data it sends a REQ message to the node. The node after receiving the REQ

message sends the data only those nodes which are interested and hence avoids higher network traffic. One pitfall of such protocols is that suppose a node X is interest in the data but is not in the neighbour of the node Y which has data. Then this node X may or may not receive the data depending on the neighbours of the node Y. If none of the neighbours of Y are interested in the data then X will not receive the ADV message for the data even if it is interested. The nodes in such protocols are capable of little computations like data aggregation which reduces the redundancy of the data. The usage of flooding to send the query of interest is better than broadcasting the data packet even to those nodes who are not interested in it.

- Quality of service based: These protocols are created to address the QoS of network as per the application using WSN. Some of the factors which fall under QoS can be delay in sending the data to the BS. It may be data reliability, location awareness, synchronised processing etc. These factors decide which routing protocol should be used for particular application. Energy is another factor which is kept under consideration while implementing QoS based protocols.

CHAPTER 3 RELATED PROTOCOLS

In this chapter we will discuss some of the WSNs related routing protocols which introduced clustering for efficient routing. These protocols has become more advance for intelligent and energy efficient transmission of data. Advancements in technology have led to a move towards wireless domain from the wired domain. Functionality of wireless sensor devices depends on the battery life time which is very limited. Each sensor node in WSN is an electromechanical sensing device, featured with small size, low-power and low-cost multifunctional smart sensor nodes. These sensing nodes have many applications like physical environmental conditions monitoring. Wireless Sensor Networks (WSNs [36, 37]) let us use these very large integrated small sensor device for multiple real life applications such as military application, manufacturing purpose, target geographical area monitoring, waste water monitoring purposes etc.

In WSNs, hundred to thousands of small sensor sense the interested data parameters and send data packets to base station. Used sensors in the target environment can be either a mobile or stationary, and we can deploy in their environment either using a random or with a proper deployment approach. There exists some distribution mechanism of nodes over the field for random deployment, while also exists regular mechanism for static deployment. Partial energy of sensors gets consumed in sensing activity and some more part of energy will get consumed during the transmission and reception of data packets. Practically it is not feasible to replace or recharge batteries of sensors once they deployed in the network field. This chapter presented a brief about the proposed routing protocols of our concern which are required to be understood to have a clear understanding of the proposed protocol. In LEACH [13], parameters cannot be changed at cluster selection time which can be done in SEP [14] and TSEP [9]. SEP improves the performance of WSNs but heterogeneity increases throughput which affects the efficiency of the network. TSEP is threshold sensitive protocol which reduces the transmission to increase the performance but it does not take care of critical information. Also TSEP has a drawback that if the SV of nodes is not meeting the hard and soft thresholds criteria, nodes will not transmit and BS will not get the information whether one or all nodes are alive or dead. Our proposed protocol provides a solution by taking into consideration the importance of critical information and introducing adaptive nature in all the nodes of the network to help the BS analyse and utilize the information network efficiently.

3.1 LEACH

A clustering based LEACH (Low Energy Adaptive Clustering Hierarchy) protocol, proposed in [13], where CH is always elected randomly and uniformly out of each and every sensor nodes in the network based upon some probability. Each node generates a random number ‘r’ between 0 to 1, if generated value i.e. ‘r’ is less than threshold of that cluster, calculated by formula mentioned below formula, then this one node will be the Cluster Head.

$$T = \begin{cases} \frac{p}{1-p[r.mod1/p]} & if \;\; p_{nrm} \in G \\ 0 & otherwise \end{cases} \tag{3.1}$$

Where, G is collection or set of sensor nodes which have not become the CHs in 1/P rounds and r is the current round. LEACH works in iterations, where each iterations or rounds includes the CH setup followed by the aggregation of sensed data packets and the transmission of that aggregated data packets to the Base station. The Formation of cluster is accomplished by CHs advertisement to all the other nodes in the network, which then associate themselves to nearest CH node based on the signal strength of the received advertisement. After formation of local clusters CH informs all the nodes in its cluster about when to send the information based on a TDMA schedule. Then in steady state phase, nodes switch on their sensors-circuit and transmit the sensed data to CH periodically as per the parameters assigned by CH. CH aggregates the received data and send it further to Base Station. Steady state continues for certain period of time and then network goes to setup phase again with CH selection and local cluster formation followed by steady state. Clusters are re-established in each iteration or round. The network where LEACH can be employed must be homogenous i.e. all the sensor are homogeneous and constrained in energy.

3.2 TEEN

Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN) [7]: is a hierarchical clustering based routing protocol, which groups sensors nodes into clusters where each cluster led by an Cluster Head (CH). The non-CH sensor within a cluster reports their sensed data information to their cluster’s CH. The cluster head collects the data from all the subsequent member nodes and sends aggregated data to their upper level cluster heads until the data packets reaches to the base station. Thus, the architecture of sensors network in TEEN protocol is basically based on a hierarchical grouping where nearest nodes makes a clusters and this same process repeats on to the second level until the base station is reached. A very useful application of the TEEN is where the trade-off of energy efficiency, data accuracy and response-time can be controlled by user, dynamically. TEEN works based on the data-centric method, with hierarchical approach. The suitability of TEEN protocol for applications like time-critical sensing applications is a most significant feature. Also since more energy gets consumed in transmitting data packets than data sensing, so energy utilization or consumption is better than the proactive networks. However, Sensing applications where periodic reports are needed, TEEN fails here, since the user may not be able get any sensed information at all, if the specified thresholds is not reached.

