Energy Efficient Routing Protocols for Wireless Sensor Network

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

Master of Engineering

in

Information Security

Submitted By

Mandeep Singh Bandral

(Roll No. 801233008)

Under the supervision of

Dr. Sushma Jain

Assistant Professor

COMPUTER SCIENCE AND ENGINEERING DEPARTMENT

THAPAR UNIVERSITY

PATIALA 147004

June 2014

Certificate

I hereby certify that the work which is being presented in the thesis entitled, *Energy Efficient Protocols for Wireless Sensor Network*, in partial fulfillment of the requirements for the award of degree of Master of Engineering in Information Security submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Sushma Jain* and refers other researchers work which are duly listed in the reference section. The matter presented in this Thesis has not been submitted for award of any other degree of this or any other University.

Mandeep Singh Bandral
801233008
ME(IS)

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

Dr. Sushma Jain
Assiatant Professor
CSED,Thapar University

Countersigned by

(Dr. Deepak Garg)
Head Computer Science and Engg. Dept.
Thapar University
Patiala

(Dr. S. K. Mohapatra)
Dean, Academic Affairs
Thapar University
Patiala

Acknowledgement

I am very thankful to my guide, Dr. Sushma Jain, Assistant Professor, Computer Science and Engineering Department, Thapar University, patiala who has been very concerned and has aided the material essential for the completion of this thesis work. She has helped me to explore vast topic in an organized manner and me to work towards a research-oriented venture.

I would also like to thank Dr. Deepak Garg Head of Computer Science and Engineering Department and Dr. Jhilik Bhatacharya PG coordinator to help me in my thesis completion.

I would also like to thank the staff members and my colleagues who were always there in the need of the hour and provided with all the help and facilities,for the completion of my thesis.

Most importantly, I would like to thank my parents and the Almighty for showing me the right direction out of the blue, to help me stay calm in the oddest of the times and keep moving even at times when there was no hope.

Mandeep Singh Bandral

801233008

ME(IS)

Abstract

Wireless sensor network consists of large number of sensor nodes and a sink which is regarded as Base station. Sensor nodes work on batteries which are difficult to recharge in harsh environments. Thus, each sensor node has limited energy and memory. If all sensor nodes send an aggregated data to the sink separately then energy of nodes reduce very fast. In this report, different methods are proposed to increase the life time of network. Sensor nodes are deployed randomly and uniformly by making clusters whereas Sink node is located at fixed location(25,150) in case of tier based energy efficient protocol. In uniform and random deployment, sensor nodes are divided into three different areas based on the distance from sink, commonly known as tires. Homogeneous energy is given to each node and minimum spanning tree is generated. After that a head node is chosen from each tier based on the maximum energy that can send sensed, aggregated data to the sink.In multipath routing algorithm multiple shorest path is selected by the greedy approach and by use the concept of fuzzy logic the more efficient and reliable path is consider for sending the data to the base station.The result shows that the MPRA is three times better than the single path routing algorithm. Because of energy being a scarce resource simulation results focus on energy comparing between the routing methods. The simulations are implemented in Python language.

Abbreviations

Abbreviations	Details
ACK	Acknowledgment
ADC	Analog to Digital Converter
DARPA	Defense Advanced Research Project Agency
ED	Energy Detection
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
LR-WPAN	Low Rate Wireless Personal Area Network
MANETs	Mobile Ad hoc networks
PHY	Physical
SNR	Signal-to-Noise Ratio
WPAN	Wireless Personal Area Network
WSN	Wireless Senor Network
BS	Base Station
SPRA	Single path routing Algorithm
MPRA	Multi path routing Algorithm
TBEEP	Tier based energy efficient protocol
QoS	Quality of Service

Table of Contents

List of Figures

List of Tables

Chapter 1
Introduction

1.1 Introduction

Wireless sensor network is a combination of many small sensor nodes also called motes with each mote having a capability of sensing and forwarding the data to the other motes (devices) using radio frequency. Each sensor node monitors the network and sends the collected data to the sink (Base station). Sensor node sends processed information to the sink either by direct transmission or by using the multi-hop transmission. In multi-hop routing each sensor node sends the fused and aggregated data by other sensor nodes to the base station. The range of these sensor nodes is very small and therefore can not send data to the base station directly. Most of the time sensor nodes are placed in an inacessible area where it is not possible to provide some power supply to these sensor nodes. The most common sensor node is zigbee (IEEE802.15.4) standard, it works in both mesh topology and point to point technology. Zigbee operates on full function device mode and reduce function device mode. Power is the most critical issue in sensor nodes. Sensor-MAC protocol is used for saving the energy of sensor nodes by sending start and stop becan packets which help to change the state of sensor node from active to sleep and vice-versa. Routing in sensor network from source to sink node is done at network layer. The routing protocol provides an efficient solution by using clustering technique.

1.1.1 Components of Wireless Sensor Network

Wireless sensor network is combination of sensor nodes and a base station. Base stations have unlimited resoures where as sensor nodes are deployed in a particular sensing field and have limited resources. The major components of wireless sensor network are shown in figure 1.1:

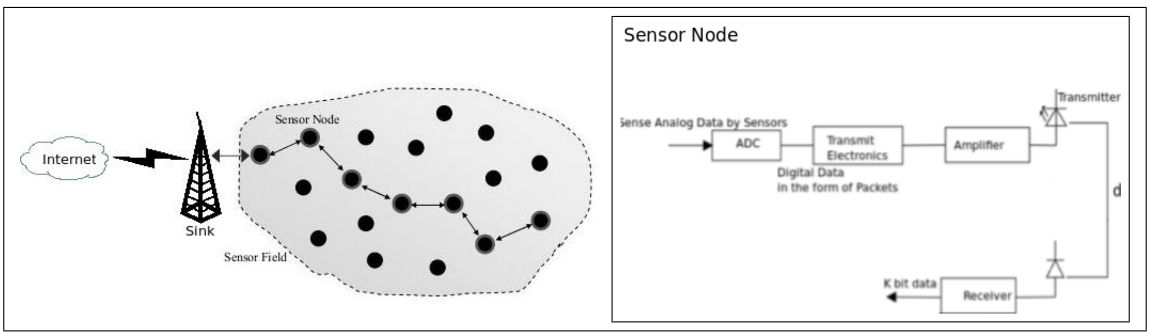

Figure 1.1: Components of WSNs

- **Sensor nodes:** Sensor nodes are the brain of the WSNs which are used to detect any event that occurs in a particular sensing field. Sensor nodes have a responsibility to collect data and perform routing.
- **Sensing Field:** Sensing field is an area in which sensor nodes are deployed.
- **Analog To Digital Converter:** Sensor nodes detect events by sensing the physical environment such as temperature, pressure and these quantities are analog in nature. So analog to digital converter is used to convert the data in digital form.
- **Transmitter:** Transmitter is a device through which it sends the data to the other sensor nodes or sink.
- **Receiver:** Receiver is used to receive the data from the neighboring nodes or from sink.

1.1.2 Classification of Sensors

Sensor can also be classified aspects like technological issues, detection means, their output signals, sensor materials and field of application. Although classification is decided as per need of an application but in general it can be categorized into following categories.

- **Active Sensors**

  Active sensors stimulate the environment in order to do the measurements. For example seismic sensors, laser scanners, infrared sensors, sonars and so on.

- **Passive Sensors**

  These sensors can sense the sensing area without disturbing the environment. Examples of these sensors are: thermometers, humidity sensors, light sensors and pressure sensors etc.

- **Narrow Beam Sensors (Passive)**

  This is the type of passive sensors which require a clear direction in order to measure the environment e.g. camera and ultrasonic sensors.

1.1.3 Protocol Stack

The TCP/IP stack is widely used for wireless sensor network as shown in figure below. The protocol stack consists of different layers. By using these layers, communication can take place between source and the base station. The stack performs the routing technique by estimating the best path. It aggregates the data at network layer and makes the sensor network more energy efficient. The different layers of protocol stack are physical layer, data link layer, network layer, Transport layer, application layer, mobility manager,task management, mobility management. The figure 1.2 represents the protocol stack for WSNs.

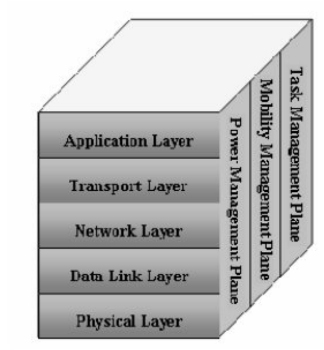

Figure 1.2: Protocol stack for WSNs

The physical layer is responsible for generating a fixed ratio frequency signal, signal modulation and detection, encryption of data, performing transmission and receiving of signals.

The data link layer supports node to node connection and is responsible for accessing a channel efficiently. Flow error and flow control techniques are used to recover the dataat this layer . It Fragment the data into number of frames. The mac layer is also responsible for making the network energy efficient.

The network layer is responsible for routing the packet over the network by finding a best and more efficient path.The transport layer is responsible for maintaining the flow of data when accessed through internet.

The application layer is user friendly layer responsible for showing all the data in human readable format. The protocol stack starts with application layer and forwards the data down to the next lower layers. Task manager and mobility manager are responsible for checking the mobile nodes and nodes responsible for forwarding and receiving of data from source node to sink. The protocol stack should meet the limitations like channel bandwidth, limited energy, wave propagation etc for wireless sensor network.

1.1.4 WSNs Challenges

In the following, we summarize some of the challenges and design issues associated with Wireless Sensor Networks:

- **Deployment of Nodes:** In wireless sensor network the deployment of sensor nodes effect the quality of service in routing. The nodes can be placed either using uniform or randomized manner. In uniform method, nodes are kept at fixed location or with respect to fixed location whereas in random deployment the nodes are scattered in a particular area. The routing can take place by using direct throwing or by using multi-hop manner.

- **Energy Consumption:** Sensor nodes can not have large capacity batteries. The sensor network sends and route the data. So, sensing consumes negligible amount of energy and they use small amount of energy for computation and transmitting the data in environment. Their energy consumption decides number of rounds they are going to complete. Thus the lifetime of sensor nodes totally depend upon the battery. Nodes become dead when they do not have sufficient energy and these sensor nodes change the topology of the network and routing takes place by using different paths. The energy used in network can be either homogeneous or heterogeneous. In most of the studies the researchers use homogeneous energy for a network.

- **Fault Tolerance:** Due to the lack of battery power some sensor nodes may fail. If some sensor nodes come in non working state then it should not affect the overall task of the network. Algorithm should be robust to overcome a bigger issue in case more than certain number of nodes fail by forming new links and adjusting the transmitting and receiving power used for relaying messages.

- **Scalability:** Sensor nodes are deployed in a sensing field in huge quantity(hundred or thousands). The routing schemes used for message communication should be able to work with all sensor nodes. The sensor nodes should be scalable enough to respond to any query. When transmission occurs some sensor nodes take part in routing and other should be in sleeping mode.

- **Network Dynamics:** Most of the times the sensor nodes are stationary but mobility of both base station and sensor nodes is necessary in lot of applications. The sensing techniques are static and dynamic. The applications such as tracking or detecting needs dynamics sensing, where as application like forest fire prevention needs static sensing.

- **Coverage and Connectivity:** Wireless sensor network is basically personal area network but the range of sensor nodes is very low about 10 meters. Sensor nodes should be strongly connected for proper linking between them as each node can cover limited amount of area in a particular field. So,coverage and connectivity are an important factor in wireless sensor network.

- **Data Aggregation:** Data Aggregation is a technique in which the number of transmission of similar messages reduce and multiple messages are fused together. Many sensor nodes send the same packet to the collector node, by using the data fusion technique. These multiple packets or messages are handled by the collector nodes and efficient routing is done by removing duplicate packets.

1.1.5 Routing for Wireless Sensor Network

The wireless sensor nodes are deployed in harsh environment.So many protocol have been proposed for the routing of packet in wireless sensor network. The algorithm used for routing basically depends on the type of application. The routing protocols are classified into different categories.

- Single path routing.
- Multipath routing.

1.1.6 Single Path Routing in WSNs

Routing in wireless sensor network is different from the existing networks due to the infrastructural variation and link unreliable problem. The routing protocol for wireless sensor network has strict energy saving requirements. The main purpose of routing protocol is to perform an end to end packets delivery based on the topology or position addressing. If the addressing is host based is called topological addressing and if a unique identification is chosen than the addressing is position based. The sensor node can deliver the data requested by the user query back to the base station. The single path routing protocol for wireless sensor network in which only one instance of packet are sent at any time. The resources used by single path routing protocol algorithm used are less than the resources used by the multipath or partial flooding routing. The delivery of data is a primary goal of single path and partial flooding routing protocol. One of the main problem is channel access problem and this algorithm gurantees to access the channel efficiently by the user to increase the throughput of network. The routing algorithm used the concept of memorization of past traffic to increase the reliability of network. The single path routing is futhur divided into different categories.

- **Energy Efficient Routing:** The power use for computation has increased in present days but battery lifetime has not increased considerably. For adjusting the signal strength large amount of energy is consumed. The energy efficient routing protocol is used to reduce the energy consumption problem both in channel activation and data transfer.

- **Planner Graph Routing:** The problem arise if the neighbors are not closer to the target and the packets are dropped by the used path. In this situation a data recovery scheme is used to recover the data. It resends the data and provide end to end delivery of packets. The use of planner graph routing increase the efficiency of network.

