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A Novel Energy Efficient Clustering Mechanism in Wireless Sensor Network

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Abstract

The area of wireless sensor networks (WSNs) is one of the emerging and fast growing fields in the scientific world. This has brought about developing low cost, low-power and multi-function sensor nodes. However, the major fact that sensor nodes run out of energy quickly has been an issue and many energy efficient routing protocols have been proposed to solve this problem and preserve the longevity of the network. This is the reason why routing techniques in wireless sensor network focus mainly on the accomplishment of power conservation. Most of the recent publications have shown so many protocols mainly designed to minimize energy consumption in sensor networks. This paper proposes a hierarchical routing technique which shows energy efficiency. Our technique selects cluster head with highest residual energy in each communication round of transmission and also takes into account, the shortest distance to the base station from the cluster heads. Simulation results show that hierarchical routing technique with different level of hierarchy prolongs the lifetime of the network compared to other clustering scheme and the energy residual mean value after some communication rounds of simulation increases significantly.

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Keywords: Clustering; Energy Efficiency; Hierarchical Routing; Network Lifetime; Wireless Sensor Network.

1. Introduction

Wireless Sensor Network (WSN) is an upcoming technology which has a wide range of application including infrastructure protection, industrial sensing and diagnostics, environment monitoring, context–aware computing (for example intelligent home and responsive environment) and so on. This kind of network usually consists of a large number of nodes that bring themselves together to form a wireless network. The components of a WSN are sensor nodes, BS and monitored events (that is, an event that is required to be sensed in the environment)[1]. A typical sensor node is made of four building blocks: power unit, communication unit, processing unit and sensing unit. The sensing component in a node measures certain physical characteristic like temperature or detects soil moisture of a location in which it is placed. The processing component[2] is responsible for collection and processing captured data from its surrounding. The wireless communication component of a sensor node is responsible for transmission or reception of captured data from one sensor node to another node or to an end user through the cluster head to the base station (BS). The sensor node, its processing and communication component requires energy to function as expected, and the power

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component, which is of limited amount, is solely responsible for provision of energy to the three other components[3]. Based on application, the monitored event can either be dynamic or static in its operation.

WSNs[4] are usually deployed in an environment to monitor static or dynamic events. The measurement of static events (such as temperature, humidity etc) is very easy to carry out. On the other hand, dynamic events are typically non-cooperative event is the movement of an unwanted vehicle in a battle field and the movement of whales in the ocean. They are not easy to monitor and they are not stable as they go up and down. Therefore, it is highly difficult to study energy saving schemes for sensing of dynamic event. For example, a forest monitoring application involves static monitoring approach whereas a target tracking application involves a dynamic monitoring approach[5].

Sensor network requires certain protocol for efficient performance. For instance, protocol can come in form of a specific application with a defined order to aggregate data and optimizing energy consumption. This kind of protocol is referred to as hierarchical routing. Moreover, we have also a data centric routing protocol which describes a network environment whereby a sensor node also relies on data centric approach which performs sensing application to locate route path from multiple sources to a single destination. With this in mind, data from every node in a network can be describe by a list of attribute value pairs called attribute-based addresses, such that a node can expose its availability to the entire sensor network[6] protocols and introduces the energy model employed and analyzes the algorithm of the protocol both in cluster formation and cluster head election. Section 4 shows the validation of the proposed technique and how it is being implemented in MATLAB by showing the simulation result of the protocol both in cluster formation and cluster head election. We also went ahead to simulate the mean and variance residual energy of the proposed protocol and see how it have effect on the energy efficient of the WSN. Section 5 conclude the report and also defines scope of future enhancements is also emphasized. Appendix-shows the mat lab code for the simulation.

2. Overview of Routing Techniques

Challenges encountered as a result of constrained energy supply and bandwidth in WSN when managing the network necessitates the need for development of energy awareness protocol at all levels of networking protocol stack. To offer efficient power management in WSN, researches have been focus on areas such as system-level power awareness like radio communication hardware, low duty cycle issues and energy-aware MAC protocols[7,15]. Also, it was observed that the network layer offers a better means through which reliable relaying of data and energy-efficient route setup within a network can help to maximize the network lifetime.