3.3 SEP

A Stable Election Protocol (SEP) [14], is a heterogeneous routing protocol, having the two different levels heterogeneity of sensor nodes using parameters like additional energy factor ‘α’ between the normal sensor and advance sensor nodes and the fraction ‘m’ of advance sensor nodes, which improves the network stability period, which is critical in many real world applications. The probabilities used by the normal nodes and advance nodes to be chosen as a cluster head will be computed by using the formulas mentioned below:

$$p_{nrm} = \frac{p}{1+m.\alpha} \qquad (3.2)$$

$$p_{adv} = \frac{p(1+\alpha)}{1+m.\alpha} \qquad (3.3)$$

Where, p represents the probability of each sensor node to be chosen as cluster head. Cluster election in SEP is done randomly using weighted probabilities of the normal nodes and advanced nodes similar to [10]. After clusters are formed all the members of the cluster send data to CH which then processes the data and sends only the required data to the BS after processing the data. SEP performs better in some aspects like lifetime and stability period of network, when compared to family of LEACH protocols and uses the heterogeneity efficiently. However SEP is not suited for time critical applications because of its periodic nature.

3.4 TSEP [9]

This protocol has two parts:

• It is reactive routing protocol:

– Transmission consumes more energy than sensing.

– will be accomplished only when a specified threshold is reached.

• Three levels of heterogeneity.

1. Normal Nodes
2. Intermediate Nodes
3. Advance Nodes

Energy for Normal nodes = E_o (3.4)

Energy for Intermediate nodes = E_{int} = E_o(1+μ), (3.5)

Energy for Advance nodes = E_{ADV} = E_o(1+α) (3.6)

The optimal probability of nodes:

$$p_{nrm} = \frac{p_{opt}}{1+m.\alpha+b.\mu} \quad (3.7)$$

$$p_{int} = \frac{p_{opt}.(1+\mu)}{1+m.\alpha+b.\mu} \quad (3.8)$$

$$p_{adv} = \frac{p_{opt}.(1+\alpha)}{1+m.\alpha+b.\mu} \quad (3.9)$$

For calculation of threshold depending on their probabilities:

$$T_{nrm} = \begin{cases} \frac{p_{nrm}}{1-p_{nrm}[r.mod1/p_{nrm}]} & if \;\; p_{nrm} \in G' \\ 0 & otherwise \end{cases} \quad (3.10)$$

$$T_{int} = \begin{cases} \frac{p_{int}}{1-p_{int}[r.mod1/p_{int}]} & if \;\; p_{int} \in G'' \\ 0 & otherwise \end{cases} \quad (3.11)$$

$$T_{adv} = \begin{cases} \frac{p_{adv}}{1-p_{adv}[r.mod1/p_{adv}]} & if \;\; p_{adv} \in G''' \\ 0 & otherwise \end{cases} \quad (3.12)$$

Where G', G'', G''' are the sets of normal, intermediate and advance nodes respectively. In TSEP, at the moment of re-formation of clusters, the cluster head broadcasts the following parameters-

• Report Time (TR)

• Attributes (A)

• Hard Threshold (HT)

• Soft Threshold (ST)

Energy Analysis of TSEP:

Total Energy of Normal Nodes, Intermediate Nodes, Advance Nodes are:

$E_0(1 - m - b.n)$, $E_0.n.b(1 + \mu)$ and $m.n.E_0(1 + \alpha)$. (3.13)

Total Energy will be $n.E_0(1 + m.\alpha + b.\mu)$. (3.14)

Energy Dissipation:

Energy Dissipation of Cluster is $E_{cluster} = E_{CH} + E_{nonCH}$ (3.15)

Where $\mathrm{E_{CH}} = \mathrm{L.E_{elec}}\left(\frac{\mathrm{n}}{\mathrm{k}} - 1\right) + \mathrm{L.}\frac{\mathrm{E_{DA}n}}{\mathrm{k}} + \mathrm{L.E_{elec}} + \mathrm{L.}\epsilon_{\mathrm{fs}}.\mathrm{d_{toBS}^2}$ (3.16)

$$E_{nonCH} = L.E_{elec} + L.\epsilon_{fs}.d_{toCH}^2 \quad (3.17)$$

Where ϵ_{fs} depends on the transmitter amplifier model.

Where d_{toCH} is the distance a cluster member from its Cluster head. Assuming all the nodes been distributed uniformly, it is mentioned as

$$E[d_{toCH}^2] = \iint (x^2 + y^2)\rho(x, y)dxdy = \frac{M^2}{2.\pi.k} \quad (3.18)$$

Where ρ(x, y) is node Distribution.

CHAPTER 4 PROPOSED WORK

This chapter gives us overview of our proposed work along with the details of the new features introduced. Our work's description is divided in two parts, part one is Heterogeneous Adaptive Threshold Sensitive Election Protocol. This protocol is developed as an improvement to make heterogeneous threshold sensitive protocol usable to more applications with the introduced new features. Our algorithm introduces some significant features to threshold sensitive election protocols which keeps the network aware of the communication infrastructure to analyze and utilize the network with great ease and control.

In the second part of our work, we represent the greedy efficient hops communication mechanism for efficient transmission of data packets from CHs to higher levels in hierarchy or BS. It considers the remaining energy of the nodes in the cluster as a parameter to take decision on transmission of the information. It results in better network life as it introduces residual energy concept in the probability based clustering protocols, which increases the balance in the load distribution. We also explain the system model used and assumptions for a better understanding of the work done. In later sections we analyze the performance of our proposed protocol i.e. Energy Efficient TSEP with conventional TSEP protocol.

