Chapter 6
Lifetime Improvement of Wireless Sensor Networks Using Tree-Based Routing Protocol

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6.1 Introduction

Wireless sensor networks (WSN), also called as wireless sensor and actuator networks, are the autonomous sensors used to monitor physical/environmental conditions using sensors and to send their data through the network to the main location. Wireless sensor networks are networks with sensors distributed to sense some physical phenomenon and then the information gathered is processed to get relevant results. Wireless sensor networks consist of protocols and algorithms with self-organizing capabilities. The development of wireless sensor networks is targeted for usage in military applications for battlefield surveillance and are used in many industrial and consumer applications such as machine health monitoring and so on.

The main aim of our paper is to minimize the total energy consumption and increase the load balance by means of a dynamic tree-based routing protocol. Moreover, data compression is provided to improve the performance and the lifetime of the network is greatly improved. To achieve our aim, we not only minimize the total energy consumption but also improve the balance of WSN load. In this paper, we have increased the lifetime of the network by balancing the load as General Self-Organized Tree-Based Energy Balance (GSTEB) routing protocol is

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used to achieve a longer network lifetime. During each round, the base station assigns a root node and sends the same to all sensor nodes. Each node selects its parent by considering only itself and its neighbor's details, thus making it a dynamic protocol. The key feature of the tree-based data aggregation scheme is to improve the network lifetime. A Lempel Ziv Welch algorithm is used to support data compression in WSNs using sensors and is computationally simple with no transmission overhead. Thus, the protocol used in the proposed system prolongs the overall lifetime of the network. The typical applications include air traffic control, surveillance, environmental monitoring, etc. The paper is organized as follows: Sect. 6.2 summarizes the literature survey related to work. Section 6.3 explains the proposed system and Sect. 6.4 provides results and discussion are done. Finally Sect. 6.5 concludes the work.

6.2 Literature Survey

A lot of work has been contributed for prolonging the lifetime of wireless sensor network. The Lempel-Ziv-Welch (LZW) compression algorithm is widely used because it achieves an excellent compromise between compression performance and speed of execution. The algorithm implements lossless compression without degrading the speed and performance. Improvement depends upon the nature of the source and the algorithm achieves a very good compression performance especially on shorter files [1]. Aiming at the problem of sensors limited energy, the algorithm developed in [2] is an improvement based on the classic clustering algorithm LEACH. The load balanced clustering algorithm incorporates two thresholds in DECSA in terms of supporting minimum and maximum acceptable load. Thus, when cluster load in one frame is smaller than the minimum threshold, cluster's frame is expanded, and when it is bigger than the maximum threshold, a fraction of cluster's load in each frame is transferred to a second channel node.

Clustering is used for wireless sensor networks due to less availability of storage (memory), energy, and resources. Clusters are controlled by cluster head which organizes the operation of the entire cluster. The cluster head is responsible for collecting, combining, and transferring the data to the base station. The algorithm makes use of two phases, namely setup phase and steady-state phase. In setup phase, the cluster head will broadcast an advertisement message to the remaining nodes for the selection of head. In steady-state phase, cluster head will perform its operation. TDMA scheduling is implemented. There is reselection of cluster head which prolongs the lifetime of the network. The transmission of packets can be controlled. There is an enhancement in the delivery of data. Fixed clusters are used to decrease the communication overhead. Thus, the protocol minimizes the overhead of cluster formation and latency in data delivery [3]. The algorithm discussed in [4] makes use of two phases, namely setup phase and steady-state phase. TDMA scheduling is implemented and there is reselection of cluster head which prolongs the lifetime of the network. The protocol minimizes the overhead of cluster formation and latency in data delivery. By applying routing algorithm, protocol was designed to improve the network time and the energy consumption is reduced [5].