1.1.7 Multipath Routing in WSNs

Wireless sensor networks are used in various applications due to their ease of deployment. WSN is a collection of sensor nodes which are limited in their computational capability and battery powers. Constraints on sensors impose many challenges in designing an efficient communication protocol for wireless sensor network. Most of protocols follow single path routing strategy but it doesnt consider the effect of different traffic load intensities. Although it is computationally cheap but its limited capacity decreases network throughput. Moreover this approach is less flexible and link failure can affect system efficiency. This makes this field important for research purpose. Thus single path routing cannot achieve high performance as per application. In the past decade multipath routing has been widely used due to its fault tolerant and reliable nature. Main issue is which method is used to send data from target to sink. Multipath routing protocol discovers a path by including several components to construct multiple paths over which network traffic is distributed. Multi hop data transmission technique is used for packet forwarding as they work in constrained range. This decision is made on basis of different parameters. Path disjointedness is a main parameter considered by almost all routing algorithms for discovering path. They are categorized as node-disjoint, link-disjoint, or partially disjoint paths.

The amount of path disjointedness is a basic criteria but considering it solely doesnt solve the purpose of constructing high quality paths. Therefore to address an issue of time-varying properties of radio communications and resource limitations of sensors various types of costs are also considered based on an application. Cost function calculates data transmission cost based on various properties of sensors and links. Considering all the factors result into multiple paths possible. But adequate number of paths is selected for transmission purpose. Path selection varies from protocol to protocol. One can select an optimal path out of multiple options and keep others as backup paths for maintaining robustness of system or can use multiple paths concurrently for reliable delivery. Next step is to distribute network traffic over selected paths. This depends on need of application. If reliable system is required, then data is transmitted through several paths even if it adds redundancy. But if issues like delay and lifetime are focused, then efficient load balancing technique is used. But all this consumes power and energy scarcity is main issue. So, path maintenance is required to reduce performance degradation. For this path is rediscovered. But rediscovering a path after breakdown of all the active paths decreases the network performance considerably. So, it is generally followed when an active path is down or certain numbers of active paths get down.Taxonomy of the existing multipath routing protocols in wireless sensor networks. It improves network quality under heavy traffic conditions and other constraints. This protocol is used in varied applications but performance gain depends on generation of sufficient number of quality paths by proposed protocol. The classification of multi path routing is shown in figure 1.3.

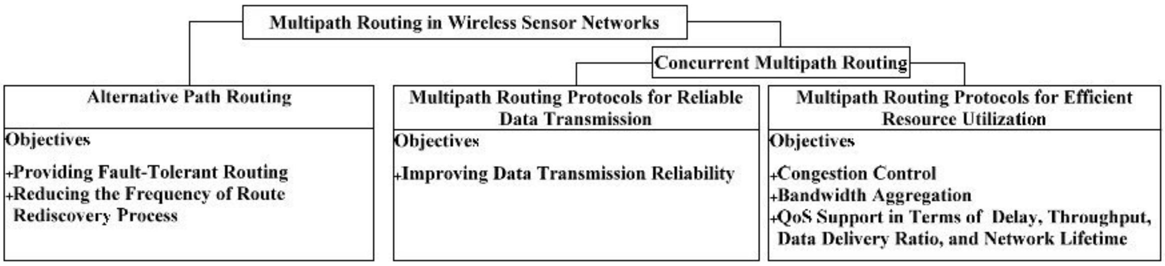

Figure 1.3: Multipath routing in WSNs

Chapter 2
Literature Review

Direct transmission is a basic approach for data relay in which each sensor node sends the data individually to the base station. Base Station is located at fixed location, far away from the sensor field which increases the transmission cost and decreases the lifetime of network. In 2000, LEACH[1] was proposed as a clustering based routing protocol that used randomized rotation of cluster i.e. instead of direct transmission, cluster heads were selected from each cluster which relay the data to the base station using radio frequency. Energy is distributed homogeneously to all the sensor nodes in this protocol. LEACH[1] is 8 times better than direct transmission. The cost of transmission from source to base station is very high due to sensor nodes low battery. So, the automated method of data fusion and data aggregation are used[18].LEACH protocol shows that the nodes is select for head of cluster is not more than 5 percent of the total sensor nodes. Leach node consider the head node can be centralized or is semi centralized.

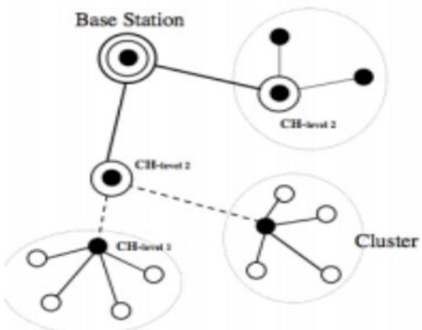

Figure 2.1: Cluster formation

O-leach stands for optimal leach is an energy efficient communication protocol for hybrid sensor network. For enhancing the power of leach protocol this protocol use the time length parameter. The filter replenishment mechanism is used to increase the efficiency and throughput of network.The gauss function is used to improve the data precision decision and maintain the stability of network.

In 2002, Lindsey *et al.*[2] proposed a protocol named PEGSIS that improved the life time of network using chain like structure of nodes which was formed by following greedy method. In this approach base station was considered far away from all the sensor nodes which communicated to its neighbor nodes and reduced the amount of energy spent per round. The data fusion is applied at every node except the last node. Tan *et al.* [3] presented an efficient algorithm known as PEDAP in which the concept of minimum spanning tree was used. The simulation results showed that this was a better approach as compared to LEACH,PEGSIS. The sensor nodes and sink were stationary which used homogeneous energy in network. In PEDAP[3] all the computations were done by the base station that resulted in a lot of overhead for base station. Aggarwal *et al.*[4] presented a TEEN protocol that increased the number of rounds by changing the threshold value which was totally dependent on the type of application. The nodes sensed the analog signals and continued to sense the environment till their threshold value is greater than hard threshold value (hard threshold value is a value below which the sensor node can not take part in relaying packet, only senses the environment and sends the data to the relay node). These nodes further sent the data to other nods whoose value was greater than soft threshold value (soft threshold value is a value below which the sensor node take part in relaying the packet and send the data to the base station though other relay nodes). Data was sent by using time count and if time count exceeds then data could be re-transmitted.

In 2005 a reliable and energy efficient data delivery in cluster was proposed by Jung *et al.*[5]. This technology used unicast based forwarding technique, forward using interleaving path and REEF based routing. This one was more reliable as compared to existing cluster based sensor network.

In 2007, Rajiullah *et al.*[24] proposed an energy-aware deterministic clustering periodical gathering protocol which showed more energy efficiency when nodes are combined to form cluster and each cluster head energy fall below a threshold energy. Protocol started with cluster formation phase. In this phase cluster head was selected for each cluster and after the cluster setup phase the protocol was divided into rounds. No new cluster head was elected at beginning, rather it was selected when energy reached to a specific threshold energy. It considered a major factor that a node can become cluster head multiple times.

In 2008 time based cluster heads were chosen but not on the basis of random number as in regular models and this factor increased the lifetime of a network[6]. Each sensor node sent an advertisement message to the others nodes and in this message a counter value was sent, if time expires or the node which received the message had counter value less than remaining nodes then that node will be elected as a cluster head. Rest of the process was same as in case of leach. In 2008, Paula *et al.*[30] proposed a blind flooding energy efficient protocol. In wireless sensor network most of the protocols broadcast their messages like control message to control the topology of the network. This protocol improved the broadcasting in wireless sensor network upto some extent only. Dynamic power management and schedulate switching modes(DPM-SSM) technique were used in blind flooding protocol for improving the battery capacity recovery effects.

Three tier based model[7] was proposed for increasing the life time of network according to which the sensor nodes which are very far away from the base station can reduce large amount of energy as compared to the nodes closer to the base station. These tiers were based on the distance from base station. The nodes, closer to the base station were placed in one tier and farther ones were placed in another tier. The higher tier nodes send the data to the lower tier nodes, lower tier nodes sent it to further lower ones by collecting the aggregated data and this process goes on till it reaches to lowest one which finally sends it to the base station. Simulation results reveal its quality of being so close to optimal solution on comparing with LEACH and PEGSIS.

In 2008, Huang and Fang[43] proposed a multi constraint quality of service routing protocol for wireless sensor network. The idea was to increase the reliability of the network and also find the best route path among all the paths that could send the data from source sensor nodes towards the base station. In 2009 new technique[8] was proposed by using relay nodes which were placed randomly with the sensor nodes in a particular field. These relay nodes chose a cluster head and relay the traffic towards base station. The simulation results showed improvement of 6%-30% as compared to LEACH[1] protocol. If the relay node got dead, even then existing network operated and it worked till the last node survived by reforming cluster again and again on need. The position of relay nodes in a sensor field was a big overhead. The Hybrid LEACH reduced this problem upto some extent.

In 2009 Yonlan *et al.*[23] proposed an energy balanced clustering routing protocol in wireless sensor networks(EBC) that selected the cluster head in a distributed manner. The signal intensity was used to calculate the distance between nodes of same cluster and those nodes whose energy was greater than the threshold energy was chosen as a cluster head and communication began with base station. The EBC protocol was divided into rounds.Each round was further divided into two stages one was establishment stage and second was stable stage. The establishment stage was used to deploy clusters in a network whereas the stable stage depended upon the number of cycles of communications. In each cycle the cluster nodes sent the packet to the cluster head, when cluster head collects the packet it fused the packets and forwarded the packet to the base station.

Alan *et al.*[27] proposed an energy aware Qos provisioning for wireless sensor network. An algorithm was proposed for increasing the lifetime of network and to achieve a desire quality of service, an energy retransmission mechanism was proposed. This increased the reliability of the network and kept the delay with in delay boundaries. A multi path routing in a single base station had some problems. All the cluster heads sent their data to the base station using single path or multi path routing. Any path did not interfare with any other routing paths and data was sent towards the destination by proper load balancing.

Hao and cia[25] proposed an energy efficient routing protocol for large scale wireless sensor network which was basically an AODV base protocol with routing identification and RREF packet capturing (AODV-RIRC).The source did not find a new route due to presence of route identification and after capturing the RREF packet nodes made the best route towards the destination silently. In AODV when RREQ packet arrived at the destination some packets are sent back towards to the previous nodes. In order to solve the problem a different address is used for them. The whole idea is to used same sink id but different addresses for differentiating the base station.

In 2009, Songzhu and Su wu[36] proposed an ant colony based multi path energy efficient protocol for wireless sensor network. Each node contained an ant and was deployed randomly in a specific area and every ant contained a list of paths and list of tabs to record the node on the network where the ant visited. By using a greedy approach a tour was build by ants such as state transactions rule. Each ant modifies the value of pheromone if using the same path. In initialization phase ants were placed on different source nodes. In path selection phase each ant find the best path from source to destination and data can transmitted to the base station.

Hang and Yang[37] proposed an rumor routing energy aware protocol for wireless sensor network EMBBR. It was a probabilistic technique that used to find the best suitable path by using two major parameters- the residual energy and energy usage by the neighbors. This protocol used two type of agents one was forward agent and other was backward agent. An agent was a query message that was sent over the network to find the path from source to sink. Forward agent found the information of the path and search for the multi path route from source to the sink. Backward agent moved in reverse direction and stored all the information regarding path in the routing table and give information to source node.

BinFu *et al.*[44] proposed a non interfering multi path geographic routing protocol for wireless sensor network. The key idea was to solve the issue of interfering multi path in wireless sensor network and proposed a non interfering protocol for sensor network too. Abdur and Choong[35] proposed analysis of energy tax for multi path routing in wireless sensor network. In this protocol an energy tax analysis was done by using analytical model. The total amount of energy used in one unit time was computed by checking two main factors route establishment and data forward to their destination. Most of the energy was consumed when performing sensing task, processing raw data, transmission and receiving of packets. Each node has four states transmitted, received, sleep and listen. The node remained in sleep mode when transmission and receiving operations go on. If the event was detected then node changed its state from sleep to active state. An ARQ ACK mechanism was used for retransmission and maximum ARQ value was fixed.The routing table stores the next best hop that can be used for discovery routing paths.

Krishna and Murthy[42] proposed a meshed multi path routing protocol for wireless mesh network. In this protocol the nodes were tagged with ID and multi path searching took the benefits of these ID .This protocol used the triggered level in which the nodes were deployed randomly in a specific area around the base station. In this case initially the base station sent the packet with low signal power and after that it increased its signal power and again packet was sent by using different ID levels. For discovering the packet each node sent the discovery packet to the other nodes and only those nodes accept the packet whose ID is less than or equal to the sender node's. After that the best path was chosen and data was sent to the external network.

HaiBo and Wenyu proposed a distributed power control algorithm with multi quality of service constraints for wireless sensor network[48]. MQDPC is a totally distributed algorithm in which a quality of service parameters are calculated by the node remaining residual energy, end to end delay and link reliablity. The MQDPC algorithm is very efficient for large scale wireless sensor network. The simulations shows the optimal results as compared with existing algorithm. This protocol use the minimum spanning tree to find the best path and send the data to the base station.