4.1 System Model

Here we will describe the network model and energy model used in our proposed algorithm. Network model describes the networking environment operations with appropriate characteristics and capabilities of sensor nodes used in the network. While the energy model represents the energy usage of sensor node when used for various responsibilities like sensing the environment for required information, transmitting the sensed information to another node or Base Station, Receiving the information from any another node in the wireless sensor network.

4.1.1 Network model

In our proposed protocol, the network comprises of N sensor nodes and one static BS for which the network model is operational. Nodes Deployment mechanism is purely random in Z x Z area with BS located in the centre. The sensor node continuously senses the target environment and transmits only the required information, after the occurrence of any desired or predefined event to control the transmission rounds, decided by thresholds parameter. The BS has the responsibility to receive the data packets from the network and perform analysis of data packets received to present the end-user with the desired reports of the network environment. The network is heterogeneous i.e. energy of all the nodes is not same. There are three levels of energy for the nodes i.e. sensor nodes are discriminated at three levels of energy. The energy of the nodes is non-replaceable and very limited, cannot be charge even. Capabilities in regards to sensing, communication and processing of data packets are same for all the nodes in the network. The transmission range of each and every node is variable and dependent on the remaining energy of the nodes. After the random deployment of the nodes, they are immobile i.e. static, cannot be moved. The BS is fixed at the centre of the network Z x Z area and has no energy constraint i.e. Base Station has unlimited power source. As most of the WSN routing protocols the nodes are left unattended after the deployment in the network area. Above described is the network model which we have taken into consideration for the development of the proposed wireless routing protocol.

4.1.2 Energy Model

To evaluate or analyse the energy dissipation of the network, we have used the first order radio energy dissipation model introduced in [3]. It has three main components; the power amplifier, the transmitter (Transmit electronic) and the receiver (Receive electronic). The transmitter uses the energy in order to run the transmitter circuitry to transmit the data packets to any other node, power amplifier in transmitting the data packets and the receiver module uses energy to run the receiver circuitry to receive the data packets. The free space and two-ray ground propagation models [3, 35] are considered. Free space propagation model says that there is a direct communication between the transmitter and receiver based on line-of-sight path. In two-ray ground propagation model there is no direct communication path between the transmitter and receiver based on line-of-sight, thus the data packet will arrive at the receiver via different paths at different times. The propagation loss in transmitting power in Free Space Propagation Model is modelled as inversely proportional to the square distance between transmitter and receiver whereas the propagation loss in transmitting power in Two-Ray Propagation Model is modelled as inversely proportional to the distance between transmitter and receiver powered to four.

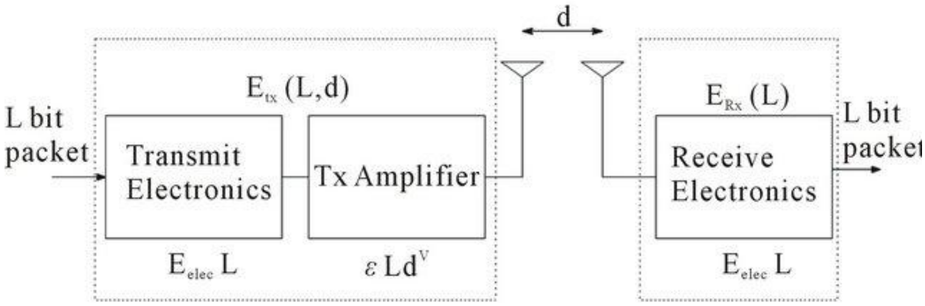

Figure 4.1: Energy Dissipation Radio Model

Power amplifier can be used for the amplification of the transmitting power for compensating the propagation loss during the transmission. Energy consumed by the radio sensor for transmission of k bit information to a node at distance d with acceptable signal to noise ratio (SNR) is given by$E_{Tx}(l,d) = \begin{cases} L.E_{elec} + L.\epsilon_{fs}.d^2 & if\ d < d_0 \\ L.E_{elec} + L.\epsilon_{amp}.d^4 & if\ d \geq d_0 \end{cases}$ (4.1)

Where E_{elec} represents per bit dissipated energy to turn on the transmitter circuit or the receiver circuit, ϵ_{fs} is the amplifier parameter of the free space propagation model and ϵ_{amp} is the amplifier parameter of two-ray propagation model basically value of ϵ_{amp} and ϵ_{fs} depends on the used model of amplifier, and d represents the distance of the sender from the receiver. E_{TX} is the energy expense in the source node transmission, Optimal cross-over distance d_0 can be obtained as

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{amp}}} \quad (4.2)$$

If the distance between the source and the target node is greater than d_0 then Two-Ray Propagation Model is applied and if the distance is less than d_0 then the Free space propagation model is implied to calculate the energy dissipation. To receive a k bit information energy expended by the node is given by

$$E_{RX}\ (k) = E_{elec}\ *k \quad (4.3)$$

4.2 Proposed Protocol –EEHTSEP

We have proved through simulation that, our Energy Efficient Heterogeneous Threshold sensitive routing protocols for time critical applications gives better result in terms network life time or efficiency, when compared to periodic clustering routing protocols. But applicability of these routing protocols is restricted because of certain limitations of such protocols like computation capabilities, limited battery. We have dedicated our work for finding the limitations of TSEP protocols and addressing a possible solution for the respective problems. In this section, we describe our new Energy Efficient Heterogeneous TSEP i.e. EEHTSEP, which dynamically keeps the BS aware of the status of the network in case if there is no transmission for long time due to reactive nature of the network.

4.2.1 Problem Statement

We have focused our work on the reactive protocols for clustered hierarchical network. The network model followed is as explained. Thus problem we addressed from our work is

Development of an energy efficient heterogeneous threshold sensitive protocol for wireless networks which can prioritize the Cluster Head selection based on the Residual energy of sensor node and keep the BS updated about the communication infrastructure of the network even in the situations of idle periods with provision to monitor the parameters dynamically.