Due to these differences, new protocols are being researched and fashioned to eliminate the problem faced in WSN. These routing protocols have been fashion on sensor nodes characteristics alongside it application and architectural requirement. The various protocols can be classified as location-based, data-centric or hierarchical. Although there are other ones developed based on flow quality.

3. Clustering in Wireless Sensor Network

Clustering is a method by which sensor nodes are hierarchically organized on the basis of their relative proximity to each other. Hierarchical (sensor nodes clustering) energy consumption creates an effective and reliable means of routing collected data from the physical environment, through the sensor nodes to the BS. Clustering of sensor nodes helps to compress the routing table such that the discovery mode between sensor nodes is done more easily. Clustering can also conserve communication bandwidth because it limits the scope of inter-cluster interactions to CHs and avoids redundant exchange of messages among sensor nodes. Each sensor node performs a route table look up for the CH in its region and then routes its collected data to the CH. The CH performs a route discovery.

4. Energy Saving Schemes in Clustering Technology

4.1 Cluster formation and rotation

With the evolving trend in application and management of WSN, clustering provides an efficient means of managing sensor nodes in order to prolong its lifetime. Several clustering formation technique have been develop in the past such

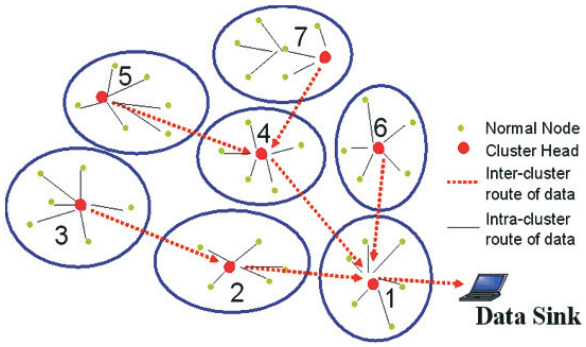

Fig. 1. Cluster Head Selection and Cluster Formation.

as random competition based clustering (RCC). RCC algorithm uses random timer and node identification for cluster formation is based on First Declaration Wins Rule. This rule assigns governorship position to any node which declares itself first as being a CH to other nodes in its radio network.

Furthermore, there are other approaches to cluster formation and an example of that is the broadcasting technique. Broadcasting can simply be described as when one sensor node is sending a packet to all other sensor node in wireless sensor network. It should be noted that not all broadcast messages are useful and also some of the messages sent by the sensor node are dropped because a sensor nodes status has already been assigned and cannot be changed.

In direct broadcasting technique, cluster advertisement message is sent to all sensors within a selected region. For instance, two clusters formation requires two random nodes are selected for broadcasting. This randomly selected node is known as an initiator. All initiators broadcast a cluster advertisement message to all sensor nodes in the network. If any node in the network that is not an initiator receives an advertisement message within the cluster, it sends a message to the initiator from which the message was received. It will not only send a reply but also refrain from accepting any other cluster advertisement message for that simulation round. Such a sensor node will however become a part of this initiator's cluster.

4.2 Cluster optimization by using K-hops

When addressing the problem of energy consumption in wireless sensor network, the size of a cluster is an important factor subject to analysis in hierarchical network. Clusters of small size save power in intra-cluster communication but it will also increase the complexity of the backbone network. Also, smaller cluster size means less load in the backbone and thus a less complicated communication, but the intra-cluster communication consumes more power and approach makes a use of the K-tree cluster framework and optimize the framework.

For instance, when two sensor nodes are placed at a far distance away from each other in the same cluster but one of them is closer to the base station, it is observed that the energy consumed by the node closer to the base station is lower compared to that which is far away. And with the help of multi-hop communication, an intermediary node is used between a source environment and BS to relay the data, a great deal of energy is conserved in the network. Figures 2 and 3 illustrate the concept of single-hop and multi-hop respectively.

Furthermore, taking computational complexity into consideration when designing cluster with uneven data traffic in each clusters when data are being transmitted[16], the size of clusters seem to be random at the time of formation. Although, in some circumstances, the cluster sizes are equal which denotes equal number of nodes, and in other scenario, the size is randomly sized.

