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Enhancing Network Lifetime in Wireless Sensor Networks using Cluster-Tree based Data Gathering

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Abstract **– Wireless Sensor Networks are identified as one of the most important technologies of this century. Advances in wireless communication and modern electronics have led to the development of low-cost, low-power; multi-functional sensor nodes which are small sized and can communicate short distances. Sensor nodes consist of components capable of sensing, data processing and communication. WSN consisting of a large number of small sensors with low-power transceivers can be an effective tool for gathering data in a variety of environments. As sensor nodes are deployed in sensing field, they can help people to monitor and aggregate data. Researchers also try to find more efficient ways of utilizing limited energy of sensor node in order to give longer life time of WSNs. Network lifetime, scalability, and load balancing are important requirements for many data gathering sensor network applications. Therefore, many protocols are introduced for better performance. In the available literature, multi-hop routing protocol is well known for power saving in data gathering [5]. Researchers have used such types of the cluster-based (e.g., LEACH, EERP), the chain-based (e.g. PEGASIS) and the tree-based (e.g. TREEPSI) to establish their energy-efficient routing protocols. In this paper, we propose an improved version which uses both cluster and tree based protocols.**

Keywords **– Wireless Sensor Networks (WSNS), First Node Death (FND), Energy Efficient, Multi-Hop Routing Protocol.**

I. Introduction

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environ-mental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations. As the advances in hardware technology enables the manufacturing of low-cost sensors, wireless sensor networks have become one of the most active research fields in recent years. Although originally used for military surveillance, wireless sensor net-works have found wide applications in many other fields, such as environmental monitoring, seismic detection, inventory tracking and health monitoring. Advances in sensor technology, low-power electronics, and low-power radio frequency (RF) design have enabled the development of small, relatively inexpensive and low-power sensors, called micro sensors, which can be connected via a wireless network [1, 2, 3]. These sensor nodes (or simply nodes) are usually deployed randomly and densely in hostile environment. They collaborate to observe the surroundings and send the information back to the network manager (or base station) when abnormal events occur. For example, sensor networks can play an essential role in emergency situation such as fires, building collapses or extreme weather phenomena [6]. Since battery replacement is not an option for networks with thousands of physically embedded nodes, an efficient energy saving protocol is required to prolong the sensor network lifetime. Generally speaking, more the sensors close to circumstance, the more sensed information is precise when sensor are sensing events. For this reason, sensor nodes always are disposed plenty and densely in the sensing field. This is also why the traditionally expensive macro-sensor cannot achieve the goals. A growing number of technologies are now available to produce a sensor node whose volume is limited in few cubic centimeters [2].

Network lifetime can be defined as the time elapsed from the network operation starts until the first node (or the last node) in the network depletes its energy (dies). Energy consumption in a node can be due to either "useful" or "wasteful" operations. The useful energy consumption includes transmitting or receiving data messages, and processing query requests. On the other hand, the wasteful consumption can be due to overhearing, retransmitting because of harsh environment, dealing with the redundant broadcast overhead messages, as well as idle listening to the media. In order to save the transmission power, clustering [5,6], and multi-hop transmission techniques can be used. Adjacent sensors may sense the same data and therefore the data gathering can reduce the redundant data collection. Sensors close to each other in the network can be grouped into clusters and data obtained from sensors in the same cluster are aggregated and then reported to the base station (BS), data report to the BS can be performed by single hop or multi-hop transmission.

II. Overview of WSN

A. Features and Requirement

Application specific wireless sensor networks consist of hundreds to thousands of low-power multi-functioning sensor nodes, operating in an unattended environment, with limited computational and sensing capabilities, they demand following requirements [1].

- A sensor node should be inexpensive.
- Data gathering protocol should be efficient enough to give longer life to the network.
- Nodes should be able to form a network automatically without any external configuration.
- Sensor nodes should be able to work together and

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aggregate their data in a meaningful way.