The solution to the problem is our proposed protocol EEHTSEP which addresses the drawbacks of the traditional threshold sensitive protocols (TSEP) keeping the energy constraints and other parameters constant.

4.2.2 Proposed solution-EEHTSEP

EEHTSEP stands for Energy Efficient Heterogeneous Threshold Sensitive Protocol. To propose an energy efficient routing algorithm, which reduces the energy consumption inside the network, by selecting the sensor node having higher residual energy from the Base Station (BS) as Cluster Head (CH) nodes to extends the Network Life Time. It also includes concept hard threshold and soft threshold to reduce the loss of energy during the transmission to CH by sensor node. Energy for Normal nodes = E_o

Energy for Intermediate nodes = E_{int} = E_o(1+μ) (4.4)

Energy for Advance nodes = E_{ADV} = E_o(1+α) (4.5)

The optimal probability of nodes:

$$p_{nrm} = \frac{E_o}{1+m.\alpha+b.\mu} \quad (4.6)$$

$$p_{int} = \frac{E_o.(1+\mu)}{1+m.\alpha+b.\mu} \quad (4.7)$$

$$p_{adv} = \frac{E_o.(1+\alpha)}{1+m.\alpha+b.\mu} \quad (4.8)$$

For calculation of threshold depending on their actual Energy instead of probabilities:

$$T_{nrm} = \begin{cases} \frac{p_{nrm}}{1-p_{nrm}[r.mod1/p_{nrm}]} * \frac{RE_{nrm}}{E_{AVG}} & if \;\; p_{nrm} \epsilon \, G' \\ 0 & otherwise \end{cases} \quad (4.9)$$

$$T_{int} = \begin{cases} \frac{p_{int}}{1-p_{nrm}[r.mod1/p_{nrm}]} * \frac{RE_{int}}{E_{AVG}} & if \;\; p_{int} \epsilon \, G'' \\ 0 & otherwise \end{cases} \quad (4.10)$$

$$T_{adv} = \begin{cases} \frac{p_{adv}}{1-p_{adv}[r.mod1/p_{adv}]} * \frac{RE_{adv}}{E_{AVG}} & if \;\; p_{adv} \epsilon \, G''' \\ 0 & otherwise \end{cases} \quad (4.11)$$

Where RE_{nrm} , RE_{int} , RE_{adv} are the residual energy of normal,intermediate and advance node respectively and E_{AVG} is the Average Energy of the all the nodes in WSN. Because here p_{nrm} , p_{int} , p_{adv} depends on the actual Residual energy of the node instead of the previously used Probabilistic constant value. Where G', G'', G''' are the set of normal nodes, intermediate and advance nodes respectively. In TSEP, at the time of cluster change, the Cluster Head (CH) broad-casts same parameters as TSEP does. Thus, we are trying to remove the Probabilistic Behaviour of the TSEP. At the start of each round, the phenomenon of cluster change takes place and CH broadcasts the following parameters:

•**Report Time (TR):** Time duration during which generated reports are being sent by each sensor node successively.

•**Attributes (A):** The physical parameters set about which information is being sent.

•**Hard Threshold (HT):** An absolute upper bound sensed value beyond which node will transmits data to Cluster head. As if sensed value becomes equal or greater over the threshold value, then only nodes turns on its transmitter to sends the information to Cluster Head.

•**Soft Threshold (ST):** Sensed smallest value at which, sensor nodes switch on their transmitters and transmits the data.

All sensor nodes in WSN keep sensing the application environment continuously. As parameters out of attribute set reaches to hard threshold, transmitter will be turned on and data will be transmitted to Cluster Head, however this is for the first iteration when this condition becomes true. This sensed value will be stored in an internal local sense variable, called its Sensed Value (SV). Then for second time onward, sensor nodes will transmits the data if sensed value is greater over the hard threshold value (TH) or if difference between currently sensed value and the previous value stored in SV is equal to or greater over soft threshold. So, by considering these both thresholds, number of data transmissions rounds can be controlled to save or control the energy of sensor node, as transmission will done only when sensed value reaches hard threshold (HT). While, the further ahead transmissions will be lessened by soft threshold value, as it will reduce transmissions rounds when there is a very small changes in values, even smaller than interests. Some of significant features along with the features of TSEP are described below:

1) Selection of Node to become CH purely depend upon the Residual Energy of sensor node using the equation (4.9), (4.10) and (4.11).

2) Nodes sense the environment continuously but transmission is not done frequently.

3) The users can change the attributes as per requirements, as attributes set always broadcasted at the time of cluster change.

4) Its now a lesser probabilistic algorithm, as works based on the Energy of nodes instead of probabilities.

5) Still the main business of this scheme is that, if specified threshold is not reached, user will never be able to get any kind of information, even if one or all of sensor nodes dies, network system will never be able to get that. So, it will not be useful for the applications where a data is required continuously.

Calculation of Residual Energy of Node:

$$\text{Residual } E_{CH} = E_{CH} - L.E_{elec}\left(\frac{n}{k} - 1\right) + L.\frac{E_{DA}n}{k} + L.E_{elec} + L.\epsilon_{fs}.d_{toBS}^2 \tag{4.12}$$

$$\text{Residual } E_{nonCH} = E_{nonCH} - L.E_{elec} + L.\epsilon_{fs}.d_{toCH}^2 \tag{4.13}$$

4.2.2.1 Heterogeneity levels

EEHTSEP uses three levels of heterogeneity i.e. advanced, intermediate and normal nodes based on initial energy of the sensor nodes. The energy of advanced nodes is highest among all the sensor nodes. Normal nodes have lowest energy among all the sensor nodes. Energy of intermediate nodes is between the normal sensor nodes and the advanced sensor nodes. Energy of the intermediate nodes in the network can be calculated as shown in equation (4.4). Energy of normal nodes is represented by E_0. Initial energy of the advanced nodes is shown in equation (4.5), for EEHTSEP we take.