Energy saving is used to calculate the performance of WSNs. Decreased energy consumption reduces the energy dissipation, thereby improving the lifetime of the network. Hierarchical routing protocol (DAIC) is better than flat routing protocol (SPIN) as it achieves greater energy efficiency. DAIC splits the network into tiers and selects the channels (cluster head) having higher energy which we use at the nearest distance from the BS (base station). It is an intelligent protocol which dynamically computes the number of cluster heads depending upon the surviving nodes of the network. The energy consumption on the network mainly depends upon the data transmission distance. The channel in the primary tries to collect the data from nodes and channel in the secondary tier transmits the data to the base station. The lifetime is prolonged by means of channel retention. Therefore the DAIC protocol is more energy efficient and can be adapted to a routing protocol for energy-sensitive WSN applications owing to its energy-efficient features [6]. The concept of cluster and graph theory is used to develop energy-efficient algorithm in [7]. This optimization is achieved in cluster head election and clusters routing. This improves the link quality, transmission efficiency, and network lifetime.

An innovative method of using an evolutionary algorithm for the purpose of centralized clustering is used. Evolution means an initial population of solutions is generated which through some generations converge to a population that contains an optimum goal. The chromosomes are selected and initialized and the survivors are evaluated with the existing population. The algorithm utilizes the two fitness functions which is basically a target function containing the maximum or minimum value. Fitness function depends upon the distance because the energy consumption depends upon the distance. Parents are selected and the crossover is implemented which is followed by mutation. After the survivor selection, the process is terminated. Random changing of cluster heads improves the lifetime of the network. Survivor selection retains the suitable chromosomes of the original population and also keeps the chromosomes of the previous generation to improve the efficiency of the algorithm. In the evolutionary algorithm, the fitness function and operators reached global whereas in simulated annealing fitness function and operators will be placed only at local minimal. So evolutionary algorithm used here is for better compared to simulate annealing. The search ability is improved to increase the network lifetime [8]. The nonadaptive measurements have the character of "random" linear combinations of basis/frame elements. The results in [9] use the notions of optimal recovery, of n-widths and the information-based complexity. They show that "most" subspaces are near optimal and show that convex optimization (Basis Pursuit) is a near optimal way to extract information derived from these near optical subspaces.

Multi-hop communication used in this algorithm increases the energy efficiency of the network. The nodes are deployed and the sink (base station) makes use of broadcasting to produce clusters. A cluster will have a cluster head which utilizes TDMA for its member nodes (sensor). The sensor node of each cluster will send the data to its respective cluster head via intra-cluster communication. The cluster heads accumulate all the data and finally sends the information via multi-hops to other cluster heads as well as the sink (base station). This is done by inter-cluster communication. If the distance between the cluster head and the base station is small (less than TD-MAX), then the data is transmitted directly, else a relay node is used to transmit the data from cluster head to base station. In this algorithm, interference is minimized by means of a locality TDMA schedule. The stability and scalability are improved by means of a distributed decision which is based on the location information of the network [10].

Wireless sensor networks are utilized in fields where the users require raw data. A centralized clustering geographic energy-aware routing (GEAR-CC) protocol is used to prolong the lifetime of the wireless sensor networks. GEAR-CC has the influence of both hierarchical routing and geographic energy-aware routing. In this protocol the sensor nodes do not care about the routing protocol but simply forwards the data to the next node. GEAR-CC utilizes the global positioning system and directional antennas to provide information about every node to the next base station. The optimum route for transmission is obtained by using the Dijkstra's algorithm. GEAR-CC is a centralized algorithm which works in three phases, namely best route finding phase, next-hop setting phase, and data transmission phase. The energy consumption model provides the optimization of energy in this algorithm. GEAR-CC is the best algorithm because the cluster head will transmit data via the optimal path and optimization is done among all nodes than cluster heads [4]. The research work in [11] focuses on design and development of new Energy-Aware Multicast Cluster (EAMC)-based routing to enhance the QoS of the MANETs. The metrics such as average delay, energy consumption, packet delivery ratio, loss, and throughput are considered in this study to measure the behavior and to enhance the service quality of the MANET.

