Tree-Based Energy Efficient Clustered Routing Strategy for Wireless Sensor Networks

Dolly
M.Tech, Scholar (CSE)
Shaheed Bhagat Singh State Technical Campus, Ferozepur, Punjab, India

Vishal Kumar Arora
Assistant Professor (CSE Dept.)
Shaheed Bhagat Singh State Technical Campus, Ferozepur, Punjab, India

Richa Sawhney
Lecturer
Shaheed Bhagat Singh State Technical Campus, Ferozepur, Punjab, India

ABSTRACT
The Wireless Sensor Network (WSN) is the collection of large no of low-cost micro-sensors which are used to collect and send various kinds of messages. Energy is the most important aspect of the WSNs because it determines the aliveness of wireless sensor node. Each sensor node sense knowledge and transmit it to its cluster head. Cluster head combination knowledge from its cluster and transmit the collected knowledge to the base station. Several energy economical gradable routing protocols are enforced within the past like LEACH, HEED, PEGASIS and TBC. To prolong the network lifetime, this work implements another tree-based cluster routing strategy known as Tree-Based Energy Efficient Clustering Protocol (TBEEC). In this work, the node having lesser distance to the base station and higher energy than the other nodes of the cluster is elevated as cluster head for a round. All nodes of cluster forward their data to the cluster head by using other intermediate nodes that lies on the way to the cluster head. Further, in this work inter-cluster communication is implemented to reduce the energy consumption. Every cluster head instead of transmitting aggregate data directly to the base station looks for intermediate cluster head that lies near to the base station. This way data has to travel at lesser distance that result in energy saving which prolongs the network lifetime? The proposed protocol overcomes the limitation of existing TBC protocol. The simulation results show that the proposed protocol performs better than the existing routing protocols such as LEACH, HEED, PEGASIS and TBC.

Keywords
LEACH, HEED, PEGASIS, TBC and WSN etc.

1. INTRODUCTION
Wireless sensor network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. WSNs were initially designed to facilitate military operations but its application has since been extended to health, traffic, and many other consumer and industrial areas. WSN's consists of more than hundreds of small spatially distributed autonomous devices using sensor called sensor nodes to monitor the physical and environmental situations such as sound vibration, temperature, pressure, motion and intensity of light at various place.

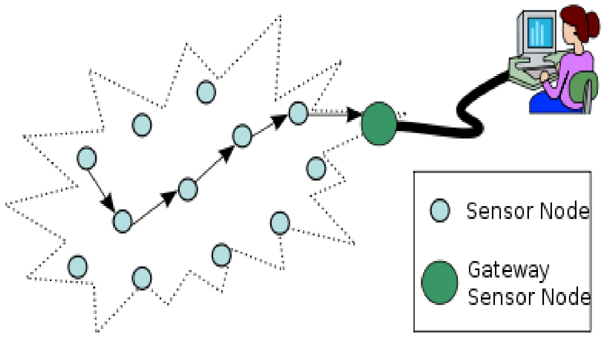

Fig 1: Wireless Sensor Network

A Wireless sensor Network is outlined as a network of devices called nodes that sense the atmosphere and communicate the knowledge gathered to the most station through wireless links. This info is temperature, pressure, sound, pollution levels, wind speed, humidity, direction etc. The WSN is made from some to many a whole lot or perhaps thousands nodes, every node is connected to at least one or many sensors.

Energy Efficiency in WSN: Energy efficiency is the important consideration in WSN. Each sensor node directly transmits data to the base station. However when base station is located far away from the target area, the sensor nodes will die quickly due to much energy consumption.

On the other hand since the distances are twines each node and base station (BS) is different, direct transmission leads to unbalanced energy consumption. To overcome the energy efficiency problems in wireless sensor network several algorithms and protocols are proposed.

Clustering: Cluster is a group of sensor nodes and connected with dedicated network. In large wireless sensor network, the sensor nodes that work together so that in many respects it can be grouped into clusters. Each cluster has a root node to organize the nodes in the cluster. Cluster structure can increase the lifetime of the network. CH collects data from base station and aggregate afterwards forward data to target node.