When the cluster sizes are approximately equal, the clusters very close to the base station will consume more energy and die quicker than the cluster that is far away from the base station. This is because the cluster head closer to the base station collects all data from other cluster heads in the network and thereby having much data to relay to the base station. Therefore, the communication traffic between clusters is uneven. In Fig. 2, the communication between clusters is clearly uneven since the cluster head 1 relays more data to the base station (due to its closeness) than all other cluster heads.

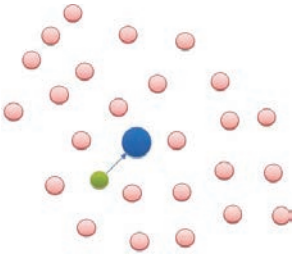

Fig. 2. The Single Hop Data Packet Transmission between the Sensor Node and Cluster Head.

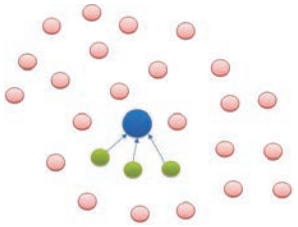

Fig. 3. The Multi-Hop Data Packet Transmission between the Sensor Node and Cluster Head.

4.3 The proposed routing protocol algorithm

Our proposed hierarchical routing protocol algorithm is based on the principle of clustering technique. With data transmission at the network layer being the core area of interest, that can be modified as the LEACH protocol in terms of hierarchical data transfer with the employment of energy prediction technique for selection of CH via any shortest path to the BS.

In the proposed model, clusters are formed based on the network size. The network size should be formed based on the sensor nodes and its cluster sizes is based on equal segmentation of area space, depending on the case being considered. To be able to use hierarchical routing for the energy efficiency simulation, it could be define based on the hierarchy of network routing topology as well as provide the sensor nodes with hierarchical addressing. Apart from these operations one cluster formation which makes use of the entire sensors area space, other formation such as two clusters formation and three clusters formation involves equal segregation of area space. The two clusters formation and the three clusters formation are otherwise known as first level and second level hierarchy respectively.

In this algorithm, the main idea of the base station is being setup to control energy efficiency with help of the hierarchical routing protocol in WSNs. While using this model, the base station will control the sensor nodes data packet transmission and then creates a sensor nodes of cluster head. Basically, the model of base station work's based on the concept of CHIRON, which divides sensor nodes into sub-groups by base station using the network operational direction. Therefore, the base station with hierarchical routing protocols techniques, is to combining the benefits of many clustering schemes to maximize the network life of sensor nodes. This algorithm simulation results are copying by the entire base station with hierarchical routing network protocol analysis will give better improvement comparing the other algorithms.

4.4 Simulation setup and scenarios

In this simulation, a total number of 250 nodes were randomly deployed within a space region on 300 m × 300 m. The Fig. 4 illustrates the simulated environment of the 250 nodes we deployed. The coordinates of X and Y are measured in meters.

With the nodes being deployed, some assumptions were made concerning the node features and these are as follows:

- All nodes are homogeneous in nature;
- All nodes starts with the same initial energy;
- The base station is situated at the (0,0) origin of the area space;
- Clusters and nodes are static;

The sensor nodes in the network are formed into clusters of different sizes of one, two and three. One indicates a non-hierarchy formation of cluster and, two and three indicate different level of hierarchy one and two respectively for data transmission. Figure 4. indicates the non-hierarchical structure of our routing technique. Likewise, Figs. 4 and 5 shows the simulation result of the cluster formation in the proposed technique.

