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Hybrid Energy Efficient and Distributed Clustering Method Using GSTEB

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Abstract

In recent researches wireless sensor network (WSN) is measured as most vital, complex and interesting new technology in data communication and gathering various kind of information which is not possible for human. Major challenges in WSN are lifetime and energy consumption; to overcome this many protocols have been constructed for better performance by considering the parameters like energy consumption, throughput and the network lifetime in WSN. To overcome this problem and to improve the performance need not only to minimize total energy consumption but also to balance WSN load. In this paper, we propose a General Self-Organized Tree-Based Energy-Balance routing protocol (GSTEB) which consist of a tree based structure for the process of routing where in each round, the BS assigns a root node and broadcasts its selection to all other sensor nodes. Simultaneously, each node selects its parent by considering themselves and their neighbors information, thus making GSTEB a efficient protocol. Hence simulation results show that GSTEB has a better performance than other protocols mainly in balancing energy consumption and prolonging the lifetime of WSN.

Index terms: Energy-balance, network lifetime, routing protocol, self-organized, wireless sensor network, Re-election of cluster head.

Introduction

Wireless Sensor Networks (WSN) is highly used in research areas. It consist of spatially distributed autonomous sensors in which it is used to monitor the particular areas physical or environmental conditions (climatic changes in case of unsustainable

pressure barriers or any kind of abnormal changes in the environment conditions) such as temperature, sound, pressure, vibrations etc. and also has the ability to cooperatively pass their data through the network to a main location.

The sensor activities is monitored and controlled using bidirectional modern networks more modern network[1]. Wireless sensor networks has its major applications towards the military battlefield surveillance; today such networks are used in many industrial and consumer applications, for industrial process monitoring and control of , machine health monitoring, and so on. The WSN is built up of numerous number of nodes which are interconnected with each other. The main architecture of a sensor network consist of a radio transceiver with antennas that work for both internal and external applications , microcontroller, and an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node can vary in many different sizes. Depending on the complexity the cost of the sensor node may get varied. The size of the sensor node depends on bandwidth. Any kind of network topology can be employed in WSN's. The propagation technique between the hops of the network can be routing or flooding.

Micro-sensor networks are also used to monitor ambient conditions like temperature, humidity and pressure in a particular area, which then transform them into electric signal[5]. Nowadays the entire network must have the ability to operate in harsh environments where humans cannot easily monitor or access and control scheduled the management. Based on this critical criteria many sensor networks are arranged in an ad-hoc fashion. By keeping in mind it considers life time and energy consumption of sensor nodes using less battery power, where in general several hundreds or even thousands of sensor are being handled in real time. In addition, sensors in such environments are energy constrained and their batteries usually cannot be recharged[7]. Therefore, it's obvious that specialized energy-aware routing and data gathering protocols offering high scalability should be applied in order that network lifetime is preserved acceptably high in such environments.

A wireless sensor network contains hundreds or thousands of these sensor devices that have ability to communicate either directly to the Base Station (BS) or among each other. The nodes in WSNs are usually battery operated sensing devices with limited energy resources and replacement of the batteries is usually not an easy task. Thus energy efficiency is one of the most important issues and designing power efficient protocols is critical for prolonging the lifetime[2]. Sensor nodes are scattered in the sensing field, being the area where we want to monitor some environmental conditions. Sensor nodes have to coordinate among themselves to get information about the physical environment. The sensor node collects the information and routes it to the base stations directly or by the other sensor nodes included in the architecture. The Base Station is generally a fixed node, which is capable to connect the sensor network to an infrastructure networks or to the Internet where users can access and process data[13]. Application of WSNs exists in variety of fields including environmental applications, medical monitoring, home based security systems, critical surveillances, secret military applications, etc. Sensors in WSNs are generally equipped with data processing and communication capabilities.