In 2010 a framework was proposed for optimal sensor redeployment approach [9] in which the network field was divided into two parts, first part was grid and the second part was the gaps between the grid and illustrated the optimal solution for redeployment problem. In 2010, Soni chaurasia *et al.*[32] proposed an energy efficiency protocol for providing Qos for wireless sensor network. This protocol solved the problems of event capturing and real time data transfer and increase the lifetime of network.

Marjan *et al.*[33] proposed a low interface energy efficient protocol for improving Qos in event driven wireless sensor network . The key focus of the algorithm was on to improve the packet delivery ratio, lifetime and latency of the network by using minimal interference and node disjoint path from source node to the destination node. This protocol also use load balancing scheme to distribute the traffic of the network into multiple paths. The lifetime of the network is 1.5 more efficient as compared with single path routing. It was a multi path based algorithm for solving the problem of event driven application. The algorithm was divided into two phases- one was initialization and second was route discovery. In initialization phase each sensor node obtained the information of routing from its closest node, for controlling the network each node sent the control packets and record was maintained for successfully received packets from its closest node and made a routing table which was useful for selecting a path. In route discovery and establishment phase when an event was triggered sensor node collected the data and sent it towards the base station. To select a route a node sent a route request packet to the base station and find the best next hop for transmission of packets. A unique identification number was given to each sensor node and each node had a track of id for which packet was sent and route reply packet was sent back to the source node and a part of the route was established. In this way whole path was discovered and then source node communicated the packets to the base station.

Xaio *et al.*[34] proposed an efficient multi path routing protocol for wireless sensor network EBMER. The algorithm used remaining residual energy and link quality to find the next best hop and routing paths.The routing tables stored all the path form source node to the destination node, when one of the path failed to transmit the data another path was used to fulfill the task. EBMER protocol decreased latency time by 51 percent and 21 percent as compared with AOMOV and REAL protocols respectively. Each node had a link quality where high link quality means a node have low error rate and low probability of retransmission. Acknowledgment mechanism was used to ensure that packet was received or not. Retransmission reduced the efficiency of the network so choosing a low link quality hop increased the lifetime of network by consuming minimum energy. This protocol used cluster approach and each cluster head collected the fused data and sent it to the based station.

Bashir and Ben[45] proposed a RELAX protocol for energy efficiency in wireless sensor network. This protocol used the relaxation phenomenon to save the energy of batteries and increase the lifetime of batteries. This protocol was also able to recover the batteries from the lost power. By using the signal to noise ratio it predicted the best suitable hop during path establishment.

In 2011 Shin and Shin[10] proposed an algorithm known as CREEC(Chain Routing with Even Energy Consumption) in which both direct throwing and hop to hop routing techniques were used. The base station calculated and stored the energy used at each round. The base station calculated the path and the throwing energy for each sensor node and then communicated the information by using becan packets to the sensor node. The sensor node sent the fused data to the neighbor node in a particular chain and at last the data was collected by throwing sensor node which forwarded it to the base station.

Nazir *et al.*[26] proposed a quality of services aware energy efficiency routing protocol for wireless sensor network(QEER) for clustering the nodes in network. A combination of fixed position base station and mobile base station was used for data fusion. The static base station sent the delay sensitivity message where as mobile base station sent the delay message. So, in this way protocol took less end to end delay and increased the performance of network. The protocol was divided into two phases one was setup phase and second was steady phase. At an initial stage each node calculated its location and its remaining energy and clustered was formed. In steady phase protocol performed the actual fusion process and forwarded the data to the cluster head or super node. The presence of mobile sink increased the end to end delay as cluster head had to wait for mobile node for longer time and the movement of cycle was according to the fixed position system.

Dubal and Achala [39] proposed a new approach called balanced scheme in which transmission of packet was done by the use of multiple path. Each source node selected one of the path by using weight factor and sent the data to the base station. If the current path had remaining energy less than threshold energy than one of the best path was chosen from the backup paths and data was transmitted to the destination. Moud *et al.*[41] proposed an energy efficient load balancing metrics by using diversity routing protocol for wireless sensor network. The goal of the protocol was to use the energy effectively over the network and also increased the lifetime of network. In addition protocol also focused on the residual energy of the nodes so that the critical nodes were avoided. This protocol showed the improvement upto 20 percent. Energy efficiency was a critical issue in wireless sensor network. Instead of sending data to the base station directly, sensor nodes used the multi hop communication. So, the limited amount of energy was reduced by sending or receiving the data to the base station. This protocol also helped to reduce the energy consumption by avoiding the bad links and made the network more reliable.

In 2012 an energy efficient extended ELEACH [11] was proposed. In this technique the clusters are formed and each cluster head forwards data to the master cluster nodes, that further sends it to the base station. In 2012 reforming cluster using C-LEACH[12, 13] was proposed.

LEACH protocol was divided into two phases setup phase and steady state. In setup phase clusters were formed and their heads were chosen. In steady phase the actual transmission of aggregated data took place. Every node chose a random value between 0 and 1, node with random value less than 1 becomes the cluster head and relays the traffic. By using equal clustering technique, equal number of nodes are placed in each cluster. The proposed algorithm uses two thresholds maximum threshold and minimum threshold. If the value of cluster node is greater than maximum threshold, then nodes with minimum threshold value can take part in clustering and rest are discarded. If the value is less than maximum threshold then all nodes of a network take part in clustering.

MSMTP[14] was a multi-hop routing protocol in which, a radio dissipated 50 nJ/bit energy wa used to run the transmitter for sending or for receiving the packet. The transmitter amplification energy $100pJ/bit/m^2$ was used for data amplification. This technique used the concept of tires which were formed based on distance of nodes from base station. Nodes which were closer to the base station were placed in first tier, nodes with average distance from base station are placed in second tier and nodes which were far away from the base station were placed in third tier. By using the kruskal algorithm the minimum spanning tree was generated for the whole network. The head nodes were chosen on the basis of maximum energy from each tier. Firstly the first tier head node send the data to the base station and after that the second tier head-node transmitted the data to the base station and the process was repeated till all nodes are not dead. These head nodes send the data until threshold energy was achieved, after that the whole network went into saturation period. And to make it active, threshold energy was reduced by half and whole process was repeated again till dead energy was reached. If the threshold energy was less than dead energy the whole network became dead. Simulation showed optimal result for increase in lifetime.

CELL-LEACH[15] protocol divided the sensing field into the small size cells. Nearly seven to eight cell make a cluster where cluster head was chosen for each one which stored the information of other clusters in the table. The table was updated by each cluster head which helped in finding the shortest path to transmit information to the base station.

Sayyed ana Naderi[31] proposed an energy efficiency real time routing protocol for wireless sensor network(EERT),which used modular approach to send the packet towards the destination. It focused on both energy transmission cost and remaining energy of router by using a shortest path in order to increase the lifetime of network. EERT protocol used a new policy called re-routing policy which allowed the packets of specific class to be routed with real time class through neighbor nodes. Real time protocol was totally dependent on the application and used the packet velocity parameter that had an advantage of not requiring any synchronization between nodes. In order to achieve uniform distribution of traffic same path was used to forward the packets and increasing the latency of network.

In 2012, Dehnavi *et al.*[28] proposed an energy efficient and Qos based multiple Hierarchical routing protocol in wireless sensor network(EQMN). The protocol satisfied the quality of service requirements with minimal energy requirements and hierarchical methods. By using multiple constraints such as energy, remaining buffer size, signal to noise and distance to the base station protocol elected the cluster heads and route discovery. A multipath approach was used to find the best path and performed better load balancing that consumed energy uniformly throughout the network. The operation of the protocol was divided into rounds. Each round started with cluster formation and elected cluster heads in each cluster. In route discovery phase multiple path was detected between cluster heads and relayed the aggregated data towards the base station. Secure-LEACH[16] was proposed to increase the security of cluster head in a sensor field. The pairwise key mechanism was used for generating the keys between between cluster nodes and cluster heads. The key idea behind this technique was to generate large number of key pools at the time of deployment. The unique key was assigned to each node randomly and each sensor node shared the pairwise key with the base station. In this technique the sensor field was divided into different square fields and each square field sensor nodes were deployed randomly and key was assigned to each sensor node from the key pool.

Ali *et al.*[21] proposed a simulation based evaluation of MANET routing protocol for static wireless sensor network. The performance was analyzed by studying the simulation results of AODV, DSR and DSDV routing protocols on wireless sensor network using Ns-2 simulator in static environment. The performance result focused on network density, size of network, end to end delay, delivery fraction and routing overheads. Nirmala *et al.*[29] proposed an energy efficient and enhanced QoS aware MAC protocol in wireless sensor network. IEEE 802.11 protocol worked on DCF (Distributed coordinate function) mode.In DCF mode the coordinator only sent the active nodes to the sensor to minimize the energy consumption.

Poonguzhali[22] proposed an energy efficient realization of clustering path routing protocol in wireless sensor network(CPHRP) and solved the problem of coverage rate and effective network lifetime of wireless sensor network. CPHRP had coverage rate of 90 percentage in network lifetime. The objective of CPHRP was to minimize the total transmission power used for aggregation of data over the network and also balancing the load among the nodes for increasing the lifetime of network. To enable load balance in a network, the cluster head node sent the packet to the inner cluster head node before sending it to the destination. This helped to figure out whether packet was forwarded to outer cluster by itself or inner cluster nodes.

Omar *et al.*[40] proposed a grid based multi path routing protocol with congestion avoidance for wireless sensor network.The idea behind it was division of sensor field into different number of grids. One of the node in each grid was master node that could collect the data from the other grid nodes and was also responsible for sending the data to the member nodes. Master grid nodes were connected to the multi path and these paths were stored in routing tables. A congestion control mechanism was used in order to solve the problem of congestion areas. This protocol saved energy up to 19.5 percent. In this algorithm there were two type of grids used. One was boundary grid that provided single path towards the base station and other was non boundary grid which contained multiple path towards the sink. In grid formation phase a global positioning system was used to find the position of each node in a particular grid. After grid formation the sink or base station sent the message to the master node to discover the path from source to destination.

Shreef and zhu[47] proposed an effective stochastic energy efficient model for wireless sensor network. In this protocol a petri net model was used to increase the life cycle of network and provided a complex interaction between process and communication components of wireless sensor network. The petri net model showed optimal results as compared to Markov chain model. The petri model was very easy to implement in comparison to Markov model. The CPU used a Markov and petri net model by using Poisson process with mean rate λ and service time $\frac{1}{\mu}$. By using these time constraints the efficiency of CPU was increased in wireless sensor network.

In 2013, Chanik and Inderjit[38] proposed a fault tolerant energy efficient routing protocol for wireless sensor network.Backup paths were used if the current path was not able to transmit the data over the network. In this approach the data packets were sent to its neighbor and checking was performed for received data with its own sensed data packet. If the data packet was found same then neighbor node was not supposed to forward the data to the next node. If the data packets are different then it send the data to sink via other sensor nodes using shortest path. In 2013 Mohapatra, and Gibson[17] proposed an algorithm for deployment of sensor nodes under water and reduced the cost of network. In this technique sensor node were placed on the ocean floor. They sensed, collected and relayed the data to the base station. This method used joint policies to reduce the deployment cost and increased the lifetime of network using minimum energy consumption.

Zahra *et al.*[19] proposed a reliable and energy efficient chain cluster based routing protocol for wireless sensor network.The REC protocols aimed to make the network more reliable by placing the cluster head(CH) in their proper positions and also computed the size and shapes of clusters without use of any error control approaches.The base station computed the location of other sensor nodes during deployment and divided the network into number of clusters based on the location of y axis and clusters were further arranged in a chain like structure. As base station handled each cluster independently. The whole logic was divided into two parts one was cluster head selection and second is cluster chain formation.

Awlan and Aggarwal proposed a multi objective quality of service for wireless sensor wireless sensor network[46] . In this paper ahop by hop mechanism was used to provide multi objective quality of service to the client. The metrics parameter were reliability, delay, energy, distance from sink and path based parameter. The simulation showed the optimal results by choosing an optimal path and transmitting the data to the base station. This protocol was totally based on the multi path selection process. This protocol provided many energy efficient solution to increase the life cycle of network. The concept of cost function used in this protocol and parameters were divided into different number of classes. By using this cost function an optimal paths from source to base station were stored in routing table. By using these path data was sent to the base station.

In 2013 Saima *et al.*[20] proposed an opportunistic protocol for routing called OFETR(optimal forward based on energy and trust, for routing). This protocol solved various issues like selecting and prioritizing forwarder list based on energy and trust value. OFETR used threshold value and thrust value to calculate the best routing path and then reduced the energy by sending the packet to the destination using multi hop routing mode. It was a location based protocol for routing and used the location to find the proper or best routing path towards the base station. OFETR also used the trust value to find the best next node. This protocol also focused on reducing the minimal energy for increasing the lifetime of network.