Using MATLAB, all 250 nodes were randomly distributed as shown in Fig. 4 with the origin plane (0, 0), being the location where BS was situated. With the initial energy level of all nodes being set at 200 J, Eelec set to 50 nJ/bit,

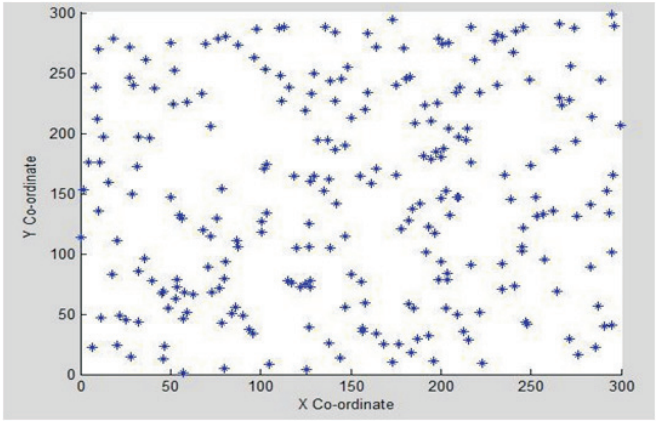

Fig. 4. 250 Nodes Deployed Randomly in a Geographical Location of X and Y Coordinates Measured in Meters.

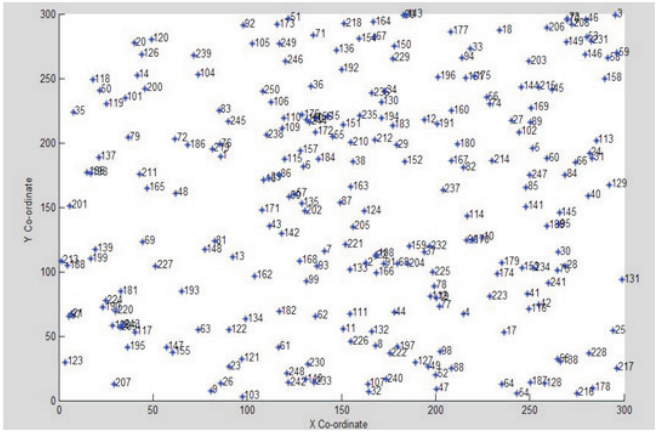

Fig. 5. Nonhierarchical Formations First Level Hierarchical Formation with Differentiated Colors Indicating Difference in Two Clusters.

Eamp set to 100 pJ/bit/m2, and the size of the sensor data set to 1024 bits, we used the radio model equation in predicting minimal transmission energy level for cluster head selection, data aggregation and transmission phase for 400 rounds for non hierarchical formation scenario, first level hierarchical formation scenario and second level hierarchical formation scenario. The cluster head(s) of m-th cluster formed aggregates the data received from other sensor nodes with its own data and transmits it to the next hop cluster head closer to the base station or to the base station depending on the cluster formation and the shortest distance between the cluster head and the BS. At every transmission or reception made, energy reduction occurs for every node, thereby cluster head rotation was utilized to help prolong the lifetime of the WSN.

4.5 Simulation results

It can be proved that the proposed hierarchical routing technique offers when compared to the non-hierarchical routing. We investigated the advantage of the proposed technique by comparing the time in which the first node dies during the 400 rounds of simulation (network lifetime) to that of the non-hierarchical routing technique. We observed that the Non-hierarchical technique had an estimated lifetime of 10 rounds, First level hierarchical technique had an estimated lifetime of 110 rounds and Second level hierarchical technique had an estimated lifetime of 130 rounds.

Table 1. Mean Value and Variance of the Residual Energy.

	Range (J)	Mean Residual Energy (J)	Variance Residual Energy (J)
Non-hierarchical Technique	21.7008	88.1270	7.4039
First level hierarchy	29.7538	13.1419	11.7406
Second level hierarchy	98.5569	43.9161	38.5569

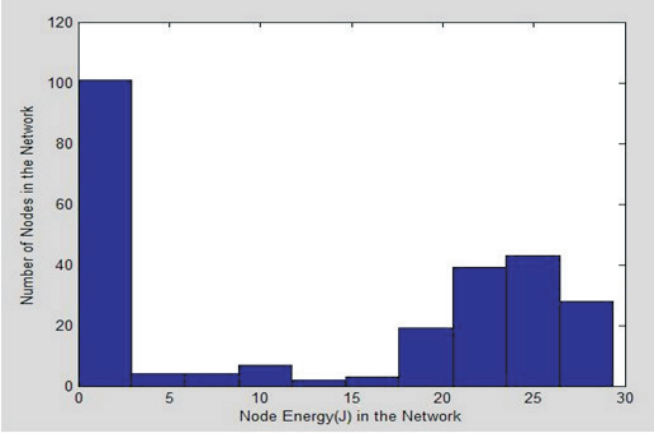

Fig. 6. Histogram of Residual Energy for Non-Hierarchical Technique.