2. RELATED WORK
As we know the working procedure of WSN is collecting various information of the given task related and sending to the Base Station [1]. The nodes are

spread in the target area deployed randomly so, the base station will be far away from the nodes after finishing the task the nodes will die due to the more energy consumption. To solve such energy inefficiency many protocols was proposed, some of them are LEACH, PEGASIS, HEED etc. Low-Energy Adaptive clustering Hierarchy (LEACH) [8] is one of representative clustering schemes. In LEACH sensors are organized into clusters and one node in each cluster acting as cluster-head takes the responsibility to collect data, aggregate them, and finally transmit them to the distant BS. Authors in [8] showed that the network is optimal in the sense of energy dissipation when around 5 percent of the total nodes act as cluster-heads. The operation of LEACH is divided into rounds, where a round begins with set-up phase followed by steady-state phase. During the setup phase each node decides by itself whether it becomes the cluster-head or not. After that, the cluster-head broadcasts an advertisement message to the rest of the nodes. Depending on the received signal strengths, each node decides the cluster-head to which it wants to belong for that round. Each cluster-head then creates a TDMA schedule for all the member nodes in its cluster and sends it to them. During the steady state phase, the member nodes start sensing and transmitting data to the cluster-heads according to the TDMA schedule, and the fused information by the cluster-head is sent to the BS. At the end of a given round, a new set of nodes become cluster-heads for the subsequent round and the process repeats.

Proxy-Enable Adaptive Clustering Hierarchy for wireless sensor network (PEACH) [11] improved LEACH by selecting a proxy node which can assume the role of the current cluster-head of weak power during one round of communication. It is based on the consensus of healthy nodes for the detection and manipulation of failure of any cluster-head. It allows considerable improvement in the network lifetime by reducing the overhead of re-clustering. The authors of [12] propose a protocol called Energy-Driven Adaptive Clustering Hierarchy (EDACH), which can increase the lifetime and reliability of sensor network in the presence of faults at the cluster-heads. This is achieved by selecting a proxy node which can assume the role of the current cluster-head during one round of communication. EDACH is based on consensus of healthy cluster-heads to detect and handle faults in any faulty cluster-head.

EDACH employs the simulation-based fault injection method for performance evaluation, which assumes that errors occur according to a predetermined distribution. It provides improvement in the stability of the system and reduces the overhead of re-clustering and system reconfiguration. Computer simulation revealed that EDACH extends the lifetime of LEACH up to about 50% in practical operational environment.

In [9], an enhancement of LEACH protocol was proposed called Power-Efficient Gathering in Sensor Information Systems (PEGASIS). PEGASIS is a chain–based protocol trying to extend the network lifetime by letting the nodes communicate with only their closest neighbors and take turns to communicate with the BS. Once all the nodes have assumed the role of communication with the BS, a new round starts. This allows power draining is spread uniformly over all nodes. Also, PEGASIS requires communication between adjacent nodes so that the transmission power can be reduced. Unlike LEACH, PEGASIS avoids cluster formation and lets only one node in the chain transmit data to the BS. To locate the closest neighbor node for each node, signal strength is used to measure the distance to the neighboring nodes and then it is adjusted so that only one node can be heard. The chain construction is performed in a greedy fashion. Simulation results showed that PEGASIS is able to increase the lifetime of the network twice as much as that of the network under the LEACH protocol.

In Tree-based Efficient Protocol for Sensor Information (TREEPSI) [10], a root node is selected before data transmission occurs. There are two ways to build the tree path. One is computing the path centrally by the sink which broadcasts it afterward. The other is running the same tree construction algorithm in each node. At the initial phase, the root node visits other nodes using a standard tree traversal algorithm. Then the data transmission phase begins from the leaf nodes towards the root node which sends the collected data to the sink. The process continues until the root node dies when a new root node is elected. The communication distance between the nodes in TREEPSI is shorter than PEGASIS which allows it to reduce power consumption about 30% compared to PEGASIS.

The PEDAP is similar to the PEGASIS protocol and is of improvised version. [9] The drawback of this protocol builds the topology which will cause the large amount of waste of energy. The BS in the network needs to build the topography to collect the information of the sensor nodes of parent and child nodes, so delay will be there.