Chapter 3
Problem Statement

3.1 Problem Statement

Problem is to design an energy efficient approach for sensor nodes communication. The main consideration is WSNs where nodes are scattered randomly, uniformly over the network. The location of the base node is fixed and have an unlimited power source. The sensor nodes communicate directly with each other and can also correspond with base station. The sensor nodes fuse the packets received from the network and produce one packet as a result. To overcome the energy problem different schemes were implemented in which the relay node delivers the data collected from the other sensor nodes to the base station, which increases the number of rounds and over all life time of the network. The lifetime of network is defined as the number of rounds completed till the particular node has sufficient energy. But term lifetime of network is not cleared until what type of service provided by sensor node is not known. In real time the quality of the system is decreased when the first node in the network does not have sufficient amount of energy and becomes dead. In first technique, a minimum spanning tree is created after every round and head node is selected from each tier then head node sends the data to the base station for a particular threshold energy. If the threshold energy is less than or equal to dead energy the node is removed from the network field. In second technique minimum spanning tree is constructed considering multiple parameters which will generate multiple paths from source to sink. Out of multiple paths stored in routing table, an optimal path is selected and others are maintained as back up. In third technique the relay nodes are deployed randomly with sensor node and the energy of relay node is greater than the sensor nodes. The relay node is a cluster head that send the data to base station through other relay nodes. Thus the thesis proposes both tier based and multi path based approaches for increasing the lifetime of wireless sensor network.

The problem is defined as ”Energy Efficient protocol for Wireless Sensor Network”.

3.2 System Model

The system model is divided into different components as shown under. It deals with sensor nodes, environments, energy consumption and different notations.

- **BS**: The base station consists of powerful central processing unit, a memory unit, small memory used for storing the data and an unlimited power source. It collects all the aggregated data from the sensor field and sends to the external network. The base station is connected to other networks such as Internet etc.

- **Sensor Nodes**: Each node contains many sensors to sense the different parameters in the environment, receiver is used to receive data from neighboring nodes and transmitter is used to send the data to the other nodes. Sensor nodes sense the analog signal from the environment and use analog to digital converter to convert the data in digital form and with help of transmitter it performs its job of transmission.

- **Node Energy**: Every node contains the homogeneous or heterogeneous initial energy level E_0. After every transmission, certain amount of energy is reduced. The nodes which contain insufficient energy for sending and receiving should be completely removed from the network and new minimum spanning tree is generated by using prims algorithm after the round is complete. In mostly cases the heterogeneous energy is divided into two parts, one is for sensor nodes and other for relaying nodes.

- **WSNs**: It consists of N number of sensor nodes which are stationary and a fixed base station BS. The sensor nodes are scattered randomly or uniformly in a fixed size sensing field. The base station is far away from the sensing field. The sensor nodes sense the environment and transmits the data to base station though multiple sensor nodes also known as relay nodes.

- **Fusion**: The k bit packet is generated by all the sensor nodes and is sent to the neighbor node to relay the packet for base station. All the relaying nodes compress the k bit packet and send it to the base station. Many sensor nodes send the same packet to the collector node by using the data fusion technique. So, the redundancy is removed.

3.3 Network Model

The network model for proposed algorithms is formed by deploying 100 sensor nodes randomly and uniformly over the network of area $50 * 50m^2$. Each node in the network has the capability to transmit data to the other sensor nodes and directly to base station. In network model a tier based, single path and multi path routing based techniques are proposed in which tiers and minimum spanning tree are made based on the distance from the base station. Each tier or cluster contains a unique identification called tier-id or cluster-id. In tiring technique a minimum spanning tree is generated by using prims algorithm and the head node from tier is chosen that can send the data to the base station directly. In clustering the clusters are formed and cluster head is chosen which is a high energy node that relays data to the base station. In single and multi tier based routing approach use fuzzy cardinality priority function to select the efficient path from the list of path and then send the data to the base station. The figure 3.1 and figure 3.2 shows the random and uniform deployment of sensor nodes in a rectangular sensing field.

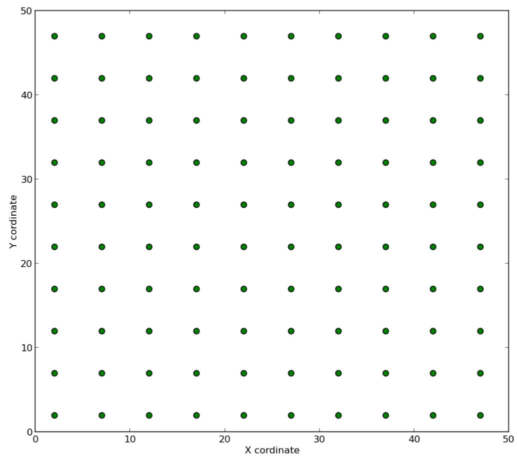

Figure 3.1: Uniform deployment of sensor nodes

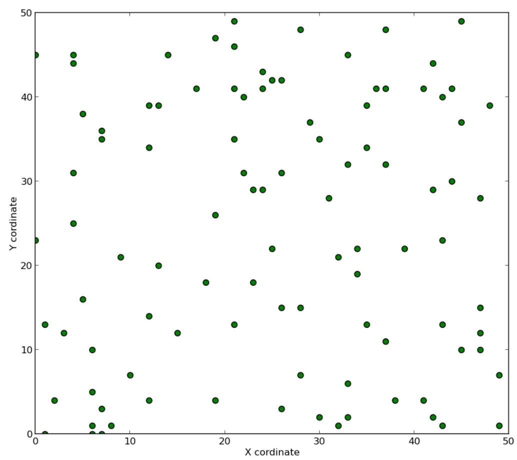

Figure 3.2: Random deployment of sensor nodes

In single path routing algorithm a fuzzy cardinality priority function is used to find the best neighbour hop from source to sink but in multi path routing algorithm (MPRA) he greedy approach is used to store all the paths in a routing table and fuzzy cardinality priority function is used to find the optimal path among all the paths stored in a routing table. During deployment phase the 100 nodes are deployed randomly in an area of 100*100m^2 and range of each sensor node is 20 meter. The delay constraints used in MPRA are application specific. If the available path is not able to transmit the data next optimal path is used to transmit the data to the base station.

The network design for single path routing algorithm and multi path routing algorithm consists of weighted connected graph *G=(V,E)* where *V* denotes the number of nodes in a network i.e *V*: $\{s_1, s_2, ..., s_n\}$ and *E* represents the number of link i.e *E*: $\{u_i, u_j | (u_i, u_j) \varepsilon V\}$. The link (u_i, u_j) represents that there is a connection from node u_i to node u_j and works in full duplex mode. The *d*(u_i, u_j) represents the distance or Range between from node i to node j. The following equation shows whether two nodes are connected or not.

$$R_{i,j} = \begin{cases} 1, & \text{if } d(u_i, u_j) \leqslant \text{R} . \\ 0, & \text{otherwise.} \end{cases} \tag{1}$$

Where *R* is the range of the node *i* to *j* and *j* to *i* and *d* is the distance of node *i* to node *j*.

3.4 Radio Model

The radio frequency model used for proposed techniques is same as discussed in LEACH. In this model the radio dissipates energy $E_{elect} = 50$nJ/bit which is used to run the circuitry of transmitter and receiver. $E_{amp} = 100pJ/bit/m^2$ is used for the amplification of the signal. The size of the data packet is 2000 bit. The energy is used for sensing, data fusion and reconfiguration of minimum spanning tree is ignored. Cost of transmission and receiving for a *k*-bit size packet in d distance are calculated by logic given below.

- **Transmitting Energy** ($E_{tr}(k, d)$):

$$E_{tr}(k, d) = E_{elect} * (k) + E_{amp}(k, d). \tag{2}$$

The transmission energy is used to send the data within a network.

$$E_{tr}(k, d) = k * E_{elect} + k * E_{amp} * d^2. \tag{3}$$

The transmission energy is used to send the data to a base station.

$$E_{tr}(k, d) = k * E_{elect} + k * E_{amp} * d^4. \tag{4}$$

- **Receiving Energy** ($E_{Rx}(k)$):

$$E_{Rx}(k) = E_{(Rx-elect)} * (k). \tag{5}$$

$$E_{Rx}(k) = E_{elect} * k. \quad (6)$$

where *k* represents the number of bits packet send during transmission and *d* represents distance between two sensor nodes. Radio model is based on an assumption that the radio channel is symmetric in nature i.e. amount of energy required to send *k*-bit packet from sensor node *A* to node *B* is same as energy required to send the packet back from node *B* to node *A* for given signal to noise ratio. All the sensor nodes sensing the environment at a fixed rate always have data to send to the end users. Receiving the data from network is a very costly operation, therefore there is a need of optimizing the amount of energy required in communication. If the nodes are deployed densely, the quality of the network is not reduce by much amount even if some of the sensor nodes die because there are many neighbour nodes that can relay the data of dead nodes. The neighbor nodes shape the traffic with the help of relay nodes and deliver the packet to its destination. The quality of network is decreased when half or more than half sensor nodes gets dead. When the last node is dead the whole network is consider to be dead. Threshold energy used is a key point behind all logic, which is a minimum amount of energy and below which sensor nodes in network are not capable to relay the traffic. The dead energy is minimum energy level with which node becomes useless as it can not perform in any transmission and is thrown out of the network.

3.5 Node Structure

The node information contains location of nodes, tier-id and energy required to transmitted the data to base station which is shown in figure 3.3. In cluster the nodes contains cluster-id instead of tier-id, unique identification, initial energy, dead energy, position of the node and distance In our proposed techniques the network is partitioned into different tires based on the distance from the base station. The algorithm assigns an identification known as tier-id to each sensor node during the setup stage to classify them from other clusters. The sensor nodes having same tier-id are placed in a same tier. The sensor nodes in one tier have approximately the same distance from the base station and have same energy to communicate with base station. The nodes which are closer to base station have a lower tier-id. The nodes having a lower tier-id are called upper tier nodes and the nodes having a higher tier-id are called down tier nodes and data from the lower tier nodes move towards upper tier nodes, upper tier nodes send it to further upper ones by collecting the aggregated data and this process goes on till it reaches to top one which finally sends it to the base station. The figure 3.3 represents the field information of each node.

NODE ID	(XY)	ENERGY THRESHOLD	TIER ID	INITIAL ENERGY	DISTANCE FROM BS	TRANSMISSION ENERGY

Figure 3.3: Node structure

where *NODE ID* is a unique identification of sensor node such as mac or ip address of any network device, *(X Y)* are the co-ordinates of the node that define the position of the sensor node, *ENERGY THRESHOLD* is the minimum amount of energy below which the sensor node can not transmit the data. The threshold energy is always reduced to half by the base station on achieving saturation point. The sensor node contains homogeneous energy but in case of clusters two different energy values are used i.e sensor node energy and relay node energy. *INITIAL ENERGY* represent the initial energy of node either homogeneous or heterogeneous. The filed *DISTANCE FROM BS* is a distance of node from the base station. *TRANSMISSION ENERGY* is the cost that is used to transmit the data to the base station. In multi path routing algorithm and single path routing algorithm the value of tier id field is zero because these algorithm do not use any concept of tiers but instead of tires a delay parameter field is added in node structure. The value of hop count is considering during path selection process. The best paths are selected on the basis of fuzzy cardinal priority ranking function applied which generated a cost value according to parameters such as transmission energy, delay and hop count used. All the paths are stored in routing table and every time a optimal path is used to send the data to the base station.

3.6 Performance Metrics

SPRA and MPRA uses multi objective QoS parameter to increase the lifetime of network are shown below

- **Energy Consumption:** The energy consumed for relaying a data towards the base station by using a single path can be expressed as

$$Er_{path_s} = \Sigma_i^{hop_s} Ec_i \tag{7}$$

Where Er_{path_s} is the average energy consumed by a single path and *Ec* is the energy consumption of single hop. hop_s represents the number of hops in a single path. Ec can be expressed as

$$Ec = Et_x + Er_x \tag{8}$$

Where Et_x is the energy that is used to send the data to its neighbour node and Er_x is the amount of energy for receiving the data from its neighbour.

The end to end energy consumed by all the paths used can be written as

$$E_{end} = \Sigma_{p=1}^{np} Er_{path_s} \tag{9}$$

Where *np* is the total number of paths in a list and Er_{path_s} ia a energy consumed by single path.

- **Delay:** The time required to send and receive the data packet from source sensor node to sink is called delay. The delay between two neighbor nodes is donated by D_{link}. The delay for a given path Dr_{path_s} is the sum of all the delay of link in a path.

$$Dr_{path_s} = \Sigma_{i=1}^{hop_p} Dr_{link} \tag{10}$$

So, end to end delay can be calculated by using the expression

$$D_{end} = max_{(i<p\leqslant np)} Dr_{path_s} \tag{11}$$

Where *np* is the total number of paths in a path list and Dr_{path_s} represents the delay of single path.

- **Data Delivery Ratio:** The probability of transmission of packet successfully or unsuccessfully can be expressed in terms of Data delivery ratio. It is defined as the ratio of number of packets generated by source to the number of packets received by the destination. If the total packet PK_{total_s} are send by the source node and the number of packets are received by sink are PK_{recv_s} then the data delivery ratio can be written as

$$DDR = \frac{PK_{total_s}}{PK_{recv_s}} \tag{12}$$

Chapter 4
Single Path Routing in WSNs

4.1 Tier Based Energy Efficient Protocol

In tier based energy efficient protocol the sensor nodes are deployed randomly in a sensing field and network is divided into three tiers depending upon node's distance from the base station. The sensor nodes are placed in different tiers according to their distance from the base station . The node which are very close to the base station are placed in $Tier_1$ and nodes which cover mediate distance are placed in $Tier_2$ and nodes which are very far away from the base station are placed in $Tier_3$ respectively.In this architecture the minimum spanning tree of the graph is generated to show connection of all sensor nodes. Every sensor node has energy, used for communication in network. The highest energy node is elected as head node which will transmit the data to the base station. The least and largest possible distances d_1 and d_2 are calculated respectively. Least possible distance is distance of base station from middle of a side which is closer to it and largest distance is estimation between base station and the corner of the network which is on the opposite side of base station. Difference between these distances is calculated and is used for determining tiers based on given formula.