B. System Architect

A sensor network can, in practice, be composed of tens to thousands of sensor nodes which are distributed in a wide area. These nodes form a network by communicating with each other either directly or through other nodes. One or more nodes among them will communicate with the user through the Base Station (BS), either directly or through the existing wired networks. Fig.1 shows a typical architecture of a sensor network in which sensor nodes are shown as small circles. Each sensor node typically consists of the five components [1] such as sensor unit, analog digital convertor (ADC), central processing unit (CPU), power unit, and communicationunit.ADC is a translator that tells the CPU what the sensor unit has sensed, and also informs the sensor unit what to do. Communication unit's task is to receive command or query from, and transmit data from CPU to outside world. CPU is the most complex unit. It interprets the command or query to ADC, monitors and controls power if necessary, processes received data,

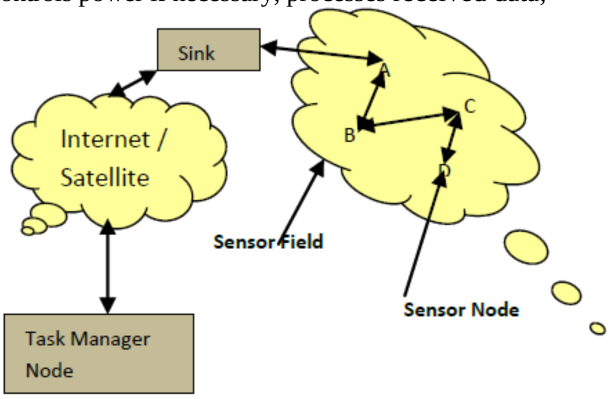

Fig.1. Architecture of Wireless Sensor Network

computes the next hop to the sink, etc. There may be many other application specific components beside these. Like in LEACH [5] and PEGASIS [7], we also use first order radio model for message transmission and reception. In this model, a radio dissipates $E_{elec} = 50$ nJ/bit to run the transmitter or receiver circuitry and $\epsilon_{amp} = 100$ pJ/bit/m^2 for the transmitter amplifier. The radios have power control and can expend the minimum required energy to reach the intended recipients. The radios can be turned off to avoid receiving unintended transmissions. An r2 energy loss is used due to channel transmission. The equations used to calculate transmission and reception costs for a k-bit message and a distance d are as below:

Transmitting:

$$E_{tx}(k, d) = E_{tx} - elec(k) + E_{tx} - amp(k, d) \quad \text{........(1)}$$

$$E_{tx}(k, d) = E_{elec} * k + \epsilon_{amp} * k * d^2 \quad \text{....... (2)}$$

Receiving:

$$E_{rx}(k) = E_{rx} - elec(k) \quad \text{........(3)}$$

$$E_{rx}(k) = E_{elec} * k \quad \text{....... (4)}$$

Data reception is also a high cost operation, therefore, the number of receptions and transmissions should be minimal to reduce the energy cost of an application. It is assumed that the radio channel is symmetric, so that the energy required to transmit a message from node i to node j is the same as the energy required to transmit a message from to node j to node i for a given signal-to-noise ratio (SNR). In addition to these, we assume a cost of 5nJ/bit/message for data fusion in receiver.

III. Related Work

In general, Wireless Sensor Networks (WSNs) can gather the sensed information by hundreds or even thousands of sensing nodes and transmit them to the sink. It uses the easiest way that sensor nodes transmit the sensed data to sink directly. Using this way is very simple, but it will have a serious problem. When a farther sensor node transmits the data, it will spend more energy than the closer one. Therefore, it is desirable to make these nodes as energy-efficient as possible and to rely on their large numbers in order to obtain high quality results. Likewise, the sensor network routing protocols must be designed to achieve fault tolerance in the presence of individual node failures while also minimizing energy consumption. Moreover, since the limited wireless channel bandwidth must be shared by all the sensors in the network, routing protocols for these networks should be able to perform local collaborations in order to reduce the bandwidth requirements. Eventually, the data being sensed by the nodes in the network must be transmitted to a control center (i.e., the sink) or base station where the end sensor nodes can access the data. At present, there are many routing methods in the wireless sensor networks [8, 9].The primary three types will be introduced as following Table 1.