3. NETWORK AND RADIO MODEL

3.1 Energy Model

We assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics. For the experiments described here, both the free space (d2 power loss) and the multipath fading (d4 power loss) channel models were used, depending on the distance between the transmitter and receivers.

Power control can be used to invert this loss by appropriately setting the power amplifier if the distance is less than a threshold, the free space (fs) model is used; otherwise, the multipath (mp) model is used. Thus, to transmit an l-bit message a distance d, the radio expends.

Energy spent by the radio to receive k bits of data is calculated using the following equation:

$$Er(k) = k * Eelec$$

It is assumed that the radio channel is symmetric such that the energy required to transmit a message from node A to node B is the same as the energy required to transmit a message from node B to node A for a given SNR. The author also assumes that all sensors are sensing the environment at a fixed rate and thus always have data to send to the end user.

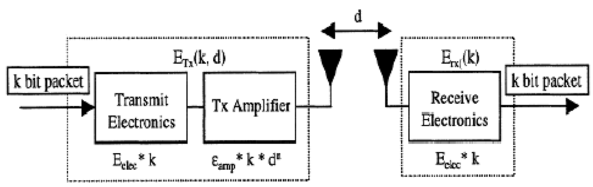

Fig 2: The radio energy dissipation model

3.2 Network Design

In this research, The author have assumed that the "N" number of sensor nodes are randomly and densely scattered in a two-dimensional 100*100 meter square field to continuously monitor the phenomenon under inspection. The wireless sensor network has the following assumptions:

- The nodes are homogeneous, randomly distributed and have no mobility.
- There is only one sink in the field, which is fixed and provides necessary data processing and storage capabilities.
- Nodes initially have the same initial battery energy and the ability to reach directly to BS.
- A node is considered to be dead when it is not capable of transmitting data to the sink.
- It is assumed that the probability of signal collision and interference in the wireless channel is ignorable and the radio transmitter, radio amplifier and data fusion unit are the main energy consumers of a sensor node.
- The consumed energy in aggregating Lk bit signals into a single k bit signal.
- Transmission power varies depending upon the distance between node and receiver.
- Every node is initially given an exclusive identifier (ID).
- Nodes are facilitated with variable transmission power levels.
- Nodes know their own position and BS position.
- The network lifetime can be described as the time at which the first node of the WSN becomes dead.

4. PROPOSED ALGORITHM

Clustering technique is one of the most energy efficient techniques being used in WSNs. Although when the network becomes large the process of clustering becomes less energy efficient. In large network the data transmission is done by multiple hops, the cluster head situated near Base Station have to transmit additional data which results in early drainage of near cluster heads. As the cluster heads near base station start draining out of energy the data transmission load gets distributed on the remaining nodes which results in more dead nodes ultimately all the nodes situated near the base station become dead. In this situation, the far away nodes have to directly transmit the data to BS. Since the distance between base station and far nodes is very large so it requires huge amount to transmission energy. Also, Nodes away from base station waste huge amount of energy in sending initial status messages to BS. These status messages contain the location and current energy level information of the nodes.

In this research work, we proposed a TBEEC (Tree Based Energy Efficient Clustering) in which we mainly focused on how to enhance the network lifetime by minimizing energy consumption. For this, we selected cluster heads on the basis of high residual energy so 5% of the nodes that we are selected. After selecting the cluster head, cluster is formed all nodes are assigned to the nearest cluster head thus forming clusters. Now average transmission distance is computed for each cluster by using this formula:

$$d_a = \frac{d_{max}}{\alpha}$$

Where d_{max} denote the distance of the path farthest from the cluster-head and α is the number of levels decided according to the size of the network and d_a is average data transmission distance between two adjacent levels of the tree. d_a can be calculated by using the values of d_{max} and α. Each cluster member node assigns a level, L (i) on the basis of average data transmission. Node at level, L (i), its parent from member node belonging to the same cluster and having the level, L (i-1). Now the data transmission phase begins these nodes transmitted its data packet to its parent, further the parent node transfer data packet to the corresponding cluster head using intra cluster communication then Further cluster head send data packet to other nearest cluster head thus using inter cluster communication to the data is reached to the BS.