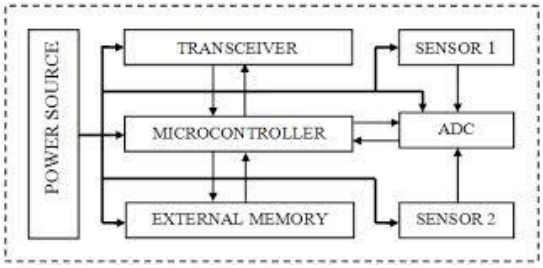

Figure 1: Block Diagram Of WSN

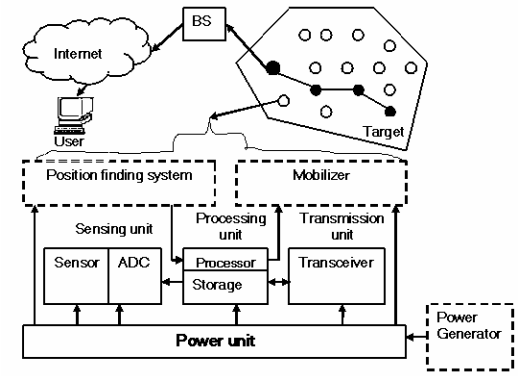

Figure 2: Architecture of WSN

Clustering Concept In Wireless Sensor Networks

To generally achieve higher efficiency and also to prolong the lifetime of WSN in large scale environments grouping of sensor nodes into clusters has been widely adopted by the research community to satisfy the above mentioned criteria. The corresponding hierarchical routing and data gathering protocols imply cluster-based organization of the sensor nodes for data fusion and aggregation, thus it leads to significant energy saving mechanism[17]. In hierarchical networking concept the structure each cluster has a leader or can also be called as cluster head, which usually performs the special tasks referred above (fusion and aggregation), and several common sensor nodes (SN) as members. The cluster formation process leads to a two-level hierarchy where the CH nodes form the higher level and the cluster-member nodes form the lower level. The sensor nodes periodically transmits the data to their corresponding CH nodes. The CH nodes aggregate the data (thus decreasing the total number of relayed packets) and then transmits them to the base station (BS) either directly or through the intermediate communication with other CH nodes. However, because the CH nodes makes the data to travel at higher distances than the common (member) nodes, hence they naturally need to spend their energy at higher rates. A common solution in order balance the energy consumption among all the network nodes, is to periodically re-elect new CHs (thus rotating the CH role among all the nodes over time) in each cluster.

A typical example is hierarchical data communication within a clustered network (assuming single hop intra cluster communication and multi-hop inter cluster communication). The BS is the data processing point for the datas to be received from the sensor nodes, and then the data is accessed by the end user. It is generally considered fixed and at a far distance from the sensor nodes[11]. The CH nodes actually acts as gateways between the sensor nodes and the BS. The function of each CH is to perform common functions for all the nodes in the cluster, like aggregating the data before sending it to the BS. Sometimes, the CH is the sink for the cluster nodes, and the BS is the sink for the CHs[9]. Moreover, this structure formed between the sensor nodes, the sink (CH), and the BS which can be replicated as many times as it is needed for creating (if desired) multiple layers of the hierarchical WSN (multi-level cluster hierarchy).

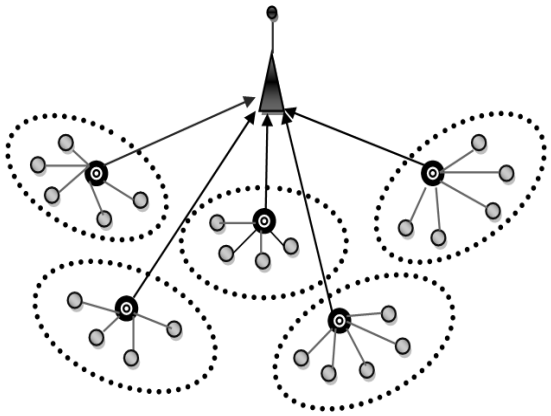

Figure 3: Sensor nodes arranged in clusters

Formation of Clusters In WSN

Number of Clusters (cluster count): In most of the recent probabilistic and randomized clustering algorithms the CH selection and formation process leads to variable number of clusters. In some published approaches, it is been noticed that, the set of CHs are predetermined and thus the number of clusters are preset.(i;e) the networks cluster formation becomes fixed. The number of clusters is usually a critical parameter on comparing to the efficiency of the total routing protocol.