We suppose that there are *n* numbers of nodes in the network. Thus the total energy of the network can be quantified as shown in equation (3.14). Where *b* is the fraction of total number of nodes which are intermediate nodes and *m* represents the fractional part of the total number of sensor nodes *n* which are advanced nodes.

Different energies of the nodes play a major role in load balancing in the network. Even though probabilistic algorithm is used for the cluster head but selection in heterogeneous networks is biased for high energy nodes. This biased feature is increasing the probability of a higher energy node, even we have focused on enabling the threshold value to be depends on their residual energies, to make the cluster head selection purely depends on the residual energy. If a high energy node is selected as CH quite often it helps in balancing the load on the network and increasing the performance. We can control the fraction part of advanced nodes and intermediate nodes as per the requirement of the application for which the routing protocol is to be used. Usage of heterogeneous nodes increases a little complexity but adds great increase in the flexibility and efficiency of the routing protocol.

4.2.2.2 Cluster head selection algorithm

In EEHTSEP, nodes are organized into local clusters set. In every cluster, there is one CH and its associated members which are sensor nodes nearest to the respective CH. All the non-cluster nodes transmit the no-priority data to the CH using single TDMA hop of communication when there is occurrence of any desired event. CH will receive the data packets from its cluster member node and then perform data aggregation and process the data for further transmission. After the data is processed, it sends the optimized data to the BS. Thus CH has very high responsibility and should have much enough energy to expend, to play the CH role. Thus responsibility of becoming CH has to be rotated between the preferable candidates of the task based on the high residual energy. In WSNs with very limited energy constraint nodes, CH has to be selected efficiently.

In our EEHTSEP, we select the CH based on the weighted election probabilities of the nodes, which basically depends on the residual energy and the threshold energy. In our proposed network election probabilities are different based on the three different levels of heterogeneity in the network. The probabilities of election of the CH for normal nodes, intermediate nodes and advanced nodes can be calculated as given in equation (4.6), (4.7) and (4.8). CH selection is done based on the thresholds. Each node generates a random value between 0 and 1 and if this value is less than its particular threshold then the node can become the CH. Calculation of thresholds based on the probabilities of the nodes and can be obtained as shown in equation (4.9), (4.10) and (4.11).

Where G' is the group of normal nodes which have not become CH in last $1/p_{nrm}$ rounds, G'' is the group of intermediate nodes that were not the CH in last $1/p_{int}$ rounds and G''' are the group of advanced nodes that were not the CH in last $1/p_{adv}$ rounds. As compared to normal nodes there is high probability of intermediate sensor nodes to become CH while the probability of advance sensor nodes is higher than that of intermediate sensor nodes which shows that the advanced nodes are more likely to become cluster heads when compared to intermediate sensor and normal sensor nodes.

4.2.2.3 Cluster Formation scheme

After the CH selection, clusters are formed. Those nodes which are not CHs i.e. member nodes are called as ordinary nodes. In EEHTSEP, the newly elected CH sends an invitation or acknowledgement to the ordinary nodes to join their cluster as their cluster members. All the ordinary nodes decide their CH based on the received signal strength from the CHs. Higher the received signal strength closer the CH is from that sensor node. Thus ordinary nodes associate themselves with the CH which is closest to them and hence the cluster is formed. After the clusters are formed in EEHTSEP, the elected CHs first broadcast the following parameters.

Attributes (A): The physical parameters set, about which information is being sent.

Hard Threshold (HT): It is an absolute value which triggers the transmission of the nodes. If the SV of the cluster node is equal to or greater than hard threshold, it will switch on the transmitter circuit and will send the sensed information to the associated CH.

Soft Threshold (ST): It is the small component of the thresholds which also triggers a nodes transmission. If difference between SV and current value is equal to or greater then soft threshold the node will switch on its transmitter circuit and transmit the interested information to the Cluster Head.

These parameters can be monitored after every cluster head selection. Changing the values of these parameters helps in controlling the trade-off between energy efficiency and requirements of the applications. Introduction of this dynamic change in the values of the parameter can assist the BS to have a greater control on how often it needs to know about the network structure to perform necessary operation.

To handle the changing requirements of the network or the end user the parameters broadcasted are changed which can further affect the efficiency of the protocol. With the introduction our residual energy dependency concept, we make it possible to each and every node to become the CH purely or up to the maximum extent, based on the residual energy, Our proposed protocol can be used in more vivid applications than in other reactive protocols. The time critical application where it not necessary that network will transmit the data packets after certain rounds can now use EEHTSEP which gives the flexibility to the user about how often BS will need the information even if the nodes are idle. We have demonstrated the applicability of EEHTSEP for environment sensing application, where we have considered the life time and dead or alive nodes rate in the network, with emphasis on newly added features. The performance is observed good and addressed our objectives as expected. Thus EEHTSEP serves as increasing the scope of the reactive network with heterogeneous sensor nodes. After these parameters are successfully broadcasted by all the CHs to their respective sensors transmission phase of the network begins.

4.2.2.4 Features

Some features of EEHTSEP are described below as:

CH selection is purely based on the energy of the sensor node, which was the only disadvantage of the TSEP [9] and BS is always aware of the network structure and status of the nodes in the network dynamically.