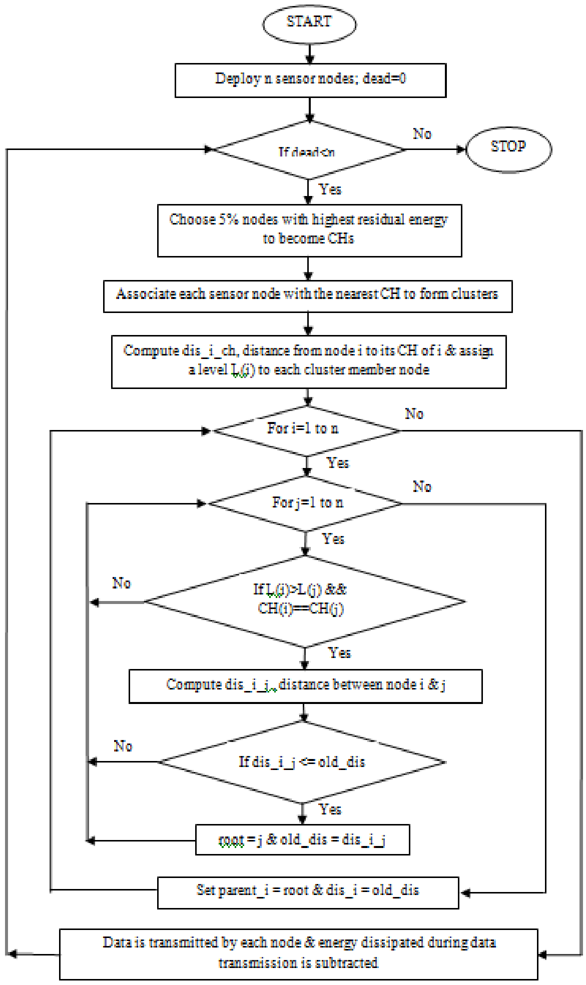

Fig 3: The flow-chart representing the working process of the proposed TBEEC protocol

5. SIMULATION AND RESULTS

The simulation is carried out using Custom Built Iterative Based Simulator in MATLAB (R2013b) which simulates the sending, receiving, dropping and data forwarding etc. MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, technical computing problems can be solved faster than with traditional programming languages, such as C, C++ and FORTRAN. It is used in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis. Add-on toolboxes (collections of special purpose MATLAB functions, available separately) extend the MATLAB environment to solve particular classes of problem in these application areas. MATLAB provides a number of features for documentary work. MATLAB code can be integrated with other languages and applications, and gives out various new algorithms and applications.

Table 1. Simulation Parameters

Parameters	Values
Network Area(meter)	100×100
Number of Nodes	100
Location of Sink	50,175
Initial Energy	0.25J
Eelec	50nJ
Eamp	0.013Pj/bit/m4
Efs	10Pj/bit/m2
Eda	5Nj/bit/signal
Data Message Packet length	2000bits
Number of Rounds	5000
Routing Protocol	TBC

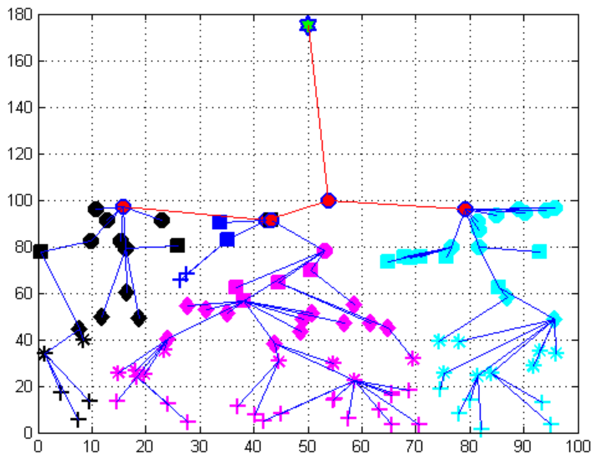

Fig 4: Topography generated by proposed TBEEC protocol with 100 nodes deployed in the square area.