- $Tier_1$ = range is between d and $d_1 + \frac{diff}{3}$
- $Tier_2$= range is between $d1 + \frac{diff}{3}$ and $d1 + 2 * \frac{diff}{3}$
- $Tier_3$= range is between $d1 + 2 * \frac{diff}{3}$ and $d2$

These three tiers follow top tier shifting approach in which each tier's nodes continuously send data to base station till there energy does not become less than current threshold value. When energy of nodes of a tier becomes less than threshold value then the nodes of next upper tier start transmitting data to base station. When the uppermost tier nodes energy goes below the threshold value then a new threshold value is defined. This whole procedure is repeated again and again till new defined threshold is less than the dead energy,and when this stage is achieved, all nodes of the network goes down and whole network environment is assumed to be dead.

The figure 4.1 shows the number of sensor nodes are placed randomly in a rectangular plane and the solid dark lines represents the number of tiers in this plane. There are three tires in this sensing field. The nodes which are closest to the base station are placed in $Tier_1$ and which

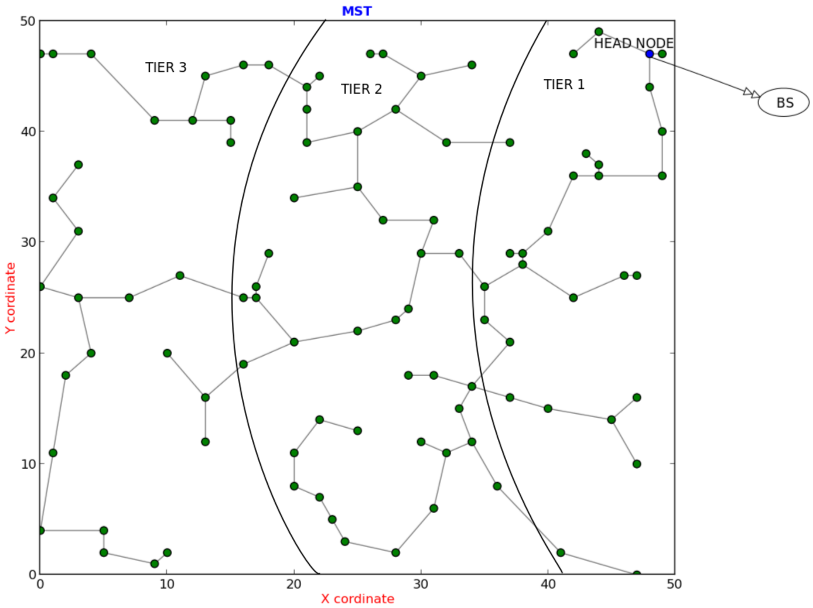

Figure 4.1: Head node from $Tier_1$ send data to BS using random deployment

are far away from the Base station are place in $Tier_3$. By using prims technique a minimum spanning tree is generated and head node is selected on the basis of maximum remaining energy and this node send the data to the base station.

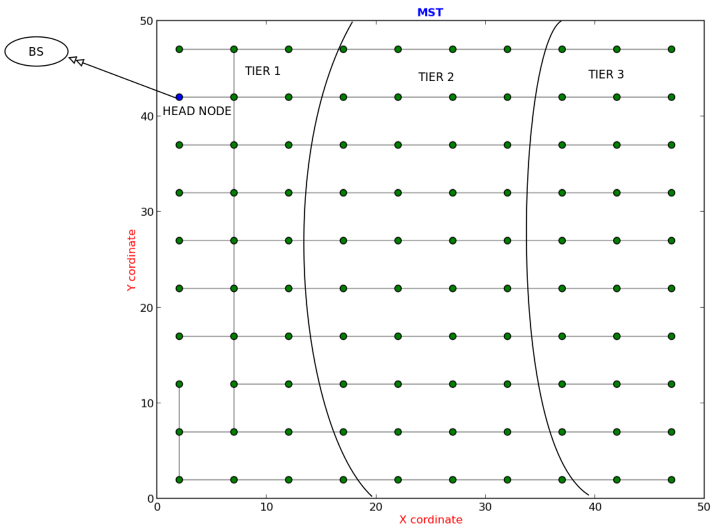

Figure 4.2: Head node from $Tier_1$ send data to BS using uniform deployment

The figure 4.2 shows the uniform deployment of nodes in a sensing field . In this technique three tires are made based on the distance of fixed position base station located at (25,150). The base station is located outside the sensing field and have an unlimited power resources. Every tier head node first compares its energy to the threshold energy and start communicating data from source node to BS using minimum spanning tree. The base station is further responsible for sending the data to the external network. The Algorithm 1 shows the step by step procedure for TBEEP.

Algorithm 1: TBEEP

1 **Algorithm** *TBEEP(Source_Node)*

2 Nodes are placed in a specified or decided area in a uniform/Random manner and each node is initialized with some initial energy. Then these nodes are classified in the form of tiers on the basis of distance from the base station.

3 MST is generated by using prims algorithm.

4 A node is selected having highest energy in tier 1 as head node. If its energy is greater than the required transmission energy then it can transmit the data to base station .

5 On transmitting data to base station, some energy value is reduced for head node and when its energy goes below dead energy then that node is discarded.

6 Now another node is chosen from tier 1 on the basis of condition described in step 4. Continue nodes selection process is repeated from tier 1 till there is no such node left in tier 1 whose energy is greater than threshold energy.

7 A node having energy greater than transmission energy is selected from next tier and data is relayed to base station from that node.

8 Nodes selection process and going to next tier is repeated till tier id gets equals to 4.

9 At this stage a new threshold value is defined which is half of the previous one and tier id is set to 1.

10 Now again tier 1 will be executed and this whole process is repeated till threshold energy goes below dead energy which will take the whole network down.

4.2 Experiment Results

Simulation is performed on 100 nodes deployed randomly and uniformly in a sensing field of area $50{*}50m^2$, taking 0.5 J/node as initial energy in this area and base station is fixed at location (25,150) in case of Tier based energy efficient protocol(TBEEP)and examine the rounds in which nodes are dead. Once the node is dead it is removed from the simulation environment. The proposed three techniques show the better and close to optimal solution as compared to LEACH. The tables 4.1 show the comparison results among three different techniques.

Table 4.1: Lifetime of TBEEP with initial energy 0.5J/node

DEAD NODE	RANDOM	UNIFORM	LEACH
1	1204	2391	803
2	1204	2393	812
3	1204	2397	821
4	1204	2398	830
5	1204	2398	839
6	1204	2398	848
7	1611	2398	857
8	1611	2399	866
9	1819	2400	875
10	1819	2402	884
11	1819	2402	893
12	1820	2402	902
13	1827	2402	911
14	1948	2403	920
15	2008	2403	929
16	2009	2405	938
17	2021	2405	947
18	2023	2405	954
19	2067	2411	962
20	2088	2411	964
21	2090	2434	966
22	2092	2434	968
23	2111	2434	970
24	2113	2434	972
25	2113	2434	974
26	2117	2434	976
27	2118	2434	978
28	2119	2434	980
29	2121	2434	982
30	2122	2434	984

Continued on next page

Table 4.1 – *Lifetime of TBEEP with initial energy 0.5J/node*

DEAD NODE	RANDOM	UNIFORM	LEACH
31	2123	2434	986
32	2124	2434	988
33	2124	2434	990
34	2127	2434	992
35	2127	2434	994
36	2141	2434	996
37	2142	2434	998
38	2143	2434	1004
39	2144	2434	1008
40	2150	2434	1012
41	2155	2434	1014
42	2156	2434	1018
43	2156	2434	1020
44	2160	2434	1024
45	2173	2434	1026
46	2198	2434	1028
47	2220	2434	1030
48	2220	2434	1034
49	2220	2434	1036
50	2220	2434	1040
51	2220	2434	1044
52	2220	2434	1048
53	2221	2435	1052
54	2223	2447	1056
55	2227	2449	1060
56	2227	2449	1064
57	2228	2450	1068
58	2229	2450	1072
59	2229	2450	1076
60	2229	2451	1080
61	2230	2451	1084

Continued on next page

Table 4.1 – *Lifetime of TBEEP with initial energy 0.5J/node*

DEAD NODE	RANDOM	UNIFORM	LEACH
62	2230	2451	1088
63	2230	2460	1092
64	2232	2467	1096
65	2232	2685	1100
66	2233	2697	1104
67	2233	2701	1108
68	2234	2702	1112
69	2236	2703	1116
70	2236	2704	1120
71	2239	2704	1124
72	2239	2708	1128
73	2241	2714	1132
74	2246	2731	1136
75	2258	2924	1140
76	2299	2936	1144
77	2299	2940	1148
78	2299	2960	1152
79	2299	2962	1156
80	2299	2962	1160
81	2299	2962	1164
82	2299	2962	1168
83	2299	2962	1172
84	2299	2962	1176
85	2299	2962	1180
86	2299	2962	1184
87	2299	2962	1188
88	2299	2962	1192
89	2299	2962	1196
90	2299	2962	1200
91	2299	2962	1201
92	2299	2962	1201

Continued on next page

Table 4.1 – *Lifetime of TBEEP with initial energy 0.5J/node*

DEAD NODE	RANDOM	UNIFORM	LEACH
93	2299	2962	1201
94	2299	2962	1202
95	2299	2962	1202
96	2299	2962	1204
97	2299	2962	1204
98	2299	2962	1205
99	2299	2962	1206
100	2299	2962	1208

The table 4.1 shows the lifetime of network for proposed protocol TBEEP in both random and uniform deployment. The initial energy of each sensor node is 0.5 joule. The proposed technique shows the better results in contrast to the existing technique. In TBEEP the network is deployed by using random and uniform deployment techniques. In random deployment first node dead at 1204 and last node at 2299 round but in uniform deployment the first node dead at 2391 and network is dead at 2962 round. In case of LEACH protocol first node dead at round 803 and last node at 1208 round. The table 4.2 shows the inputs parameters for transmission of 2000 bits message over the network.

Table 4.2: Input requirements

1	Initial Energy	5 joule
2	Packet size	2000 bits
3	E_t	5 nj/bit
4	E_{amp}	100 pj/bit/m^2
5	Number of nodes	100
6	Area	50*50 m^2
7	Dead Energy	0.002 joule
8	Threshold Energy	0.256 joule
9	Position Of BS	(50,100)

The table 4.3 results are simulated on a network comprising of 100 nodes scattered in the area of $50m * 50m$ in which all the nodes are having initial energy 0.5 joule and base station is located at (25,150) which is far away even from the nearest node. A node is considered to be dead when its remaining energy reaches to dead energy which is 0.002 joule. Initially threshold energy is defined to be 0.256J which becomes half of its previous value when the threshold energy is same on each tier.

Table 4.3: Transmission cost of packets when 1%, 20%, 50%, 100% nodes die.

Energy J/Node	Protocol	1.00%	20.00%	50.00%	100.00%
0.25	RANDOM	620	834	1083	1180
0.25	UNIFORM	601	1013	1103	1156
0.25	LEACH	402	480	523	635
0.5	RANDOM	1204	2067	2220	2299
0.5	UNIFORM	2391	2411	2434	2962
0.5	LEACH	803	962	1036	1208
1	RANDOM	3217	3349	4591	4781
1	UNIFORM	2409	3935	4574	4677
1	LEACH	1610	1921	2055	2351

The figure 4.3 includes results of proposed work, giving details for the round number corresponding to which a node dies.

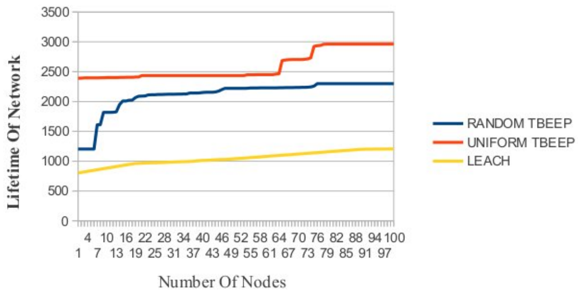

Figure 4.3: Round number corresponding to which a node dies

The figure 4.4 depicts compared analysis of percentages of nodes died and the number of rounds they survived for all techniques. This results the round in which the 1%, 20%, 50% and 100% nodes are dead.

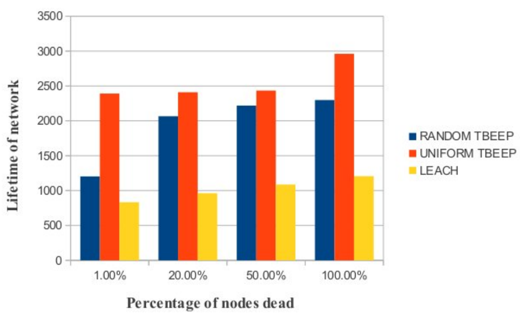

Figure 4.4: Results for a 50m*50m network with initial energy 0.5J/node

4.3 Single Path Routing Algorithm

The single path routing algorithm use only a single path for communication. The idea behind to identify the optimal path from the sensing field by the use of fuzzy cardinal priority ranking as described in algorithm 3 and this path is used for sent the data to the base station. This process is repeat again and again either the data is sent to the destination or the packet is dropped. The figure shows the optimal path identification process by using single path routing algorithm.