The performance of EEHTSEP in terms of Dead and ALIVE sensor node rate, is better than LEACH [13], SEP [14], TSEP [9] and TEEN [7] protocols.

CHAPTER 5 SIMULATION RESULTS & ANALYSIS

An efficient and flexible tool for the performance evaluation of working ability of any protocol under the various environmental conditions is its simulation. In this chapter, EEHTSEP technique proposed in chapter 4 is being evaluated on a simulation tool. We have used the METLAB as the simulation tool for our Performance evaluation. The performance of our protocol is compared with other conventional protocols in terms of lifetime, throughput and energy efficiency, which are basically the significant aspects of implementation. The base protocol of our proposed EEHTSEP technique is TSEP routing protocol and then we have compared our proposed routing protocol with the base protocol TSEP, comparison is made on the performance of routing protocol with and without the proposed technique in terms of network life-time, energy efficiency and throughput.

5.1 Simulation Environment Setup

We have used the MATLAB simulation tool for evaluation of EEHTSEP technique. Our aim with this implementation demonstration is to compare TSEP with our EEHTSEP protocol in respect to energy and network lifetime.

We are deploying 100 sensor nodes in the network. All the 100 nodes are deployed randomly in the network field. While the network is of 100*100 fields dimension. The location of Base Station is at the centre of the simulation network field. The field has a varying temperature in different regions. The temperature range is [50^0, 200^0] with optimal values of the broadcasting parameters. We have used the First order radio model as the energy model in our simulation demonstration as described in the previous sections. We have considered the number of rounds as 10000, for our simulation. We have assumed the Length of the data packet to be 4000 bits for every evaluated protocol with capability of perfect data fusion by the CHs. Every protocol is made to run for 10000 rounds to get a better idea of the performance metrics. The values of the parameters, we used in our simulation are listed in the table 5.1, shown below...

Parameters	Value
E_{elec}	50nJ/bit
E_{DA}	5nJ/bit/message
ϵ_{fs}	10pJ/bit/m^2
ϵ_{amp}	0.0013pJ/bit/ m^4
E_0	0.5J
N	100
p_{opt}	0.1
a	1
m	0.1

Table 5.1: Parameter Setting

5.2 Performance Evaluation-EEHTSEP

Here we presents the simulation demonstration of EEHTSEP into MATLAB environment and compare with three conventional routing protocols LEACH [13], SEP [14] and TSEP [9]. We have also prepared the simulation environment for the purpose of comparison with most of conventional clustering based protocol. LEACH is clustering based homogeneous hierarchical protocol with rotation of cluster formations process. Selection of CH is probability based with optimal number of CHs fixed for the network. SEP is heterogeneous WSN protocol with two level of heterogeneity. CH selection in SEP is also probability based with different election probabilities as per the levels of heterogeneity. TSEP is another clustering protocol which is a threshold sensitive protocol with three levels of heterogeneity with normal, intermediate and advanced nodes. It is a reactive protocol in which transmission is triggered based on drastic changes in the environment and is monitored by the hard and soft thresholds. The objective of our proposed protocol is to prolong the network life time and make the Threshold sensitive protocol more efficient by improving the cluster head selection process, We compare the performance of EEHTSEP with all the above mentioned protocols.

5.2.1 Performance metrics

Performance metrics we used for analysis of the protocols are

- *Alive Nodes:* No. of alive nodes per round.

- *Dead Nodes:* No. of dead nodes per round.
- *Throughput:* No. of packets sent to BS from CH.
- *Network Lifetime:* It is the time till the last node of the network is not dead.

5.2.2 Simulation results

In this section we present simulation results of EEHTSEP with the performance metrics in consideration compared to LEACH, SEP and TSEP in similar simulating environment of 100 nodes in 100*100 network area for 10000 rounds.

The Described below Figures represents the execution results of the simulation in the MATLAB, the first Figure 5.1 represents the uniform and random deploymeny of the nodes in the network area.

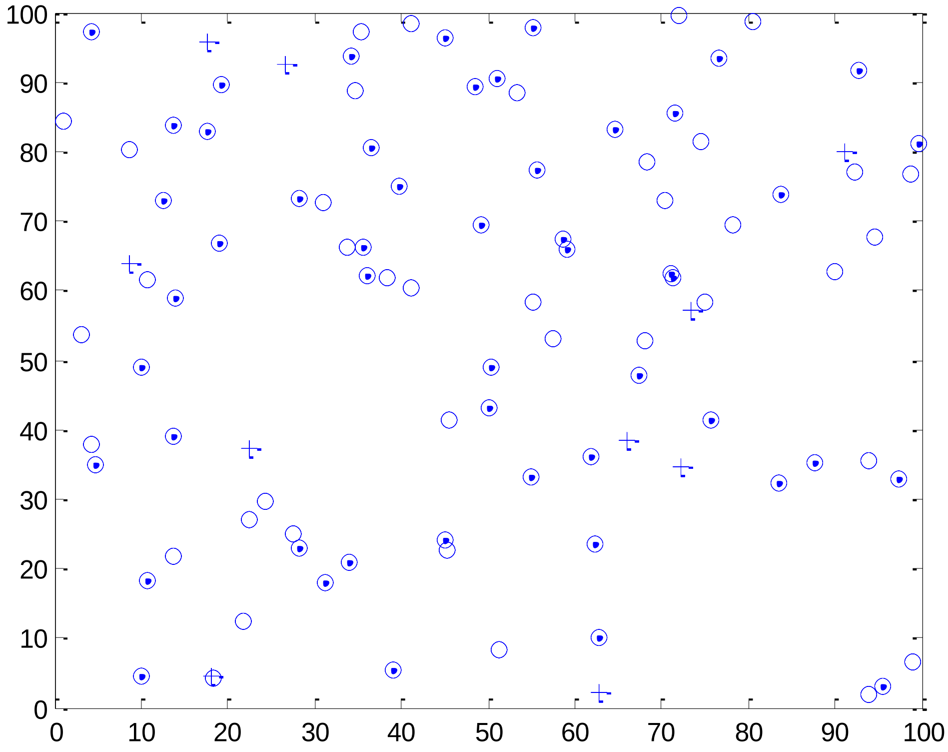

Figure 5.1: Random deployment of the sensor node in the network field.