Table 1: Comparison of protocol type

Protocol Type	Characteristics
Cluster Based	Nodes divide several clusters for cluster head sending
Chain Based	Nodes forming a long chain for chain head fuse
Tree Based	Build a tree like path for root node aggregation

i) LEACH

In [5], authors proposed a Low-Energy Adaptive clustering Hierarchy (LEACH) protocol. LEACH is representative cluster-based of routing protocols. It is also the first proposed in wireless sensor network and can reduce power consumption on avoiding the communication directly between sink and sensor nodes. In a sensor field, sensor node senses data and sends data to the sink that called "round". The working procedure for LEACH will be finished in a round. Before gathering the sensed data at each round, the huge number of sensor nodes will divide into several clusters and choose a cluster head randomly by self organization. Each cluster head is in charge of gather the sensed data from the sensor nodes in the cluster.

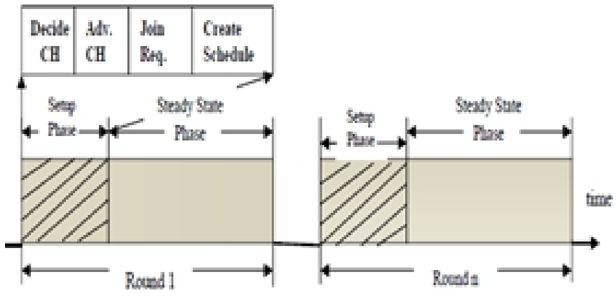

Fig.2. Round of Low-Energy Adaptive clustering Hierarchy (LEACH) protocol

The cluster head will aggregate the received data, and then send to the sink directly. After sink received all the data from cluster heads, a round will be ending. There are two phases in each round about LEACH, Setup phase and Steady-state phase.

This phase consists of two major steps: cluster formation and cluster head selection. Once the base station forms the primal clusters, they will not change much because all sensor nodes are immobile, whereas the selected cluster head in the same cluster may be different in each round. During the first round, the base station first splits the network into two sub clusters, and proceeds further by splitting the sub clusters into smaller clusters. The base station repeats the cluster splitting process until the desired number of clusters is attained. When the splitting algorithm is completed, the base station will select a cluster head for each cluster according to the location information of the nodes. For a node to be a cluster head, it has to locate at the center of a cluster. Once a node is selected to be a cluster head, it broadcasts a message in the network and invites the other nodes to join its cluster. The other nodes will choose their own cluster heads and send join messages according to the power of the many received broadcast messages. When the cluster head receives the join message from its neighbor node, it assigns the node a time slot to transmit data.

When the first round is over and the primal cluster topology is formed, the base station is no longer responsible for selecting the cluster head. The task of cluster formation is shifted from the base station to the sensor nodes. The decision to become a new cluster head is made locally within each cluster based on the node's weight value

ii) PEGASIS

In [6, 7], authors proposed a Power-Efficient Gathering in Sensor Information Systems (PEGASIS). PEGASIS is based on chain-based protocol and differ from LEACH. This proposal is building all sensor nodes to form a chain according to Greedy algorithm that the sum of edges must be minimum in wireless sensor networks. At the initial phase before each round, they must choose a chain head. The N represents the number of nodes and all the nodes use the natural number from 1 to N. Then WSNs utilize the i = j mod N to choose chain head. If i is equal to zero, then choose N. The two end-point of the chain will start send sensed data to the parent's nodes for forwarding data to the chain head. All the nodes in the chain only transmit data to its neighbor. Each edge only send or receive data one time. In [6], after the chain head received the two children nodes, it will aggregate the data and transmit the collecting data to sink directly.

iii) TREEPSI

In [4], authors proposed a Tree-based Efficient Protocol for Sensor Information (TREEPSI). TREEPSI is tree-based protocol that is different from abovementioned protocols. Before data transmission phase, WSNs will select a root node in all the sensor nodes. Set the root identify id=j. There are two ways to build the tree path. One is computing the path centrally by sink and broadcasting the path information to network. The other can be the same tree structure locally by using a common algorithm in each node. At the initial phase, root will create data gathering process to the children nodes using any standard tree traversal algorithm. The go into the data transmission phase after building the tree. All the leaf nodes will start sending the sensed data towards their parent nodes. The parent nodes will collect the received data with their own data. Then send the collected data to their parent. The transmission process will be repeated until all the received by the root node. After root node aggregating data, it send collecting data to sink directly. The process will go around until the root node dead. WSN will re-select a new root node. Root id number would be j+1. Then do the initial phase again like above. The tree path will not change until the root node dead. TREEPSI and PEGASIS are using the same way to transmit data from leaf node to chain/root head. The length of path form end leaf node to root/chain node in TREEPSI is shorter than PEGASIS. The data will not send data for a long path. For this reason, TREEPSI can reduce power consumption less in data transmission than PEGASIS. The TREEPSSI has better performance about 30% than PEGASIS. It still have a problem that restriction on the binary tree algorithm, The path has made a detour in the topology is discussed in table 2.