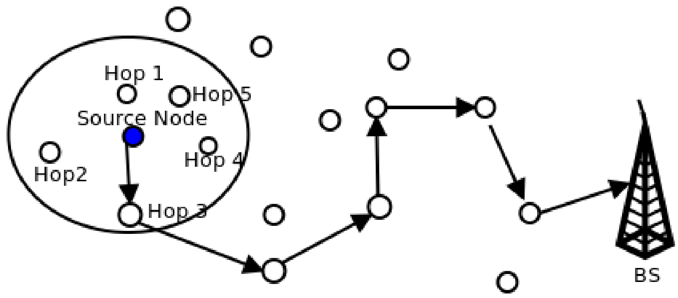

Figure 4.5: Single path routing algorithm

The list of the hops that are directly connected to source node are obtained and we have to find out the optimal hop suitable for data transmission. The objective of algorithm is to calculate the total energy and maximum delay . To find out the total energy consumed by each hop to transmit the data we have to calculate the transmission energy of each node by using radio model as described in section 3. The total delay of a hop is maximum delay introduced by each link . The mathematical representations of the above are as follows.

$$Er_{hops} = E_{TX} \tag{13}$$

$$Dr_{Hop_s} = Dr_{link} \tag{14}$$

Where E_{TX} is the transmission energy and Dr_{Hop_s} is the delay of hop. After getting this data we have to calculate maximum energy and minimum energy and maximum delay and minimum. This is done by performing comparison between all the hops. By using these parameters we can get the membership sets whose range is between 0 and 1. These membership sets are used to calculate β factor. For this purpose the formulae used are shown below.

$$\mu_1 = \frac{E_{max_{hop}} - E^k}{E_{max_{hop}} - E_{min_{hop}}} \tag{15}$$

$$\mu_2 = \frac{D_{max_{hop}} - D^k}{D_{max_{hop}} - D_{min_{hop}}} \tag{16}$$

Where

k: hop number

E: Energy of k^{th} hop

D: Delay of k^{th} hop

The problem is to find out the best hop among the hops, with low transmission energy and minimum delay . Therefore multi objective parameters are used by the fuzzy cardinal priority ranking algorithm to find optimal hop.

4.3.1 Optimal Hop

Two membership sets of all hops are obtained. After calculating the cost function value for each hop a set of optimal values are obtained. For the communication purpose one optional hop is selected from the set and is called as best optimal hop. This done by using the membership function β_k, which provides the cardinal priority ranking of each hop. The hop for which the value of β_k factor is maximum is considered as the optimal hop. The β_k can be calculated by using the expression below.

$$\beta_k = \frac{\sum_{j=1}^{Mobj} \rho_j^l}{\sum_{j=1}^{Mobj} \sum_{l=1}^{K} \rho_j^l} \tag{17}$$

Where M_{obj} is the number of multiple objective used in communication and *k* represent the number of hops in the list. This process is repeat again and again till the optimal path is identified for communication.

Algorithm 2: SPRA

```
Algorithm SPRA(Source_Node)
    Deploy nodes in a specified or decided sensing field in a random manner and
    initialize each node with some amount of initialize energy.
    Delay of particular link is distributed randomly in a network.
    Assign a unique identification number to each node in a network.
    Apply the Fuzzy Cardinal Priority Ranking as described in Algorithm 3 to find the
    optimal neighbour node for communication and repeat this process till it reaches the
    destination .
    After identifying the optimal path send the data to BS .
    Deprive the energy consumed by the path to transfer the packets. If the available or
    remaining energy of the nodes is lesser than the dead energy then remove all the
    dead nodes from the network.
    If the current path is not able to transmit the data then packet is dropped by receiver.
    Repeat this process untill the threshold energy is not equal to the dead energy and
    network is considered to be dead.
```

The following algorithm is used to find optimal path for communication are shown below.

Algorithm 3: Fuzzy Cardinal Priority Ranking for Finding Best Hop

Algorithm *fuzzy logic(Neighbour_ list)*
    /* Neighbour_ List is actually list of list in the form [(a,b,2,4,1) (b,c,3,6,1)] */
    initialization
    Total Neighbour Energy Cost← 0
    Total Neighbour Delay Cost← 0
    for $i \leftarrow 0$ **to** $length(Neighbour\_List)$ **do**
        Total Energy(i)←Sum of energy of each hop of Neighbour List
        Total Delay(i)←Sum of delay of each hop of Neighbour List
    end
    Total Energy and Total Delay lists will be obtained
    $E_{max} \leftarrow$ maximum of Total Energy
    $E_{min} \leftarrow$ minimum of Total Energy
    $D_{max} \leftarrow$ maximum of Total Delay
    $D_{min} \leftarrow$ minimum of Total Delay
    for $i \leftarrow 0$ **to** $length(Neighbour\_List)$ **do**
        Fuzzy Energy Cost(i)← $(E_{max} - i)$ / $(E_{max}$ - $E_{min})$
        Fuzzy Delay Cost(i)← $(D_{max} - i)$ / $(D_{max}$ - $D_{min})$
        Total Fuzzy Energy Cost=Total Fuzzy Energy Cost(i)+Fuzzy Energy Cost(i)
        Total Fuzzy Delay Cost=Total Fuzzy Delay Cost(i)+Fuzzy Delay Cost(i)
    end
    This will give cost list according to all two parameters in range of 0 to 1
    Sum ← Total Fuzzy Energy Cost+Total Fuzzy Delay Cost
    for $j \leftarrow 0$ **to** $length(FuzzyEnergyCost)$ **do**
        β factor list(j)← $FuzzyEnergyCost(j) + FuzzyDelayCost(j)$ / sum
    end
    βmax← maximum in β factor list
    return path with value βmax
/* maximum value of beta max gives first optimal path. */
/* second maximum value gives next optimal path(second). */

Chapter 5
Multipath Routing in WSNs

5.1 Multi Path Routing Algorithm

The first part of this algorithm is shown in figure 5.1. The nodes are deployed randomly in a fixed size sensing field. When the event is triggered the sensor nodes sense the analog data and by the use of ADC converted into digital data. In MPRA protocol initial energy, delay and hop number are distributed randomly over the network. Multiple minimum spanning trees are generated from source sensor node to the BS and stored in a routing table. By using Fuzzy Cardinal Priority ranking algorithm the optimal path is chosen and data is sent to base station. If the current path is not able to send the data the next optimal path is chosen from the routing table by using Fuzzy Cardinal Priority ranking algorithm and tries again. This process is repeated again and again either the data is sent to the destination or all the paths are exhausted. The packets are dropped if all the path are exhausted.The figure 5.1 shows number of node which are in range of source node in a circle. The source node find all the possible paths through which it can communicate to sink. The sink are represented by the wireless tower which act as a base station with unlimited power. The base station is connected to the external network or end user for transmitted the packets to the end users.

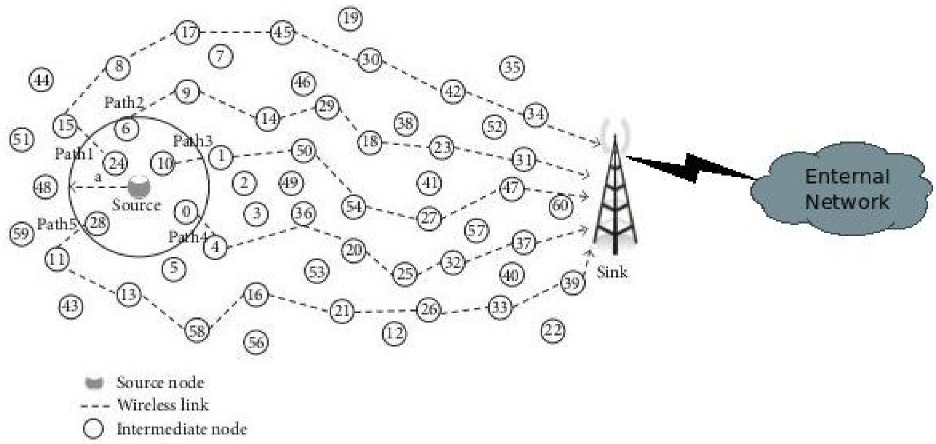

Figure 5.1: Multi path routing algorithm

After getting the table of these paths we have to find out the optimal path suitable for data transmission. The proposed algorithm calculate the total energy, maximum delay and the hop count of each path. To find out the total energy of a path we have to add the energies of all the nodes involved in a path. The total delay of a path is identified by adding the delay introduced by each link between two hops while the hop counts are the number of nodes involved in a particular path. The mathematical representations of the above are as follows.

$$Er_{path_s} = \Sigma_i^{hop_s} Ec_i \tag{18}$$

$$Dr_{path_s} = \Sigma_{i=1}^{hop_p} Dr_{link} \tag{19}$$

$$HC_{path_s} = \Sigma_{i=1}^{hop_p} hop_n \tag{20}$$

where Er_{path_s} is the amount of energy consumed during transmission of data, Dr_{path_s} is the total delay during communication and HC_{path_s} represents the number of hops in communication. After getting this data we have to calculate maximum energy and minimum energy, maximum delay and minimum delay and maximum hop count and minimum hop count. This is done by performing comparison between all the paths. By using these parameters we can get the membership sets whose range is between 0 and 1. These membership sets are used to calculate β factor. For this purpose the formulae used are shown below.

$$\mu_1 = \frac{E_{max} - E^k}{E_{max} - E_{min}} \tag{21}$$

$$\mu_2 = \frac{D_{max} - D^k}{D_{max} - D_{min}} \tag{22}$$

$$\mu_3 = \frac{H_{max} - H^k}{H_{max} - H_{min}} \tag{23}$$

Where

k: Path number

E: Energy of k^{th} path

D: Delay of k^{th} path

H: Hop count of k^{th} path

The problem is to find out the best path among the paths, with low transmission energy, minimum delay and less number of hops. Therefore multi objective parameters are used by the fuzzy cardinal priority ranking algorithm to find optimal path.

5.1.1 Optimal Path

After calculating the cost function value for each path a set of optimal values are obtained. For the communication purpose one optional path is selected from the set and is called as best optimal path. This done by using the membership function β_k, which provides the cardinal priority ranking of each path. The path for which the value of β_k factor is maximum is considered as the optimal path. The β_k can be calculated by using the expression below.

$$\beta_k = \frac{\sum_{j=1}^{Mobj} \rho_j^l}{\sum_{j=1}^{Mobj} \sum_{l=1}^{K} \rho_j^l} \tag{24}$$

Where M_{obj} is the number of multiple objective used in communication and *k* represent the number of paths in each list. The fallowing algorithms show step by step procedure for communication.

Algorithm 4: MPRA

---

1 **Algorithm** *MPRA(Source_ Node)*

2 Deploy nodes in a specified or decided sensing field in a random manner and initialize each node with some amount of initialize energy.

3 Delay of particular link is distributed randomly in a network.

4 Assign a unique identification number to each node in a network.

5 By the use of greedy approach find the multiple optimal or best paths from source node towards base station(BS) and stored in a routing table.

6 Follow algorithm 5 by using fuzzy logic to find the best optimal path by using the parameters transmission energy, remaining energy, hop count and delay.

7 If the optimal path is obtained in a result go to step 9. If the resultant is not an optimal path then go to step 8.

8 If the routing table do not have any path from source node to the base station then packet dropped go to step 11.

9 Now the transmission of data take place through this path and this process will consume the energy (as specified in radio model) and increase the packet received variable by 1 go to step 11. If the remaining energy of any node is less than the transmission energy and receiving energy then the node is consider to be dead node and the current path is not used for communication and go to step 10.

10 Now choose a next optimal path from the routing table and apply step 7.

11 The process repeat untill the energy of node is not equal to dead energy which will take the whole network down.

The following algorithm shows the procedure for find best path among the path list using Fuzzy Cardinal Priority Ranking algorithm.