And now the Figure shown below represents the Alive node and Dead node rate in the considered network field and the

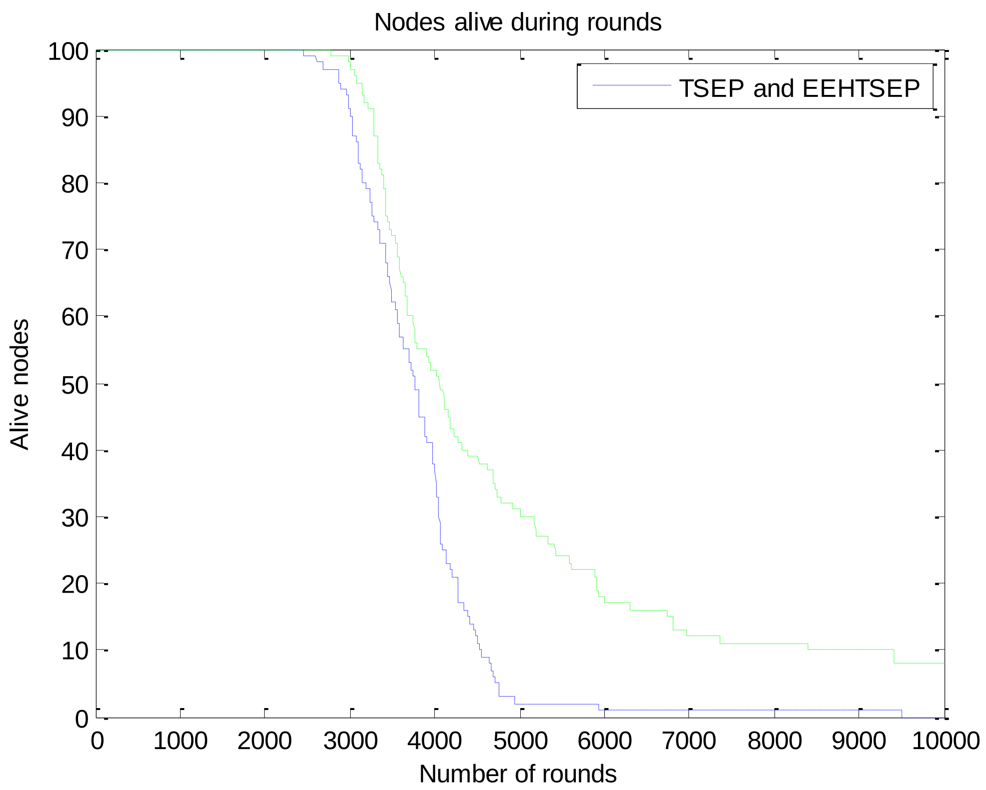

Figure 5.2: Alive nodes rate

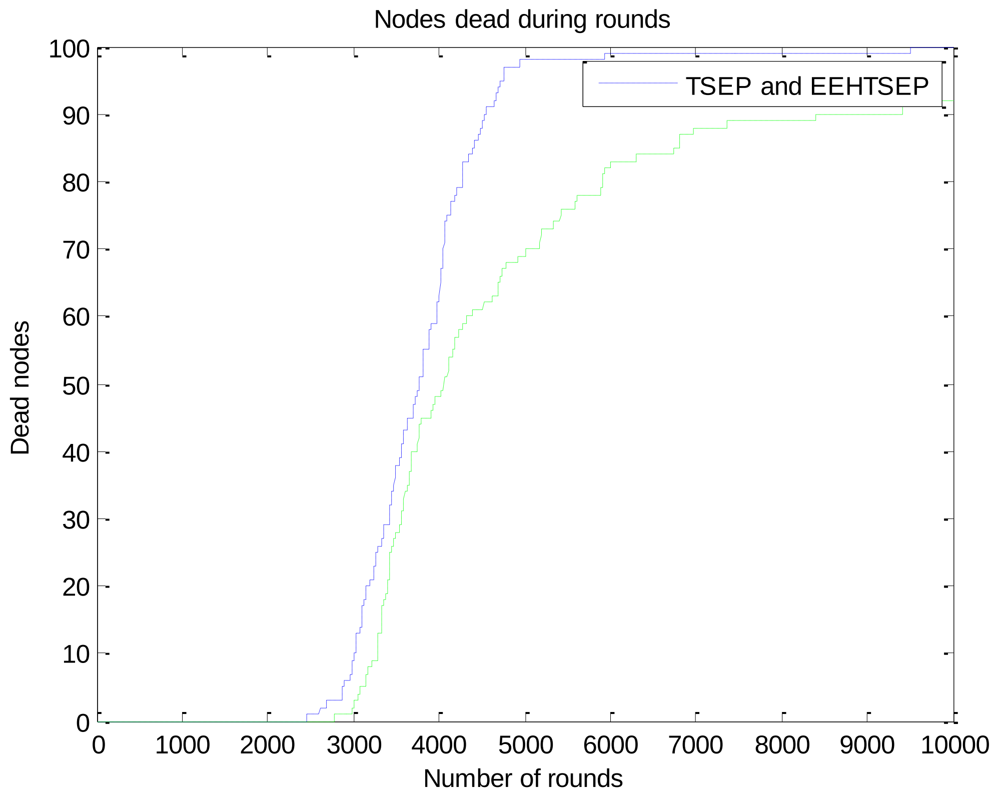

Figure 5.3: Dead nodes rate.