Intra Cluster Communication: Initial in some of the clustering approaches the communication between a sensor and its CH is assumed to be direct one way or hop communication, but nowadays multi-hop or hop to hop intra cluster communication is often required and is been used when the communication range between the sensor nodes is limited or the number of sensor nodes is very large and the number of CHs is bounded.

Nodes and CH Mobility: In this process we assume stationary sensor nodes and stationary CHs which are normally leads to stable clusters with sophisticated intra cluster and inter cluster network management scheme. On the other hand , if the CHs

or the nodes that are assumed to be mobile, the cluster membership for each node gets dynamically changed, this generally forces the clusters to take more time for transmission and probably needs to be continuously maintained in each case.

Nodes Types and Roles: In some proposed network models (i.e., heterogeneous environments) the CHs are assumed to be equipped with significantly more computation and communication resources than others. In most usual network models (i.e., homogeneous environments) all nodes have the same capabilities and just a subset of the deployed sensors are designated as CHs.

Cluster Formation Methodology: Mostly in the recent approaches, when CHs are regular or normal sensors nodes and time efficiency is a primary design criterion, by this clustering is being performed in a distributed manner without coordination. In some of the earlier methodologies a centralized or a hybrid approach was been generally followed, where one or more coordinator nodes are used to partition the whole network offline and control the cluster member by themselves.

Cluster-Head Selection: The leader or the primary nodes of the clusters CHs in some proposed algorithms in the case of heterogeneous environments can be pre defined. However in most of the cases homogeneous environments are considered, where the CHs are picked from the deployed set of nodes based on their residual energy or any other probabilistic approach or just in a random way completely random manner.

Multiple Levels : In some of the earlier approaches the concept of a multi-level cluster hierarchy was been introduced to achieve even more better energy distribution and total energy consumption. The improvements offered by multiple level of clustering are to be further used, especially when we have very large networks and inter cluster communication efficiency which is been highly used.

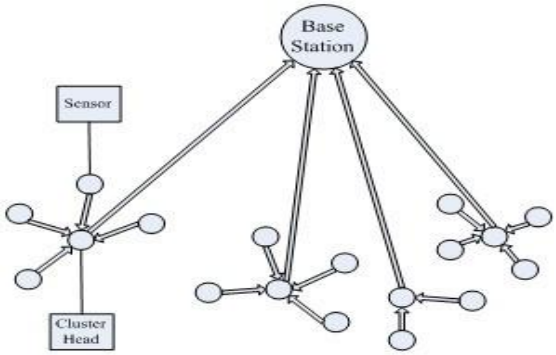

Figure 4: Communication between CH and the BS

Low Energy Adaptive Clustering Hierarchy

The main idea behind LEACH protocol is to divide the entire wireless sensor networks into several clusters in order to make the network communication simple. Here the cluster head node is randomly selected, the opportunity of each node to be selected as cluster head is equal, and energy consumption of whole network is

averaged (i;e) more or less the energy consumption of each network will be the same. Therefore, LEACH can prolong network life-cycle [5]. LEACH algorithm concept is cyclical which provides a conception of round process. This protocol runs with many rounds. Each round consists two states: cluster setup state and steady state. In cluster setup state, it forms cluster in self-adaptive mode, in steady state, it transfers data from the source to destination .

The time of second state is usually longer, by considering that P is the desired percentage of cluster heads (e.g. is 7% or 8%), where r is the current round, and G is the set of nodes that have not been elected as cluster heads in the past one by p rounds. Using this thresholding concept, each node will be a cluster head at some point of time within the one by P rounds[5]. Nodes that have been cluster heads cannot become cluster heads for a second time for one by p minus one rounds is usually a common rule. After that, each node has a one by p probability of becoming a cluster head in every round. At the end of every round, every member node that is not a cluster head select the nearest cluster head and joins that group of cluster to transmit the data. The cluster heads combines and compresses the data and forwards it to the base station, by this method we are able to achieve a greater amount of lifespan for all the nodes. In this algorithm, the energy consumption will be allocated approximately which is uniform among all nodes and the non- cluster head nodes will get turned off as much as possible. LEACH assumes that all nodes are in range of wireless transmission of the base station which is not the case in many sensor deployments. In general 5% of the total nodes acts as cluster heads in every round. Time Division Multiple Access (TDMA) is employed for better management and scheduling process.