Algorithm 5: Fuzzy Cardinal Priority Ranking

Algorithm *fuzzy logic(Path_ list)*

/* Paths_ List is actually list of list in the form [(a,b,2,4,1) (b,c,3,6,1)] */

initialization

Total Fuzzy Energy Cost← 0

Total Fuzzy Delay Cost← 0

Total Fuzzy Hop count Cost← 0

for $i \leftarrow 0$ **to** $length(Paths\_List)$ **do**

Total Energy(i)←Sum of energy of each sub path of path

Total Delay(i)←Sum of delay of each sub path of path

Total Hop count(i)←Sum of hop counts of each sub path of path

end

Total Energy, Total Delay, Total Hop count lists will be obtained

$E_{max} \leftarrow$ maximum of Total Energy

$E_{min} \leftarrow$ minimum of Total Energy

$D_{max} \leftarrow$ maximum of Total Delay

$D_{min} \leftarrow$ minimum of Total Delay

$H_{max} \leftarrow$ maximum of Total Hop count

$H_{min} \leftarrow$ minimum of Total Hop count

for $i \leftarrow 0$ **to** $length(Paths\_List)$ **do**

Fuzzy Energy Cost(i)← $(E_{max} - i)$ / $(E_{max}$ - $E_{min})$

Fuzzy Delay Cost(i)← $(D_{max} - i)$ / $(D_{max}$ - $D_{min})$

Fuzzy Hop count Cost(i)← $(H_{max} - i)$ / $(H_{max}$ - $H_{min})$

Total Fuzzy Energy Cost=Total Fuzzy Energy Cost(i)+Fuzzy Energy Cost(i)

Total Fuzzy Delay Cost=Total Fuzzy Delay Cost(i)+Fuzzy Delay Cost(i)

Total Fuzzy Hop count Cost=Total Fuzzy Hop count Cost(i)+Fuzzy Hop count Cost(i)

end

This will give cost list according to all three parameters in range of 0 to 1

Sum ← Total Fuzzy Energy Cost+Total Fuzzy Delay Cost+Total Fuzzy Hop count Cost

for $j \leftarrow 0$ **to** $length(FuzzyEnergyCost)$ **do**

β factor list(j)← $FuzzyEnergyCost(j) + FuzzyDelayCost(j) + FuzzyHopcountCost(j)$ / sum

end

βmax← maximum in β factor list

return path with value βmax

/* maximum value of beta max gives first optimal path. */

/* second maximum value gives next optimal path(second). */

5.2 Experiment Results

Simulation is performed on 100 sensor nodes are scattered randomly in an area of 100*100 m^2.The MPRA is compared with SPRA (single path routing algorithm) and MPRA shows better results.The range of each sensor node is 20 meter and the position of base station is (90,90). During initialization phase the energy of each node is 0.5 joule and delay is distributed randomly in a range of [1,10]ms. The delay is regarded as application specific. The table 5.1 shows the life time of network using MPRA and SPRA algorithm.

Table 5.1: SPRA and MPRA lifetime

DEAD NODE	SPRA	MPRA
1	1138	3912
2	1148	4434
3	1158	4751
4	1168	5237
5	1178	5518
6	1188	5749
7	1198	5982
8	1208	6027
9	1218	6285
10	1228	6488
11	1238	6513
12	1248	6600
13	1258	6655
14	1268	6656
15	1278	6657
16	1288	6658
17	1290	6659
18	1309	6660
19	1319	6661
20	1328	6662
21	1338	6663
22	1359	6664
23	1368	6665

Continued on next page

Table 5.1 – *SPRA and MPRA lifetime*

DEAD NODE	SPRA	MPRA
24	1368	6666
25	1377	6667
26	1383	6668
27	1399	6669
28	1407	6670
29	1410	6671
30	1428	6672
31	1438	6673
32	1448	6674
33	1458	6675
34	1468	6676
35	1478	6677
36	1488	6678
37	1499	6679
38	1507	6680
39	1518	6681
40	1518	6682
41	1536	6683
42	1548	6684
43	1558	6685
44	1567	6686
45	1577	6687
46	1585	6688
47	1597	6689
48	1608	6692
49	1610	6694
50	1628	6695
51	1628	6696
52	1638	6697
53	1648	6698
54	1650	6699

Continued on next page

Table 5.1 – *SPRA and MPRA lifetime*

DEAD NODE	SPRA	MPRA
55	1668	6700
56	1678	6701
57	1688	6702
58	1699	6703
59	1705	6704
60	1718	6705
61	1728	6706
62	1738	6707
63	1748	6708
64	1758	6709
65	1768	6710
66	1778	6712
67	1788	6713
68	1799	6714
69	1805	6715
70	1818	6726
71	1829	6737
72	1839	6749
73	1848	6750
74	1858	6761
75	1868	6773
76	1878	6784
77	1888	6795
78	1898	6817
79	1908	6830
80	1919	6841
81	1929	6852
82	1939	6863
83	1948	6875
84	1957	6886
85	1966	6897

Continued on next page

Table 5.1 – *SPRA and MPRA lifetime*

DEAD NODE	SPRA	MPRA
86	1977	6900
87	1988	6911
88	1999	6923
89	2000	6937
90	2002	6949
91	2004	6952
92	2006	6963
93	2008	6975
94	2010	6986
95	2011	6990
96	2012	7001
97	2013	7004
98	2014	7008
99	2015	7009
100	2015	7010

The following figure 5.2 and 5.3 shows the life cycle of MPRA and SPRA protocol.The x-axis represent the number of nodes and the y-axis represent the lifetime of network.

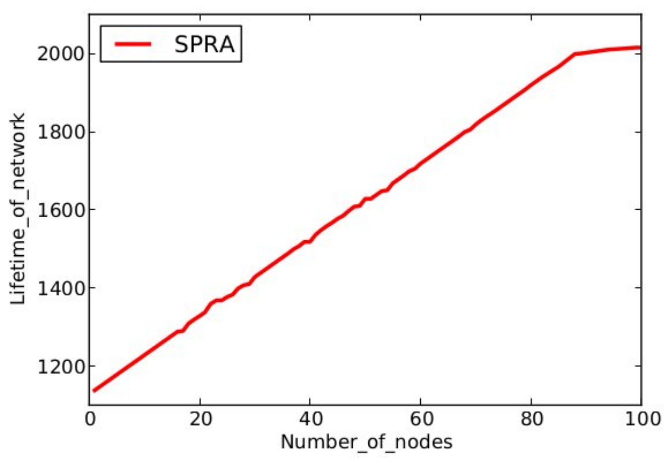

Figure 5.2: Single path routing algorithm lifetime

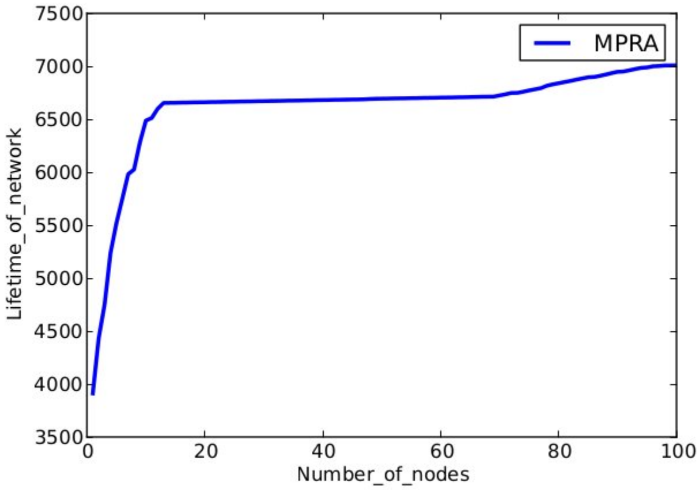

Figure 5.3: Multipath routing algorithm lifetime

The diagram 5.4 shows the percentage of dead nodes in a network when SPRA and MPRA routing algorithm are used. The x axis shows the percentage of nodes dead and y axis shows the life time of network.

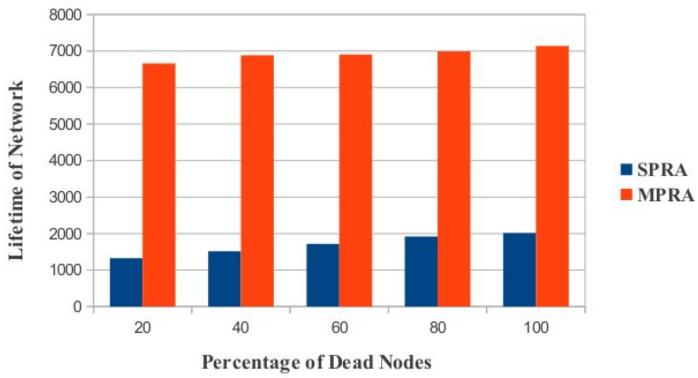

Figure 5.4: Comparison of transmission cost of packet vs percentage of node dead

The energy used for transmitting the packet is a combination of energy used to start the circuitry i.e E_{elect} and the energy used for amplification denoted by E_{amp}. The energy used by E_{elect} is 50 nj/node and for amplification is 100 pj/m^2. The transmission energy and delay are distributed randomly all over the network links.

The energy consumed for transmitting a data from source to the based is calculated by using the formula as shown in section 3. The graph shows the comparison of single path routing protocol and Multi path routing algorithm average energy consumption. The x-axis shows the number of packet send by both the protocols and y-axis shows the average energy consumption. The value of delay constraint is 20ms. The initial energy of each sensor node is 0.5 joule .The range of the network is 20 m. The position of sink node is (90,90).

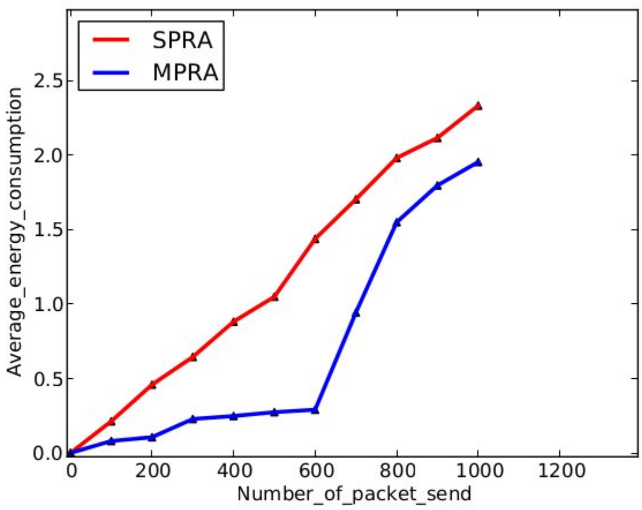

Figure 5.5: Average energy consumption

The figure 5.5 shows that the if the number of packet send by sensors nodes are increased the average energy consumption is increased linearly in case of single path routing algorithm. But in case of Multi path routing algorithm the results are better than the SPRA. In contrast to SPRA the energy used to transmit the data towards the base station is less in MPRA.

The reliability of network depends on the successful transmission of data. If the nodes send certain amount of data and the sink receives all the packets then the data delivery ratio probability is 1. The data delivery ratio is the amount of data received by the receiver. The energy for transmission is 100 pj/m^2 and 50 nj/node. The position of sink node is fixed at 90,90 coordinate. The range of the network is 20 meter. The figure 5.6 show the amount of data delivery ratio probability while considering the delay constraint. The delay parameter is application specific. The x-axis represent the application specific delay and y axis shows the data delivery ratio.

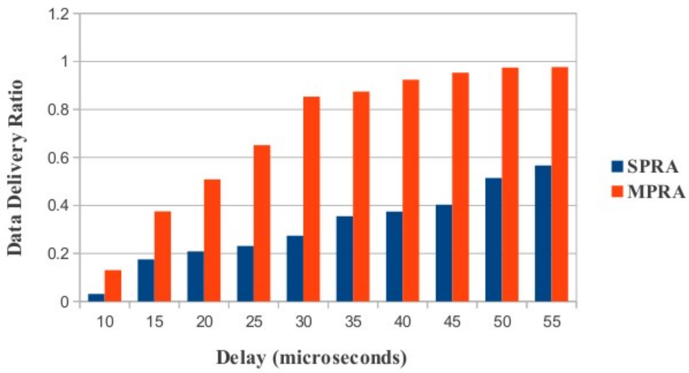

Figure 5.6: DDR Probability

The above figure represents the data delivery ratio probability and results near to optimal in case of MPRA. The graph shows the range of delay constraint in range of 10 to 50 microsecond. The delay is application specific parameter which is used by the user according to their application requirement. The data delivery ratio in case of SMPA is not more than 0.6 but in case of multi path routing algorithm the value reaches upto 0.9. If the value of delay constraint are limited by application then the DDR ratio dropped but if the delay constraint value is increased the data delivery ratio probability is also increased.

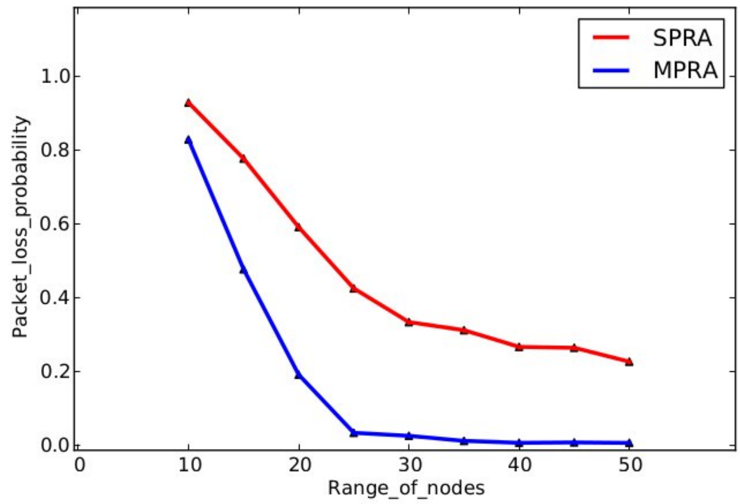

Figure 5.7: Packet loss probability

The packet loss probability is the amount of packet that are dropped by the receiver during the transmission. The graph is shown between the range of nodes and the packet loss probability. The base station is fixed at 90,90 and initial energy of sensor node is 0.5 nj/node. The energy used for transmitting the packet is a combination of energy used to start the circuitry i.e E_{elect} and the energy used for amplification denoted by E_{amp}. The energy used by E_{elect} is 50 nj/node and for amplification is 100 pj/m^2. The above graph shows that the packet loss probability in case of multi path routing algorithm which reaches near to Zero but in case of SPMA it do not show any optimal results. The x-axis represents the range of node and y-axis shows the packet loss probability. The range of node is considered between 0 to 50 meters. The above graph shows that if the range of node is between 0 to 10 meter then the probability of packet loss is high but when the range of node is increased up to 50 meters the probability of packet loss ratio gets reduce in both the protocols. The MPRA shows the better result in comparison to SPRA.