Table 2: Comparison of Scenarios

Issues	**LEACH**	**PEGASIS**	**TREEPSI**
Computation	Compare signal strength of cluster head periodically	Select chain head with Greedy algorithm	Select root head with standard tree algorithm
Framework	Cluster head	Chain based	Tree Based
Aggregation	Store cluster head	Store two neighbors	Fusion in each node

IV. Proposed Efficient Protocol

As in the above-mentioned section, the energy efficiency in tree-based protocol like TREEPSI is better than cluster based and chain-based protocol. If some sensor

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nodes send data to the sink, this information of nodes will make a detour. Thus, that will cause more power dissipation in data gathering. This situation is happened as building the binary tree paths, especially when the sensor field is large and the numbers of sensor nodes are large. In order to improve the reduction of power dissipation, we propose a novel protocol to combine the cluster-based and tree-based protocol to improve it. In the following, we will describe the deployment and method of the protocol. And the first we can see the flow chart of protocol clearly as Figure 3. According to reference above-mentioned routing protocols, the network assumptions can be initiated as follows [4, 5, and 6].

1) Each node or sink has ability to transmit message to any other node and sink directly.
2) Each sensor node has radio power control node can tune the magnitude according to the transmission distance.
3) Each sensor node has the same initial power in WSNs.
4) Each sensor node has location information.
5) Every sensor nodes are fixed after they were deployed.
6) WSNs would not be maintained by humans.
7) Every sensor nodes have the same process and communication ability in WSNs, and they play the same role.
8) Wireless sensor nodes are deployed densely and randomly in sensor field.

Sink could get the whole location and energy information about sensor nodes by two or other manners. One is recorded in the sink at the initial state as nodes were deployed. The other is that sink broadcast whole network, and then received the back message form sensor nodes.

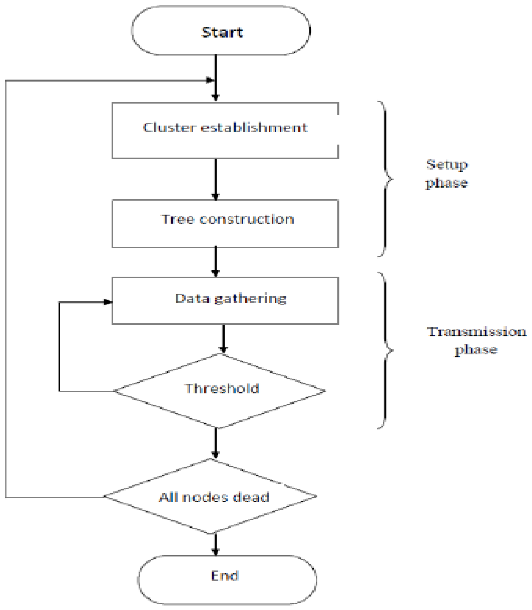

Fig.3. Flow chart of proposed protocol

i) Cluster establishment

Setup Phase

This phase consists of two major steps: cluster formation and cluster head selection. Once the base station forms the primal clusters, they will not change much because all sensor nodes are immobile, whereas the selected cluster head in the same cluster may be different in each round. During the first round, the base station first splits the network into two sub clusters, and proceeds further by splitting the sub clusters into smaller clusters.

Neighbor id	Residual Energy	Distance	Distance to BS	State	Weight

Fig.4. Neighbor table information

The base station repeats the cluster splitting process until the desired number of clusters is attained. When the splitting algorithm is completed, the base station will select a cluster head for each cluster according to the location information of the nodes.