A. Set Up Phase

Each node decides independently with the other nodes if it has to become a CH or not. This is decided when the node served as a CH for the last time (the node that hasn't been a CH for long time is more likely to elect itself than nodes that have been a CH recently). To become a CH in the following advertisement phase the CHs inform their neighbor nodes with an advertisement packet. The advertisement packet is picked up by the non-CH node with the strongest received signal strength. The CH become a member to the cluster with a joint packet which contain their ID’s using CSMA where in the next cluster setup phase, the member nodes inform the CH that they become a member. At the end of the cluster-setup sub phase, the CH knows the number of member nodes and their IDs[5]. To broadcast the TDMA table to cluster members using all messages received within the cluster, the CH creates a TDMA schedule, and picks a CSMA code randomly.

After that steady-state phase begins. Initially, when clusters are being created, each node decides whether to become a cluster-head or not for the current round. This decision is made by the node n choosing a random number between 0 and when the number is less than a given threshold value, the node becomes a cluster-head for the current round. To broadcast the advertisement message to the rest of the nodes each node has elected itself as a cluster-head for the current round. Using the CSMA-MAC protocol all cluster-heads transmit their advertisement using the same transmit energy. To hear the advertisement of all the cluster head nodes the non-cluster-head nodes

must keep their receivers on during this phase of set-up[5]. After this phase is complete, each non-cluster-head node decides the cluster to which it will belong for this round. This decision is based on the received signal strength of the advertisement.

B. Steady State Phase

When data transmission begins, nodes send their data during their allocated TDMA slot to the CH. This transmission uses a minimal amount of energy (chosen based on the received strength of the CH advertisement). The radio of each non-CH node can be turned off until the nodes allocated TDMA slot, thus minimizing energy dissipation in these nodes. When all the data has been received, the CH aggregate these data and send it to the BS. LEACH is able to perform local aggregation of data in each cluster to reduce the amount of data that transmitted to the base station. Although LEACH protocol acts in a good manner, it suffers from many drawbacks such as CH selection is randomly, that does not take into account energy consumption. It can't cover a large area. CHs are not uniformly distributed; where CHs can be located at the edges of the cluster. The process of transferring aggregated data or sensed data from all the sensor nodes to the sink or base station is done under steady state phase. During this phase, nodes in each cluster sends data based on the allocated transmission time to their local cluster heads.

To reduce the energy dissipation, the receiver of all non-cluster head nodes would be turned off until the node defined allocated time. After receiving all the data from the nodes, the cluster head aggregates all the data sent from the member nodes into a single signal and transfers it to the base station. The duration of the steady state phase is longer than the duration of the set-up phase in order to minimize overhead. To complete the set-up phase, each node sends a join-request message after they receive a broadcast from the elected cluster-heads using a non-persistent CSMA MAC protocol[5]. The cluster-head creates a TDMA as shown in the LEACH flow chart and finally the nodes forming each cluster wait for their schedule before transmission. The steady phase starts immediately after the set-up phase. The cluster-heads gather all data from their respective cluster members and send the respected data to the base station.

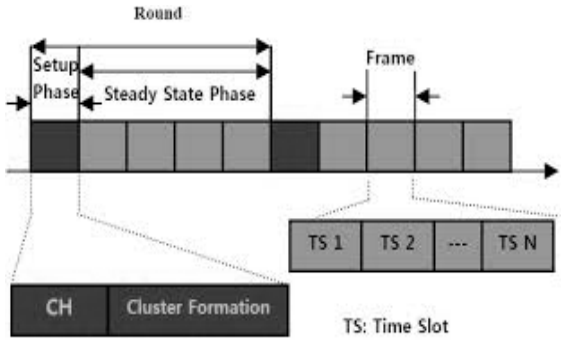

Figure 5: Architecture of LEACH Protocol

Generalised Self Organised Tree Based Energy Balanced Routing Protocol (GSTEB)

GSTEB is developed to achieve a longer network life- time for different applications. Here in each round, BS assigns a root node and broadcasts its ID and its coordinates to all sensor Nodes. Then the network computes the path either by transmitting the path information from BS to sensor nodes or by having the same tree structure being dynamically and individually built by each node. For both cases, GSTEB can change the root and reconstruct the routing tree with short delay and low energy consumption. The operation of GSTEB is divided into Initial Phase, Tree Constructing, Self-Organized Data Collecting and Transmitting Phase, Information Exchanging.