Chapter 6
Conclusion and Future Scope

In this work, three techniques are TBEEP, SPRA and MPRA are proposed and compared with an existing LEACH protocol. The simulation results show that the algorithms perform near to optimal. In Multi path routing algorithm a back up path is used when available path is not able to forward the packet to the base station. The energy consumption for both the schemes is less in comparison to LEACH. These proposed algorithms increase the lifetime of the network by increasing the number of rounds. In each round the minimum spanning tree is generated and tries to balance the load properly in network. In this present work the nodes contain homogeneous energy which are deployed randomly and uniformly in the network and remain static through out the routing scheme. As a future reference one can think of network incorporate mobility and using heterogeneous energy. In future we can make network more reliable by data storage capability, because in these algorithms if receiver node died before accepting data from sender all data will be lost. we can stop this limitation by storing data at sender before transferring to neighbor node.

References

[1] Heinzelman, Wendi Rabiner, Anantha Chandrakasan, and Hari Balakrishnan, ”Energy Efficient Communication Protocol for Wireless Microsensor Networks,” *In Proceedings of the Third Annual Hawaii International Conference IEEE*,pp. 1-10, 2000.

[2] Lindsey, Stephanie and C.S. Raghavendra, ”PEGASIS: Power Efficient Gathering in Sensor Information Systems,” *In Proceedings of Aerospace conference proceedings IEEE*, pp. 1125-1130, 2002.

[3] Tan, Huseyin Qzgur and Ibrahim Korpeoglu, ”Power Efficient Data Gathering and Aggregation in Wireless Sensor Networks,” *Artifical Computer Machine Sigmod Record*, vol.32(4), pp. 66-71, 2003.

[4] A.Manjeshwar, Arati and D.P. Agrawal, ”TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks,” *In IPDPS*, vol.1, pp. 189-196, 2001.

[5] Jung, Jongsik, Taekeun Park and Cheeha Kim, ”A Forwarding Scheme for Reliable and Energy-Efficient Data Delivery in Cluster Based Sensor Networks,” *IEEE Communications Letters*, vol.9(2), pp.112-114, 2005.

[6] H.Junping, Hu, Jin Yuhu and Dou Liang. ”A Time Based Cluster Head Selection Algorithm for LEACH.” *In Symposium on Computers and Communications IEEE*,pp. 1172-1176, 2008.

[7] Xin Liu, Quanyu Wang and Xuliang Jin, ”An Energy Efficient Routing Protocol for Wireless Sensor Networks,” *In Proceedings of the seventh World Congress on Intelligent Control and Automation IEEE*, pp. 1728-1735, 2008.

[8] Akramul Azim and M.M Islam, ”Hybrid LEACH: A Relay Node Based Low Energy Adaptive Clustering Hierarchy for Wireless Sensor Networks,” *In Proceedings of Ninth Malaysia International Conference on Communications IEEE*, pp. 325-339, 2009.

[9] Zhong Shen, Yilin Chang, Hai Jiang, Yanling Wang and Zhongjiang Yan, ”A Generic Framework for Optimal Mobile Sensor Deployment,” *IEEE Transactions on Vehicular Technology*, vol.59(8), pp. 4043-4057, 2010.

[10] Jisoo Shin and Changjin Suh, ”CREEC: Chain Routing with Even Energy Consumption,” *Journal of Communication and Networks*, vol.13(1), pp. 17-25, 2011.

[11] Meenakshi Sharma and Kalpana Sharma, "An Energy Efficient Extended LEACH," *In Proc. of Communication Systems and Network Technologies International Conference IEEE*, pp. 377-382, 2012.

[12] S.H Gajjar, K.S Dasgupta, S.N Pradhan and K.M Vala, "Lifetime Improvement of LEACH Protocol for Wireless Sensor Network," *In Proc. International Conference of Engineering IEEE*, pp. 1-6, 2013.

[13] Rupesh Mehta, Abhishek Pandey and Pratik Kapadia, "Reforming Clusters Using C-LEACH in Wireless Sensor Networks," *In Proc. of International Conference on Computer Communication and Informatics*, pp.1-4, 2012.

[14] Devendra Prasad and Gaurav Bathla, "An Energy Efficient Routing Protocol for Homogeneous Wireless Sensor Networks," *International Journal on Cloud Computing*, vol.1(1), pp. 22-29, 2011.

[15] Arezoo Yektaparast, Fatemeh-Hoda Nabavi and Adel Sarmast, "An Improvement on LEACH Protocol (Cell-LEACH)," *In Proc. of Advanced Communication Technology* , pp. 992-996, 2012.

[16] Mona, El.Saadawy and Eman Shaaban, "Enhancing S-LEACH Security for Wireless Sensor Networks," *In Proc. of Electro Information Technology International Conference IEEE*, pp. 1-6, 2012.

[17] A.K. Mohapatra, Natarajan Gautam and R.L. Gibson, "Combined Routing and Node Replacement in Energy Efficient Underwater Sensor Networks for Seismic Monitoring," *International Journal Of Oceanic Engineering*, vol.38(1), pp. 80-90, 2013.

[18] Hall, David and James Linas, "An Introduction to Multisensor Data Fusion," *In Proceedings of the IEEE Computer Society*, pp. 16-23, 1997.

[19] Zahra Taghikhaki, Nirvana Meratnia and J.M. Havinga, "Reliable and Energy-efficient Chain-cluster Based Routing Protocol for Wireless Sensor Networks," *In Proc. of Second International Conference of Sensor Networks*, pp. 248-253, 2013.

[20] Saima Maqbool, Nidhi Chandra and Shivraj Dagadi, "Selecting Optimal Forwarder based on Energy and Trust for Routing in WSN, " *In Proc. of Fifth International Conference on Computational Intelligence and Communication Networks*, pp. 368-373, 2013.

[21] Ali Ihbeel, H.I Sigiuk and Abdelhadi Alhnsh, ”Simulation Based Evaluation of MANET Routing Protocols for Static WSN,” *In Proc. of IEEE Computer Society*, pp. 63-68, 2012.

[22] P.K.Poonguzhali, ”Energy Efficient Realization of Clustering Patch Routing Protocol in Wireless Sensors Network,” *International Conference on Computer Communication and Informatics*, 2012.

[23] Yao Lan, Gao Fuxiang and Li Peng, ” An Energy-balanced Clustering Routing Protocol in Wireless Sensor Networks,” *In Proc. of Second International Conference on Power Electronics and Intelligent Transportation System*, pp. 283-286, 2009.

[24] M.Rajiullah and Shigeru Shimamoto , ”An Energy-Aware Periodical Data Gathering Protocol Using Deterministic Clustering in Wireless Sensor Networks (WSN),” *In Proceedings of IEEE Communications*, pp. 3016-3020, 2007.

[25] Binbin Hao and Xuelian Cai, ” Energy-efficient Routing Protocol for Large Scale Wireless Sensor Networks,” *Proc. of IEEE Computer Society*, pp. 1411-1415, 2009.

[26] Babar Nazir and Halabi Hasbullah, ” QoS aware Energy Efficient Routing Protocol for Wireless Sensor Network,” *In Proc. of IEEE Conference on Open Systems*, pp. 375-380, 2011.

[27] Muhammad Mahbub Alam, Md. Abdur Razzaque, Md. Mamun-Or-Rashid and Choong Seon Hong, ” Energy-Aware QoS Provisioning for Wireless Sensor Networks Analysis and Protocol,” *Journal of Communications and Networks*, vol.11(4), pp. 390-405, 2009.

[28] Maryam Dehnavi, Mohammad Reza Mazaheri, Behzad Homayounfar and Sayyed Majid Mazinani, ”Energy efficient and QoS based Multi-path Hierarchical Routing Protocol in WSNs,” *In proc. of International Symposium on Computer Consumer and Control*, pp. 414-418, 2012.

[29] Nirmala and Nallusamy, ”An Energy-Efficient and Enhanced QoS Aware of MAC Application Specific Protocol in the Distributed Wireless Sensor Networks,” *In Proc. of Fourth International Conference on Advanced Computing*, 2012.

[30] Paulo, Marco Aur and Angelo Perkusich, ” Energy Efficient Blind Flooding in Wireless Sensors Networks,” *In Proc. of IEEE Conference on Computer Society*, pp. 1736-1741 2008.

[31] Sayyed Majid and M.A.Naderi, ”An Energy-Efficient Real-Time Routing Protocol for Differentiated Data in Wireless Sensor Networks,” *In Proc. of 17th International Conference on Engineering of Complex Computer Systems*, pp. 302-307, 2012.

[32] Soni Chaurisia, Siddhartha Chauhan and L.K Awasthi, ”Energy Efficient Protocol for providing QoS for Wireless Sensor Network,” *In Proc. of International Conference on Industrial Electronics, Control and Robotics*, pp. 263-268, 2010.

[33] Marjan Radi, Behnam Dezfouli, Shukor Abd Razak and K.A Bakar, ”A Low-Interference Energy-Efficient Multipath Routing Protocol for Improving QoS in Event-Based Wireless Sensor Networks,” *In Proc. of Fourth International Conference on Sensor Technologies and Applications*, pp. 551-557, 2010.

[34] Xiao Shuo, Wei Xueye and Wang Ya, ” Multipath Routing Protocol for Wireless Sensor Network for Mine Security Monitoring,” *Journal of Mining Science and Technology science Direct* , vol.20, pp. 0148- 0151, 2010.

[35] Md. Abdur Razzaque and Choong Seon Hong, ”Analysis of Energy-Tax for Multipath Routing in Wireless Sensor Networks,” *Journal of Ann Telecommunication*, vol.65, pp. 117-127, 2010.

[36] Songzhu Xia and Su Wu, ” Ant Colony Based Energy-Aware Multipath Routing Algorithm for Wireless Sensor Network,” *In Proc. of IEEE Computer Society*, pp. 198-201, 2009.

[37] Lu Hong and Jing Yang, ” An Energy-Balance Multipath Routing Based on Rumor Routing for Wireless Sensor Networks,” *In proc. of Fifth International Conference on Natural Computation*, pp. 87-91, 2009.

[38] Prasenjit Chanak and Indrajit Banerjee, ” Energy Efficient Fault-Tolerant Multipath Routing Scheme for Wireless Sensor Networks,” *Journal of China Universities of Posts and Telecommunications*, vol.20, pp. 42-48, 2013.

[39] S.S Dubal and Achala Deshmukh, ” Energy Efficient Multipath Routing for Wireless Sensor Networks,” *International Conference of Current Trends in Technology*, pp. 382-481, 2011.

[40] Omar Banimelhem and Samer Khasawneh,” GMCAR: Grid-Based Multipath with Congestion Avoidance Routing Protocol in Wireless Sensor Networks,” *Computer Networks Elsevier*, vol.10, pp. 1346-1361, 2012.

[41] Sofiane Moada, M.T Hansenb, Raja Jurdakc, Branislav Kusyc and Nizar Bouabdallaha, " Load Balancing Metric with Diversity for Energy Efficient Routing in Wireless Sensor Networks," *Journal of Computer Science Elsevier*, vol.5, pp. 804-811, 2011.

[42] S.k Tejaswi and R.M Garimella, " Meshed Multipath Routing with Leveling in Route Discovery:An Efficient Strategy in Wireless Sensor Networks," *In Proc. of IEEE Conference of Creative Society*, 2009.

[43] Xiaoxia Huang and Yuguang Fang, " Multiconstrained QoS Multipath Routing in Wireless Sensor Networks," *In Journal of Wireless Network Springer*, vol.14, pp. 465-478, 2008.

[44] Bin Fu, RenFa Li, Xiongren Xiao, Caiping Liu and Qiuwei Yang, " Non-interfering Multipath Geographic Routing for Wireless Multimedia Sensor Networks,"*In Proc. of International Conference on Multimedia Information Networking and Security*, pp. 254-258, 2009.

[45] Bashir Yahya and Jalel Ben-Othman, " RELAX: An Energy Efficient Multipath Routing Protocol for Wireless Sensor Networks," *In Proc. of IEEE Computer Society*, pp. 750-755, 2010.

[46] Hind Alwan and Anjali Agarwal, "MQoSR: A Multiobjective QoS Routing Protocol for Wireless Sensor Networks," *International Journal of Sensor Networks*, vol.13, pp. 1-13, 2011.

[47] Ali Shareef and Yifeng Zhu, "Effective Stochastic Modeling of Energy-Constrained Wireless Sensor Networks," *Journal of Computer Networks and Communications*, vol.12, pp. 1-20, 2012.

[48] YANG Hai-Bo and CAI Wen-Yu, "Distributed Power Control Algorithm with Multi-QoS Constraints for Wireless Sensor Networks," *In Proc. of IEEE Conference*, pp.1031-1036, 2009.

List of Publication

[1] Mandeep Singh Bandral, Dr. Sushma Jain, ”Energy Efficient Protocol for Wireless sensor Network,”*IEEE International conference on recent advance and innovation in engineering*, May, 2014.

[2] Mandeep Singh Bandral and Sushma jain ,”Multi-criteria multi path routing using fuzzy cardinal priority ranking”. (Communicating)