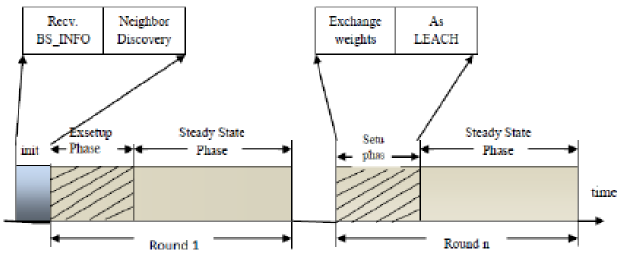

Fig.5. Extended Round of table

For a node to be a cluster head, it has to locate at the center of a cluster. Once a node is selected to be a cluster head, it broadcasts a message in the network and invites the other nodes to join its cluster. The other nodes will choose their own cluster heads and send join messages according to the power of the many received broadcast messages. When the cluster head receives the join message from its neighbor node, it assigns the node a time slot to transmit data. When the first round is over and the primal cluster topology is formed, the base station is no longer responsible for selecting the cluster head. The task of cluster formation is shifted from the base station to the sensor nodes. The decision to become a new cluster head is made locally within each cluster based on the node's weight value.

The pseudo code for all operation is given below:

Initialize {
1) Base station: acquire the number of clusters N;
2) Split the network into N clusters;
3) Choose cluster head from each cluster;
4) Notify the node to be cluster head.}
Repeat :{
1) Node i: if (Receive the notify message from the base station)
2) Work in cluster head mode;
3) If (Receive the broadcast message from cluster head node)
4) Work in sensing mode.
For cluster head i:{
1) Receive data born cluster member j;
2) Compute the weight value W_i and W_j;
3) If ($W_i > W_j$), W_i Work in cluster head;
4) Else i work in sensing mode;
5) Notify j to be cluster head ;}

ii) Constructing cluster based tree

Sink will collect the information that cluster head had labeled in each cluster and build path in minimum spanning tree to compute the tree path. The Minimum Spanning tree (MST) concept in the Greedy algorithms used to solve the undirected weight graph problem. After eliminating some of the connection links, the sub-graph still have the connection ability. For this reason, sub-graph can reduce the sum of the weights. A sub-graph who has the minimum sum of weights must be a tree like framework. Spanning tree could let all nodes conform to tree definition which is connected in the graph. A connected sub-graph which has a minimum sum of weights must be a spanning tree. On the contrary, it is not correctly absolutely. There could be several kinds Minimum spanning tree in a graph, and it is not the only one. But their sum of weight should be the same. If we use Brute Force to find the minimum spanning tree, it will produce huge computation time.

iii) Data Aggregation

After the routing mechanism has established, every tip nodes transmit gathering data to upper level nodes. Then the upper level nodes will fuse received data and sensed data by itself, and send the data to next upper level nodes. The process will keep going until the root node, cluster head, has aggregated the data in the cluster. It is called a "round" as all root nodes has finished transmitting data.

V. Methodology and Implementation

Our proposed method has several advantages in WSNs for data gathering. When first node death we has better performance. We can maintain the integrity of WSNs until FND (first node death). As Sink is far away sensor field, our method has the best rounds of data gathering obviously. Then we can get a results that nodes in dead uniformly in WSNs at each percentage of nodes death. We compare the topology of nodes death with other related protocols. The threshold mechanism plays an important role. It protected the root node death slowly, because each node has chances to be roots.

It also increase the number of nodes alive, means it increase the network lifetime as compare to others. With the help of simulation analysis and results we will show, how our protocol outperforms in terms of energy efficiency and first node death as compare to other conventional protocol of data gathering in wireless sensor networks.

In my work, the one new data gathering protocol for wireless sensor network has been introduced. Detailed simulations of wireless sensor network environment demonstrate that our DGP can reduce energy consumption, improve evenness of dissipated network energy and the ability of extending the life span of the network. In cluster-tree data gathering protocol presented for energy efficient data transfer in wireless sensor network. In this concept selecting the cluster heads in each cluster i have considered remaining energy in battery and distance as the factor. This protocol provides flexibility of assigning different energy's to different scenario. It reduces power consumption by avoiding the communication directly between sink and sensor nodes. Moreover, since the limited wireless channel bandwidth must be shared by all the sensors in the network, routing protocol for these networks should be able to perform local collaborations in order to reduce the bandwidth requirements.