In this approach, assume that the system model has the following properties:

- In general sensor nodes are randomly distributed in the square field and there is only one BS which is fixed and is deployed far away from the area.
- In this concept sensor nodes are stationary and energy constrained. Once they are deployed, they will keep operating until their energy gets exhausted.
- Here sensor nodes are location aware. A sensor node can get information about its own location by other mechanisms such as GPS or any other kind of position algorithms.
- Each node has its own unique identifier in order to represent them with a separate ID.

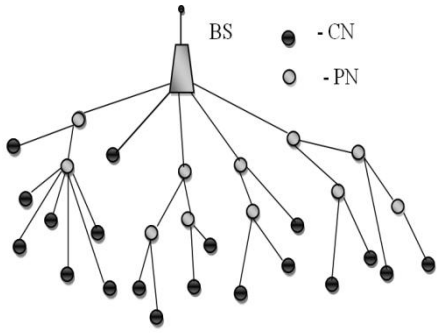

Figure 6: Architecture of GSTEB

Initial Phase: BS broadcasts a packet to all the nodes. Then All Sensors sends its packet in a circle and sends a packet which contains its entire neighbor's information.

Tree Constructing Phase: BS assigns a node as root and coordinates to all sensor nodes. Each node tries to select parent in neighbors using Energy Level. Parent nodes are computing every Node neighbors' Record.

Self-Organized Data Collecting and Transmitting Phase: Leaf Node (L) Sends Beacon. Parent Node (P) and tries to receive Beacon from Leaf Node. More than one (L) need to send data. (P) Monitor channel one which is chosen send the data others keep sleep.

Information Exchanging: Each node needs transmit data in each round; it may exhaust its energy and die. The dying of any sensor node can influence the

topography. So nodes that are going need to inform others. Even though GSTEB needs BS to compute the topography, which leads to an increase in energy waste and a longer delay, this kind of energy waste and longer delay are acceptable when compared with the energy consumption and the time delay for data transmitting.

C. Re-Election of Cluster Head (CH)

Sensor nodes in a network consume energy in a non-uniform manner, hence we use this re-election techniques. On designing clustering protocols that are heterogeneity aware is still an open issue in sensor networks. This work focuses on hierarchically clustered heterogeneous sensor networks[12]. In general the sensor nodes organize themselves into self organized groups called clusters. Each cluster consists of a cluster head and its own member nodes. The sensor network consists of nodes of two different energy levels. In present situations the current heterogeneity aware protocol are unable to distribute the usage of energy amongst the sensor nodes uniformly. Hence we have taken the process of re-electing the cluster head to minimize the power consumption and prolonging the lifetime of WSN. By implementing the re-election factor the major issues can be controlled or reduced in greater amount. Therefore, this process is able to exploit the heterogeneity present in a sensor network in an efficient manner.

D. Master and Slave Communication Concept

During the process of communication between the nodes when none of the CH is not ready to accept the request sent by the nodes it generally decides to drop out from the group and acts itself to be the master. And the other sensor nodes which are dropped out again becomes its slave nodes[8]. This is known as master slave communication. The node which comes out first will be known as master. This master node will send link to all other nodes. There are only two types of nodes they are master node and slave node. The slave nodes are one which connects to these master nodes when they break their connection with their particular CHs. After the distribution of link from master node the slave nodes will join to the master. There is no connection between slave nodes. There is connection between master and slave nodes. For each slave which receives the link it will send acknowledgement signal back to master node whether to join or not. This master slave communication also reduces the drop rate in the case where the balancing of clusters is not possible.