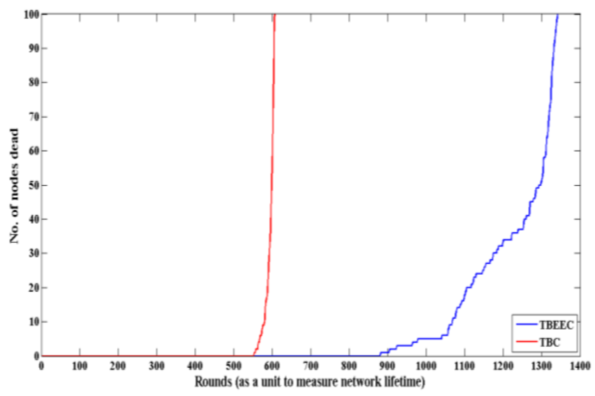

Fig 5: Graph showing comparison of nodes being dead with rounds for TBC and proposed TBEEC protocol.

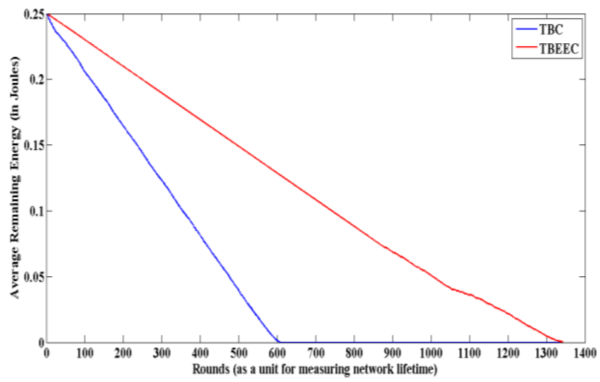

Fig 6: Graph showing comparison on the basis of average remaining energy between the TBC and TBEEC protocol

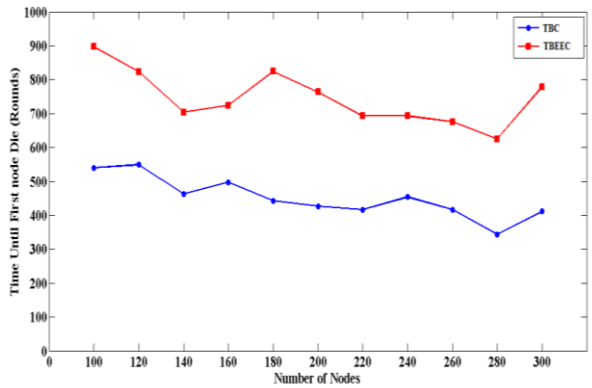

Fig 7: Graph showing first node dead comparison for TBC and TBEEC protocol for 100-300 nodes deployed in square area.

6. CONCLUSION AND FUTURE SCOPE

In this paper to prolong the network lifetime, this work implements another tree-based cluster routing strategy known as Tree-Based Energy Efficient Clustering Protocol (TBEEC). In this work, the node having lesser distance to the base station and higher energy than the other nodes of the cluster is elevated as cluster head for a round. All nodes of cluster forward their data to the cluster head by using other intermediate nodes that lies on the way to the cluster head. Further, in this work inter-cluster communication is implemented to reduce the energy consumption. Every cluster head instead of transmitting aggregate data directly to the base station looks for intermediate cluster head that lies near to the base station. This way data has to travel at lesser distance that result in energy saving which prolongs the network lifetime. The proposed protocol overcomes the limitation of existing TBC protocol.

It is clear that the proposed protocol gives a better lifetime & minimized energy consumption by efficient cluster head replacement after very first round and dual transmitting power levels for intra-cluster and inter-cluster communication. The future work includes expanding the proposed tree-based clustering approach to allow node mobility. Also, we will develop a formal model deciding the optimal number of levels inside a cluster to further increase the efficiency and lifetime of the network. In addition, we will investigate how to minimize the data collection and transmission time in order to reduce the total energy consumption.

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