The progressive increase of network lifetime employed by our proposed technique offers efficient energy usage for each node in the entire network.

Also, it was observed that the Non-hierarchical technique network completely stopped functioning at an earlier simulation rounds compared to our proposed technique. We saw that the functional capacity for Non-hierarchical network lasted till an estimated value of 120 rounds of simulation, while the functional capacity of the First level Hierarchical approach and Second level hierarchical approach lasted till an estimated value of 180 rounds and 330 rounds of simulation.

Furthermore, we also observed in Fig. 6 that the network lifetime increased to a certain length in the three cluster formation scenario (second level hierarchy). With this increase, the WSN's lifetime was further prolonged when compare to the two cluster formation and the nonhierarchical technique.

The Table 1 shows the range, mean and variances of the residual energy after 400 rounds simulations for the hierarchical routing technique employed. The mean value of the residual energy increases in each round of simulation as the hierarchical structure increases. This implies better network performance since the nodes has more energy in the latter level of hierarchy.

It is also observed in the Table 1 that non-hierarchical technique has the lowest variance and the second level hierarchy has highest standard deviation value. The highest value implies the residual energy values after those rounds of simulation are spread out over a large range. Likewise, a lower variance value indicates that the residual energy of each node after the entire value indicate how dispersed the residual energy of all node is from the mean value after the entire it implies a better performance of network since most of the node will die almost at the same time in the end of the simulation. The Fig. 6, 7 show the plot of the histogram of the histogram of the residual energy after 400 rounds of simulation.

Comparing the Fig. 6 and 7 histogram results, we proposed algorithm is purely justified based on the network base station with hierarchical routing protocol techniques. This type of algorithm will shows to control the energy efficiency in wireless networks data packets transmission between the sensor nodes and cluster head. So, the final result of our proposed model is improves to network life time as well as energy will be using very effective manner in the wireless networks with help of the sensor nodes.

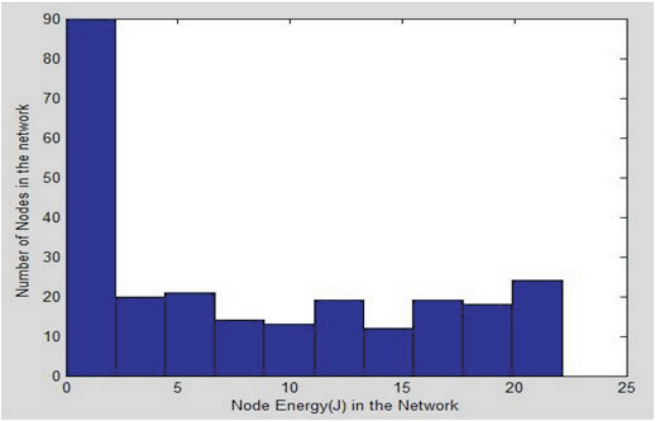

Fig. 7. Histogram of Residual Energy for First Level Hierarchy.

5. Conclusions

In this paper, we propose an energy efficient hierarchical routing technique in which cluster heads are elected based on the prediction of transmission energy via a shortest distance to the base station. Our approach applies a geographical formation of sensor nodes into clusters, rotating the role of CH, and optimizing the CH selection by prediction of energy transmission energy in every rounds of simulation, and aggregating data before transmission to the BS. The important features which includes cluster formation and rotation, cluster head election and rotation, and cluster optimization of our proposed hierarchical routing technique in transmitting data to the base station was analyzed and emphasized. We also extend the validation of our technique by further evaluating the second level hierarchy in which three cluster were formed in the network, and observed an improved network lifetime which indicate a better energy efficiency in the WSN.

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