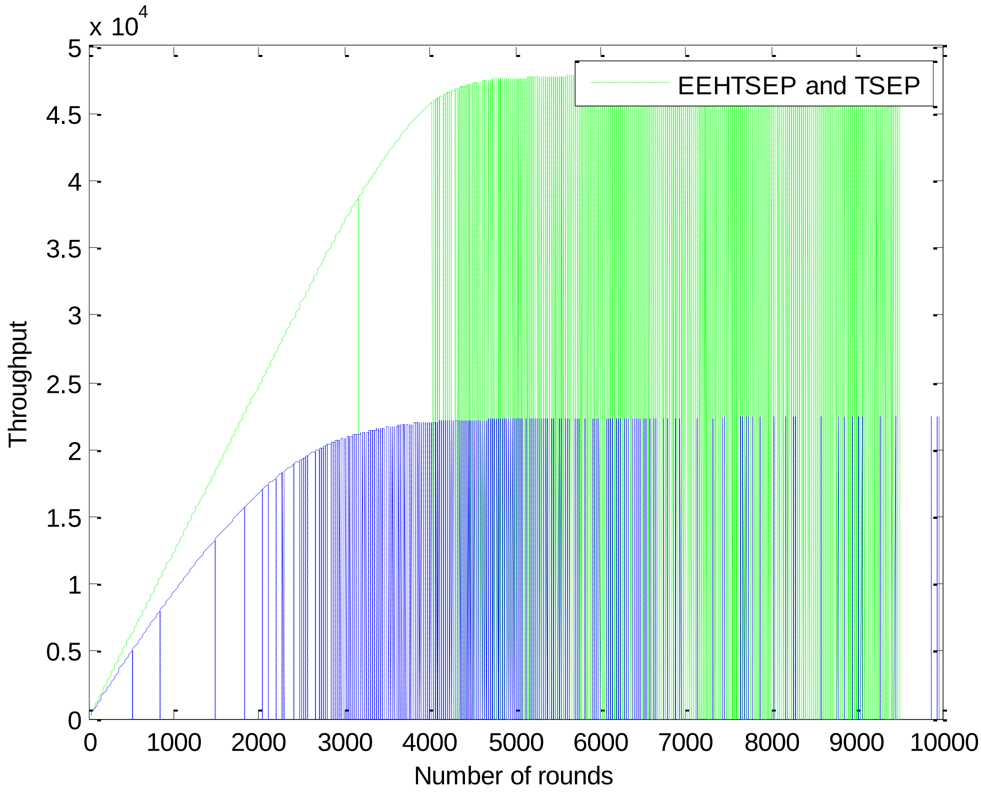

Figure 5.4: No. of packets sent to the BS.

We have demonstrated the implementation of EEHTSEP Protocol. By analysing simulation results, we can conclude that our proposed protocol works better than the TSEP, in terms of Alive node rate, Dead node, Throughput of the system.

5.2.3 Analysis

In Figure 5.1, we have represented the uniform and random deployment of the sensor nodes in the defined network area. We have defined the static number of clusters in our heterogeneous network and number and type of nodes in each of the clusters in the defined simulation network field. And the figure represents the network architecture in the starting of the network simulation.

In Figure 5.2, we have represented the number of alive nodes per round in the sensor network, which is better in our proposed protocol than the TSEP, this could be easily analysed in the given graph. Our proposed protocol gives us the better network lifetime as well as the rate of alive nodes in every round in the simulation.

In Figure 5.3, we have shown a graph which represents the number of dead nodes per round in the network simulation environment. And this can be analysed that our proposed EEHTSEP gives us the better network lifetime and the network dead ratio in every round in the simulation. Where the x-axis represents the number of rounds in the simulation and y-axis represents the dead node rate in the every round.

In Figure 5.4, we have represented the throughput of the network system in both the cases, while in our case i.e. in EEHTSEP we got the better throughput than the already introduced TSEP.

CHAPTER 6 CONCLUSION AND FUTURE WORK

We dedicated out work to the cause of finding better solutions for the known problems in the threshold sensitive routing protocols in WSNs. In the course of our study we dissected the problems and investigated their genesis based on which we proposed a novel technique named EEHTSEP for tackling the problem of maximizing the network lifetime of a sensor network. The proposed algorithm, EEHTSEP is a threshold sensitive routing protocol which elects the node with highest residual energy as the CH, for this we introduced an additional parameter in the CH election procedure of TSEP as described in section 4.2.

The results of the simulations substantiate our claims on the efficiency of our proposed algorithm (EEHTSEP) when gauged in terms of the residual energy of the nodes in the sensor network and stability period of the network. The EEHTSEP is seen to outperform its contemporary algorithms namely TSEP , which can be attributed to the changes that were suggested by us , hence we can undoubtedly conclude that our proposed algorithm can cater to a wider range of real time applications and is successful in achieving the objectives of our study.

Though our work is able to achieve the predetermined objectives of our study, the room for improvements and further enhancements is still wide open. A possible augmentation to our work can be introduction of encryption schemes in the data transmission phase of EEHTSEP to secure the data on route to the destination from known security breaches that compromise the integrity and confidentiality of the message.

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