CBERP: Cluster Based Energy Efficient Routing Protocol for Wireless Sensor Network

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Abstract: - Since all sensor nodes in wireless sensor networks work by their own embedded batteries, if a node runs out of its battery, the sensor network cannot operate normally. In this situation we should employ the routing protocols which can consume the energy of nodes efficiently. Many protocols for energy efficient routing in sensor networks have been suggested but LEACH and PEGASIS are most well known protocols. However LEACH consumes energy heavily in the head nodes and the head nodes tend to die early and PEGASIS - which is known as a better energy efficient protocol - has a long transfer time from a source node to sink node and the nodes close to the sink node expend energy sharply since it makes a long hop of data forwarding. We proposed a new hybrid protocol of LEACH and PEGASIS, which uses the clustering mechanism of LEACH and the chaining mechanism of PEGASIS and it makes the lifetime of sensor networks longer than other protocols and we improved the performance 33% and 18% higher than LEACH-C and PEGASIS respectively.

Key-Words: - LEACH, PEGASIS, Clustering, Sensor Network, Network Lifetime, Routing Protocol

1 Introduction

MANET (Mobile Ad-hoc Network) is a kind of a wireless network which enables the devices to move communicating without any aid or intermediation of wired networks. This network is not appropriate to apply the currently existing routing protocols due to the limited amount of energy resources and mobility of its wireless nodes. Accordingly, there have been many sensor network routing protocols proposed to solve various kinds of problems, demanded in sensor networks. Presently, widely suggested routing techniques are distributed among several classes which are: flat, hierarchical, and location-based techniques.

LEACH(Low Energy Adaptive Clustering Hierarchy) [1][13][14] is a widely accepted hierarchical routing protocol, and PEGASIS(Power-Efficient GAthering in Sensor Information Systems)[2][12][15], which is devised to make up for the weak points in LEACH, is notable as well. However, the drawbacks of LEACH(or LEACH-C) lie in the fact that the headers become exhausted earlier than other nodes, and PEGASIS, known as more efficient than LEACH, also has a weak point to make the route from the source node to the sink node significantly lengthy.

We suggest a hybrid routing algorithm based on LEACH and PEGASIS, which solves the problems of those two algorithms and advances the sensor network to last longer by making the nodes consume more efficiently.

2 Problem Formulation

PEGASIS Routing technique has various weak points with one core matter which is energy. First of all, when head node is chosen, the energy information is not collected for each node. The problem also occurred while forming a chain when a node that has weak energy must also form chain again, this result in energy constrained.

Secondly, phenomenon of time prolongation can occur when applying Greedy algorithm. Greedy algorithm is an algorithm that appears to solve Knapsack Problem. Greedy algorithm is an algorithm to select a procedure of data as in search of weighting value. This algorithm is used in our approach to decide procedure nodes by giving routing weighted values of nodes as specified in PEGASIS Routing technique. However, though the algorithm for decides a procedure of nodes is used, the prolongation of time, as the number of nodes increases, most comes to suffer.

At last, lack of data packet collected time in the case of far-off distance nodes within the head node time, and the sink electing head node can be over before the data packet arrive. Also when collecting data at the head node enter simultaneously, bottleneck can occur.

3 Problem Solution

Normally considered, the most important part in sensor networks is the life span of the nodes. Each node in a sensor network becomes useless after wasting its energy completely because its power totally depends on the embedded battery and it is unlikely to be returned due to the remoteness of the area. LEACH and PEGASIS are the two energy efficient routing protocols devised to extend the life span of the nodes in the networks with the above-explained traits. In sensor networks, once a node starts to die then the whole network is considered to be dead since the first node triggers others nodes to die soon as well. In this paper, we suggest a new routing protocol with the goal to prolongate the life span of the firstly dying node in the sensor network.