E. Multiple Clustering Concept

In the wireless sensor network if single cluster is formed there is a disadvantage that the single cluster may not be able to handle its entire cluster member[3]. Hence multiple clusters are formed. Also in multiple cluster method to reduce the delay of packet transmission two clusters deployed with same frequency or code set if they are not neighbouring clusters. This can save much resource. So, In this concept while using multiple number clusters this approach becomes more simple and is very easy for communication between the required source node to the destination node or even to the base station. Here in this concept clusters are present in multilevel and the cluster heads from each group can easily communicate simultaneously to the required

base station in order to reduce the energy consumption and also to minimize the delay of transmitting the data from one end to the other end. By this kind of approach we can achieve efficient energy consumption which automatically prolongs the lifetime of WSN.

Results and Discussion

The main goal of WSN is prolonging network life time by reducing the energy consumption among nodes. Design of every routing protocol is based on reducing a quick death of sensor nodes due to power consumption. LEACH reduces the total energy consumption but consumes more energy from head nodes which leads to the death of that node quickly. Our simulation results show that GSTEB protocol outperforms than LEACH. So we conclude that GSTEB protocol gives better performance when compared to LEACH. When compared to LEACH protocol it generally selects the cluster head on a random basis so we assume some kind of methodology in order to avoid confusion as which node has to take the leader's position in transmission of data, Hence GSTEB results shows that it gives better efficiency and the life of WSN is increased in a larger amount.

Comparitive Analysis Table For Leach And GSTEB

Table 1: Comparison of LEACH and GSTEB under various parameters

Protocol	Structure	Delay	Packet Loss	Throughput
LEACH	Cluster-Based	More	High	Low
GSTEB	Tree-Based	Less	Low	High

Delay Graph

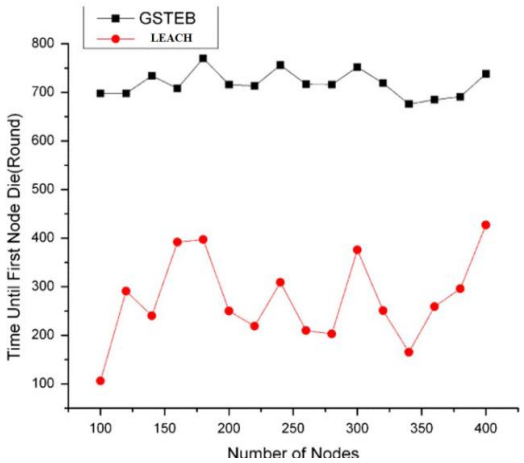

Figure 7: Comparison of Time Delay graph for GSTEB and LEACH

Packet Loss Graph

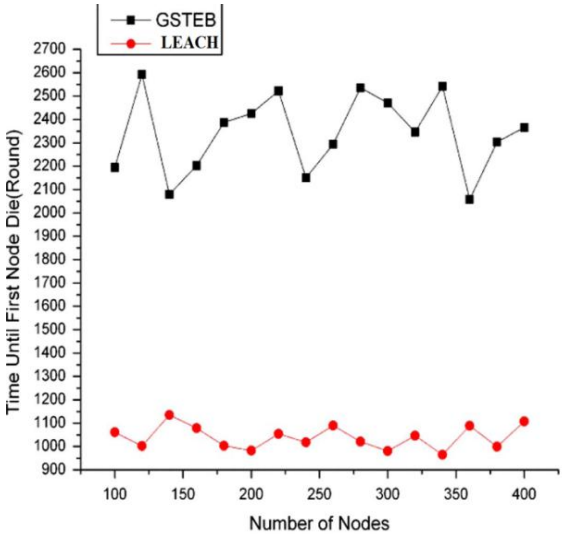

Figure 8: Output graph for loss ratio between existing system and proposed system