Wireless sensor networks make use of the ELDC protocol which is nothing but an artificial neural network-based energy-efficient and robust routing scheme for environmental monitoring. The protocol achieves its objectives by means of an artificial neural network (ANN) which is basically arithmetic algorithms capable of learning the complicated mappings between input and output. ELDC helps in the selection of chief node and reduces the selection time required, thereby performing the desired task. The protocol follows a three-layered structure and so it is an extension of Energy-Efficient Unequal Clustering (EEUC) and Energy-Efficient Multiple Distance-Aware Clustering (EEMDC) protocols. ELDC suffers from a large amount of packet loss due to the absence of load balance which reduces the reliability of the network. The random selection of cluster heads reduces the energy level and due to heavy energy burden there is an early death of the cluster head. In ELDC only intraprocess communication takes place successfully and there is a great possibility of errors which might occur in interprocess communication. This is because in interprocess communication any external node consisting of some malicious or unwanted data might enter a group and corrupt the nodes having the data required for transmission and so there is no proper security of data. These factors greatly reduce the lifetime of the network [12].

6.3 Proposed System

In order to overcome the limitations of ELDC protocol, we propose the use of GSTEB protocol which is a General Self-Organization Tree-Based Energy-Balancing protocol that implements efficient data operations on a large amount of data in wireless sensor networks (WSN). The network is a system composed of a large number of low-cost micro-sensors which is used to collect and send various kinds of message(data) to the base station(destination). WSN comprises a large number of low-cost nodes with limited battery power and so it is highly difficult to replace the batteries of all the nodes in the network. The only solution to offer a long-life work time is to improve the energy efficiency of the network and so GSTEB can be used to minimize the total energy efficiency and offers load balance which prolongs the lifetime of the network. The performance is further enhanced by means of data compression and this data compression is implemented using S-LZW compression algorithm which is a lossless compression and S stands for Sensors used in the network. The proposed algorithm increases the reliability of the WSNs by increasing its lifetime.

The block diagram of GSTEB protocol is shown in Fig. 6.1. The brief explanation of each block is as follows.

- Source: The source consists of the sensor nodes which act as a client. The data is transmitted from the source.
- Initial phase: In this phase, the basic parameters of the network are initialized. In the beginning, BS broadcasts a packet to all the nodes and each node sends its packet with a particular radius, and finally the neighbors receive the packet and store the information in the memory
- Tree Constructing Phase: This stage is very important as the routing tree is built in this phase. The BS assigns a node as root and broadcasts root ID and root coordinates to all sensor nodes. Each node tries to select a parent from its

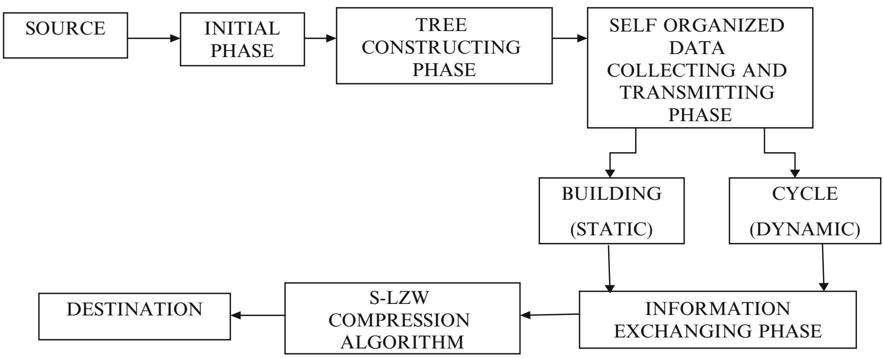

Fig. 6.1 Block diagram of GSTEB protocol

neighbors, and if a node has no child node, then it defines itself as a leaf node from which the data is transmitted.