5.1 Simulation Setup

Proposed protocol for randomly distributed 100 sensor nodes in network. The sensor fields of area 50m * 50m and 100m * 100m with sink located at (25,150) and (50,300) respectively. And we assume different initial energy (IE) levels as 0.25J, 0.5J, 1.0J for each node. Data packet length is assumed to be of 2000 bits.

We have used first order radio model for message transmission and reception. This radio model has already used in different protocol as LEACH [16], PEGASIS [13] and TREEPSI [12]. In this model, a radio dissipates Eelec = 50 nJ/bit to run the transmitter or receiver circuitry and Eamp = 100 pJ/bit/m^2 for the transmitter amplifier and a cost of 5 nJ/bit/message for data fusion in receiver. Therefore, the energy expended to transmit a *k*-bit packet to a distance *d* and to receive that packet with this radio model is:

E_{Tx} (k, d) = E_{elec} * k + E_{amp} * k * d^2

E_{Rx} (k) = E_{elec} *k

VI. Simulation Results and Performance Analysis

We have done the simulations for our proposed protocol to compute the maximum possible rounds of communication at different initial energy levels. Figure-1 shows a random distribution of 100 nodes in a 50m * 50m sensor field, where each node was having 0.25J initial energy and figure-2 shows a cluster formation of sensor nodes in network and in figure-3 trees are created in each cluster for data gathering process.

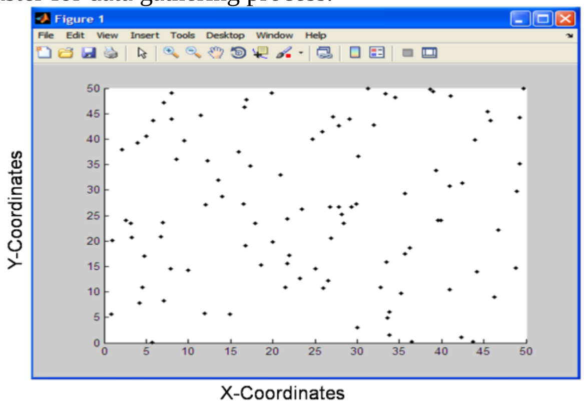

Fig.6. Random distribution of 100 nodes in 50m * 50m sensor field

We have observed the death rate of nodes in sensor network from simulation of different existing and proposed protocol, and we have collect information about the death rates of nodes with rounds of communication, it

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means that the round in when node begins to die to the round where all the nodes become dead.Table-1, table-2 and table-3 shows the possible round of communication for different protocol with different initial energy (IE) levels (0.25, 0.5 and 1) in 50 *50 m area, which are also shown in fig 4 for 0.25J/node, fig 5 for 0.5J/node and fig 6 for 1J/node.

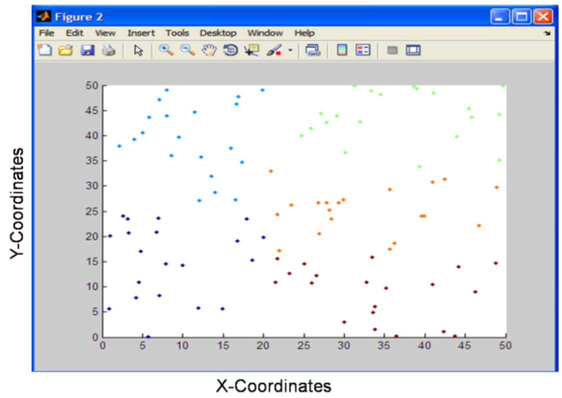

Fig.7. Cluster formation of sensor nodes

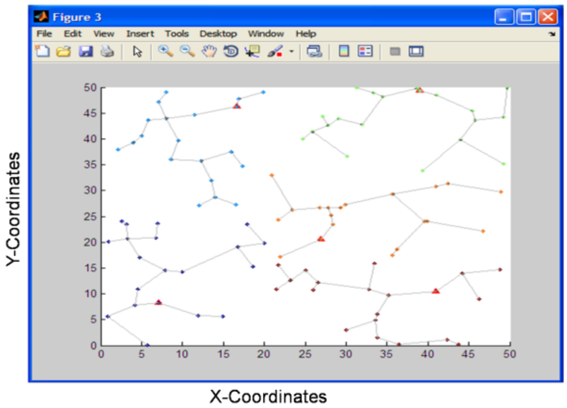

Fig.8. Tree constructed for data gathering

Table 3 Rounds of communications of different protocol for IE = 0.25 J/node

Energy (J/node)	Protocol	Round first node dies	Round last node dies
0.25	Direct	54	117
	LEACH	402	635
	PEGASIS	788	1096
	CTDGP	808	1110