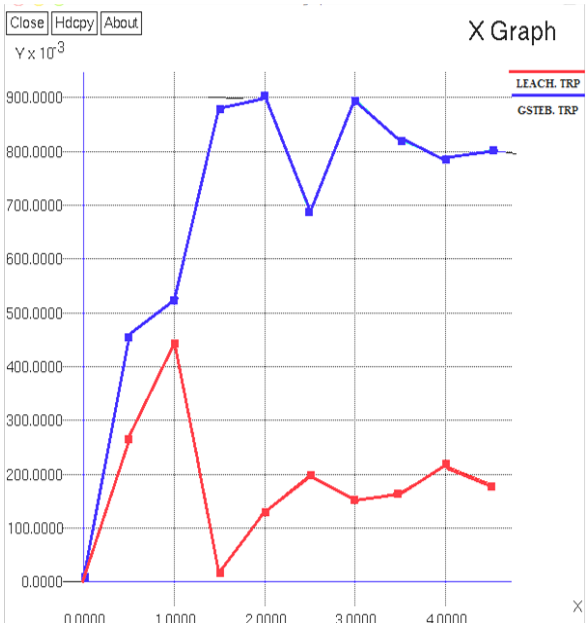

Figure 9: Throughput Graph for Leach and GSTEB

Comparison Graphs of Network Lifetime For Various Distances

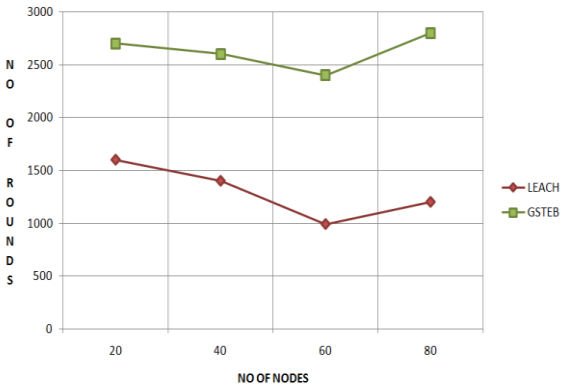

Figure 10: Network Lifetime Range For 30m

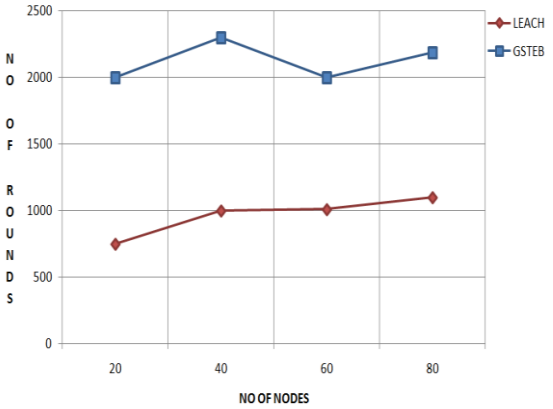

Figure 11: Network Lifetime Range For 70m

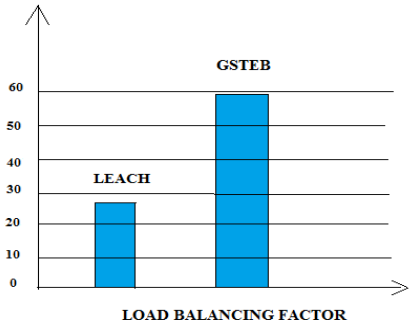

Figure 12: Comparison of Node's Lifetime

Conclusion and Future Works

In Wireless Sensor Networks (WSNs) have intrinsic and distinctive features rather than traditional networks. They have many different constraints, such as computational power, storage capacity; energy supply and etc are the important issue is their energy constraint. Energy aware routing protocol plays a significant part in the wireless sensor network, but it considers only energy supply of the system. Due to this the protocol is not more efficient. As a result considering other parameters adjacent to energy efficiency is essential for protocols efficiency. In this paper, GSTEB protocol is enhanced using the cluster tree topology and introducing the load balancing scheme in GSTEB. Routing protocol separates network into more number of clusters, then by means of distance, protocol is proposed to constructs a routing tree for each cluster. In routing tree, most number of children for cluster nodes is determined. Proposed protocol manages load balancing, using routing tree, node's neighbours average queue length and residual energy of nodes as parameters. The effectiveness of the protocol is validated by simulation. Simulation results show that our protocol achieved its goals.

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