- Self-Organized Data Collecting and Transmitting Phase: After the construction of routing tree, each node collects the information to generate a data packet to be transmitted to the base station. If the information is fixed (static), then additional information cannot be included and it is called as BUILDING. If the information is not fixed (dynamic), then information can be added or removed and it is called a CYCLE.
- Information exchanging phase: The dying sensor nodes greatly influence the topography of the network and so the nodes that are going to die must inform the other nodes so that the topography remains unaffected. This phenomenon of information exchange is done in this phase.
- S-LZW Compression Algorithm: The data is compressed after the construction of tree and sent to the destination. The algorithm implements lossless compression for the sensor nodes in the network.
- Destination: The destination consists of the base station which is the server and receives the compressed data from the source.

6.3.1 Tree-Based Data Aggregation Scheme

The tree-based data aggregation concept focuses to maximize the network lifetime where the sensor nodes are distributed in tree structure. Data aggregation operation is done at the intermediate nodes along the tree and the final aggregated data is sent to the root node.

The proposed system (GSTEB) maintains a data aggregation tree in a WSN. For tree construction, the tree root first broadcasts a control message which contains information related to the sensor node identification, the parent node, the residual power, the status of the sensor node, and the hop counts from the sink. Based on these data, sensor uses a timer to count down to identify the idle channel. The neighboring node with more residual power and shorter path is found along the tree. The process is repeated till all sensor nodes are added to the tree.

After tree is built using data aggregation concept, a residual power threshold is compared with threshold P_{th} to maintain the tree structure and its child nodes. The network lifetime is maximized in terms of the number of rounds where each round corresponds to the aggregation of sensing data transmitted from different sensor nodes. To achieve this objective, the proposed GSTEB aims to reduce the total energy consumption of sensor nodes in each round by calculating a minimum spanning tree over the network with link costs.

6.3.2 S-LZW Compression Algorithm

The compression concept with sensors implies that the data compressed can be recovered from a small number of nonadaptive, randomized linear projection samples. Thus, they can exploit compressibility without relying on any prior knowledge or assumption on sensing data. Lossless compression and data aggregation techniques are combined to select a subset of sensor nodes to collect and fuse the sensing data sent from their neighboring nodes and to transmit the small-sized aggregated data to the sink node of the tree. The LZW algorithm is computationally simple and has no transmission overhead as the same initial dictionary entries are used at both ends of transmitter and the receiver. Based on input and the existing dictionary data, the receiver can recover the complete dictionary from the compressed data.

6.4 Results and Discussion

This section deals with the results obtained from our paper, the results observed in terms of graphs after the simulation of the existing and proposed system.

It is clearly evident from the simulation window of the existing system shown in Fig. 6.2 that the existing system (ELDC) suffers from packet loss and there is no possibility of simultaneous transmission and reception of data. Also, the load is not properly balanced.

The simulation window of the proposed system shown in Fig. 6.3 depicts the dynamic tree-based routing used in the proposed system (GSTEB) and there is no packet loss. The simultaneous transmission and reception of data is possible and so GSTEB protocol achieves load balance and prolongs the lifetime of the network. There is a security feature in our proposed system where the protocol prevents the entry of unauthorized node containing malicious data by means certificate revocation. So the sensor nodes are prevented from malicious attack.

Wireless network with communication model is established using TCL script. End-to-end delay is calculated using awk script which processes the trace file and produces the result in a file. Delay is the difference between the time at which the sender generates the packet and the time at which the receiver receives the packet. Delay is calculated using awk script which processes the trace file and produces the result. The end-to-end time delay plot shown in Fig. 6.4 compares the delay of the existing system (ELDC-RED) and proposed system (GSTEB-GREEN) and it is observed that the red curve has a greater delay than the green curve and so GSTEB is more efficient.