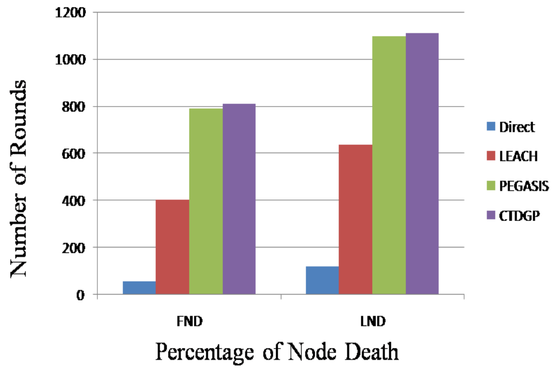

Fig.8. Performance results for a 50m * 50m network with initial energy 0.25J/node.

Table 4: Rounds of communications of different protocol for IE = 0.5 J/node

Energy (J/node)	Protocol	Round first node dies	Round last node dies
0.5	Direct	108	235
	LEACH	803	1208
	PEGASIS	1578	2192
	CTDGP	1621	2228

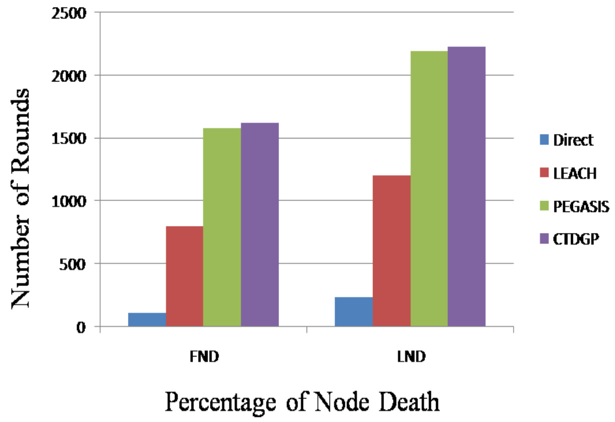

Fig.9. Performance results for a 50m * 50m network with initial energy 0.5 J/node.

Table 5: Rounds of communications of different protocol for IE = 1 J/node

Energy (J/node)	Protocol	Round first node dies	Round last node dies
1	Direct	215	471
	LEACH	1610	2351
	PEGASIS	3159	4379
	CTDGP	3251	4475

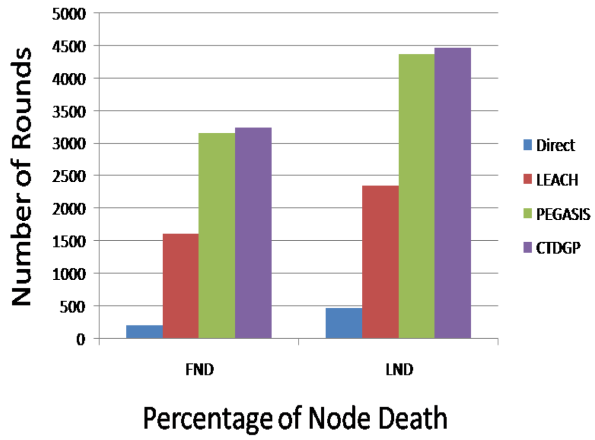

Fig.10. Performance results for a 50m * 50m network with initial energy 1 J/node.

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having Master degree in Computer Science and is a member of CSI (Computer Society of India) and is pursuing Ph D in Wireless Sensor network(WSN). He has a credit of many national and international papers. His qualifications are fortified with a great deal of creativity and problem solving skills. He has also a proven record of teaching for the last 7 years with presently working as Head of Department (CSE).