A node loses a particular amount of energy for every packet transmitted and also for every packet received. The packet delivery ratio for a particular number of nodes must be high to ensure the energy efficiency of the nodes. The node packet delivery plot shown in Fig. 6.5 gives the packet delivery ratio for the nodes in both

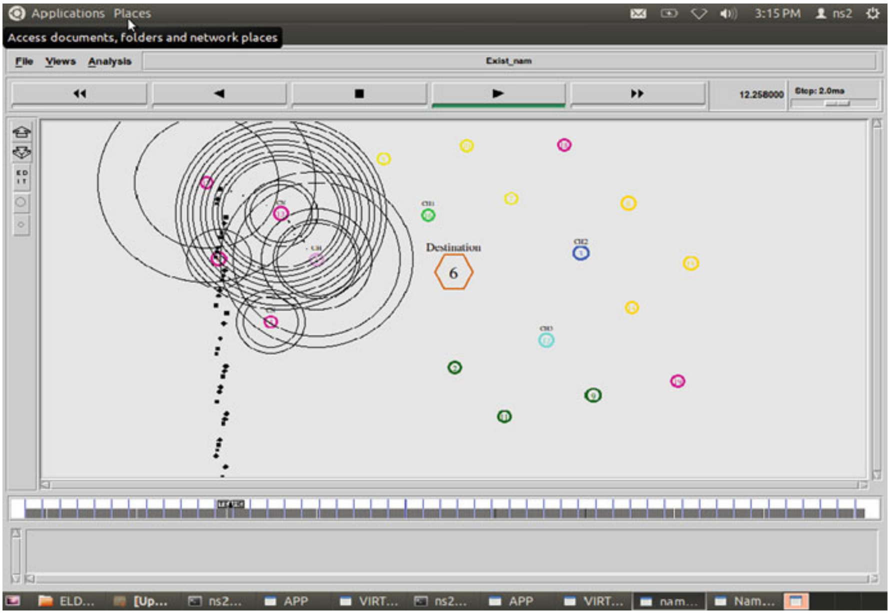

Fig. 6.2 Simulation window of the existing system

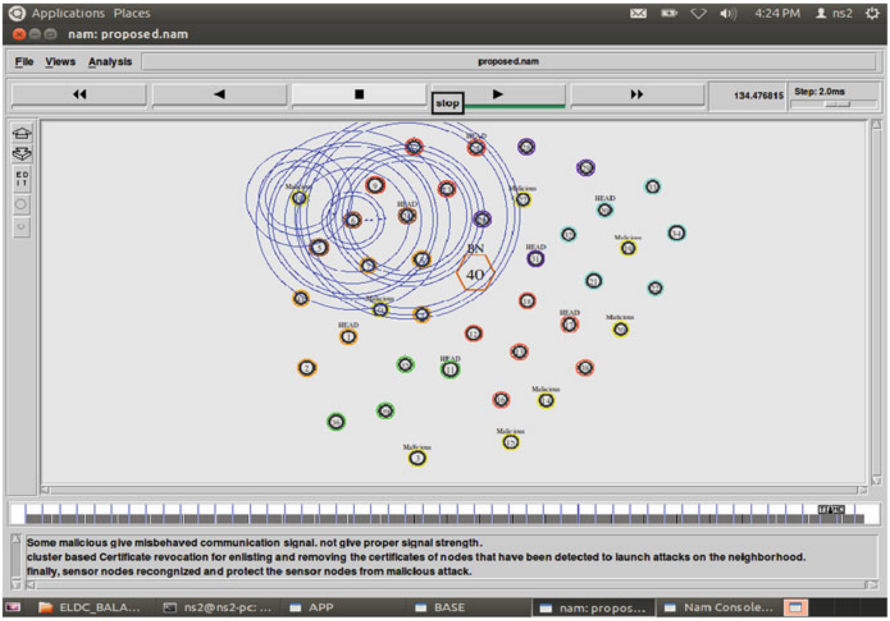

Fig. 6.3 Simulation window of the proposed system

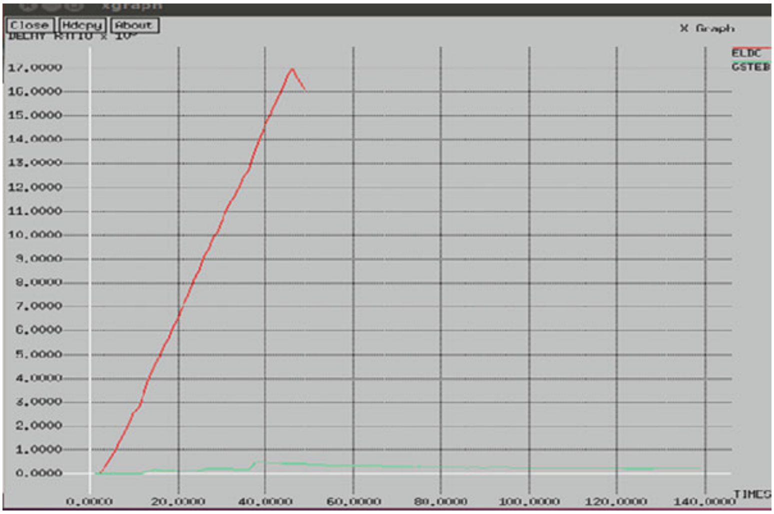

Fig. 6.4 Delay plot

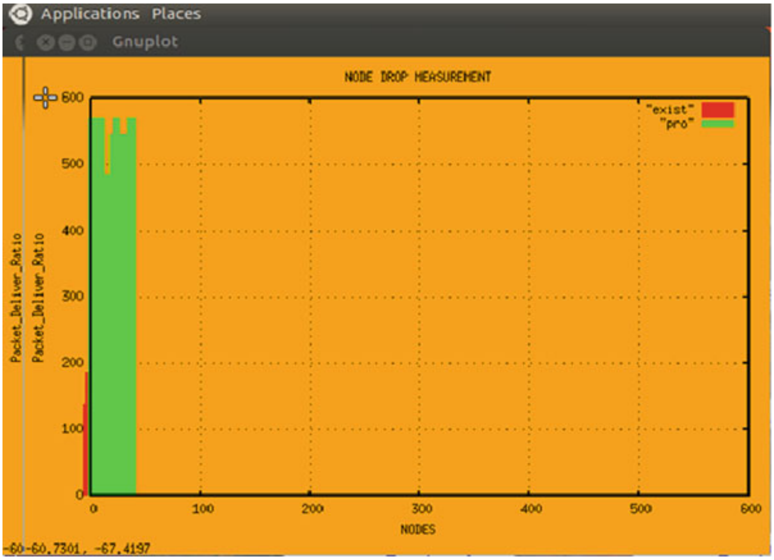

Fig. 6.5 Node packet delivery plot

the existing system (ELDC-RED) and proposed system (GSTEB-GREEN). It is observed that the packet delivery ratio is extremely high for the proposed system (GSTEB-GREEN), thereby achieving greater energy efficiency.

6.5 Conclusion

In this paper, we have successfully provided the load balance for 40 nodes by means of the tree-based routing algorithm. The protocol used has minimal packet loss and so the reliability of data transmission is improved. Moreover, S-LZW compression algorithm offers excellent data compression which further enhances the performance of the network. It could be inferred that the load balance provided by GSTEB is 100% more than that of ELDC and so the lifetime of the network is greatly improved. An important advantage of our proposed system is that the GSTEB protocol prevents the unauthorized entry of node during the inter process communication by means of certificate revocation. So the sensor nodes are prevented from malicious attack. Additionally, we have provided a QR scanning before the beginning of the simulation of the proposed system. Higher versions of the GSTEB protocol used in our paper can be developed by improvising the methodology utilized. This can be done by updating the branches of the tree without any degradation in the energy. The protocol can be implemented on large servers and finds its application in big data analytics. Real-time environmental monitoring, surveillance, air traffic control, etc. are some of the applications of our paper.

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