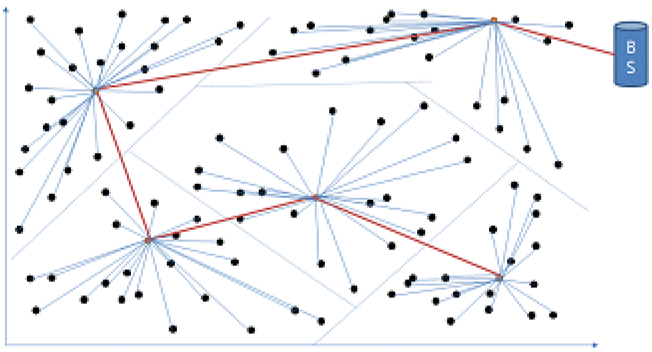

Figure 1. CBERP Routing Protocol

As in the figure 1, the new protocol organizes clusters with the headers chooses by the BS as LEACH-C does. In this figure, the red spots are the headers and the black spots are their nodes. In addition, we apply the Greedy algorithm used in PEGASIS to chain the headers. All member nodes in each cluster transmits its data to the header, and all the headers send the data to its leader node along the chain, finally the leader node transfers the collected data to the BS. The leader node is not statically selected but is dynamically decided in the order of the remaining amount of energy to avoid one certain node to die earlier than others. After all, CBERP organizes clusters using the same mechanism of LEACH-C but different from LEACH-C where each of the headers permit to transmit data directly to BS, while CBERP uses chaining to send data more efficiently as in PEGASIS.

In the case of LEACH-C that the headers transmit data to the BS directly, the amount of energy spent for the transmission varies depending on the distance from the header to the BS. Furthermore, the mechanism causes the headers to die early because the headers have to do both collecting the data from the members and sending them to the BS, and the number of transmission is more than other nodes do. In contrast, CBERP keeps the balance of the energy consumption among the headers since it chooses the leader node with the greatest amount of energy for data transmission, and consequently it helps the whole network last longer.

PEGASIS, the protocol designed to overcome the drawback of LEACH-C that the headers spend too much energy, forms a chain through all nodes, yet it delays data transmission because the length of the chain is too long, and the chain might be broken by one dead node in the middle. CBERP however greatly enhances the performance for data transmission by shortening the average length of the chain, contrasting to PEGASIS. In reality, the BS to headers are more likely to die early since they have more chances to do transmission. On the other side, CBERP does not have the same problem since it chains only the headers, and effectively selects the leader of them.

3.1 Selecting Cluster Headers

CBERP uses the energy tolerance limit E to advance the header selection method of LEACH-C and to use energy more efficiently.

At first, we simply select the node with the highest remaining energy as the header of the cluster. More specifically, we choose the node that gives the highest E value in the following formulas.

$$E = E_{resi}/E_{INIT} * CH_{pnt} \quad (1)$$

$$E` = \sum E_{resi}/\sum E_{INIT} * CH_{pnt} \quad (2)$$

In formula (1) and (2), E_{resi} indicates the remaining amount of energy for the node, E_{INIT} is the amount of its initial energy, CH means the header of the cluster, and CH_{pnt} indicates the proportion of the number of the headers to the number of all nodes in the network. In addition, CH_{pnt} is used as the constant to decide the tolerance limit for the header as well. The proportion of the headers plays an important role. In this paper, we uses 5% for the proportion, which is the same ratio that LEACH-C[2] uses.

When a newly-calculated E is greater than the value of the current header E', the node with the E becomes a new header. The new header assumes the right to collect the data from the member nodes and announces that it has become the header to them. Since every node in the network send data to the BS, and the BS broadcasts the information of the headers to all nodes while selecting the headers, it is better not to initiate the header selection algorithm too often. It is very likely that the node with the second-greatest remaining amount of energy becomes the header for the next round since each node of the cluster does not generally spend too much energy comparing with the amount of the initially given energy. CBERP however selects another three headers except the one explained above though LEACH-C chooses only one header based on a heuristic method.

The number of the candidates for the header can be from one to n but if more than four candidates are selected or five nodes have the remaining energy less than the amount of the tolerance limit, a new header selection algorithm should run because it has been a long time. In this way, even if a certain node spends too much energy more than usual in an abnormal situation, it will avoid selecting that node because the node has existed in an old candidate list. Consequently, we could reduce a quarter of the overhead occurred by the header selection in LEACH-C.

3.2 Proposed Algorithm

Step 1 : Initialization
BS broadcasts messages for header selection to all nodes.
All nodes send location and energy information to BS.

Step 2 : Header Selection
BS selects four nodes with the greatest remaining energy: NA, NB, NC & ND.
E(NA)>E(NB)>E(NC)>E(ND): NA becomes the first header and other nodes become the candidates.
BS sends NA the E`after calculating it.
If E > E` of NA, NA becomes CH.

Step 3 : Chain Formation
End_CH sends the TOKEN to Next_CH.
CH sends the TOKEN to BS
BS broadcasts the 'chain completion' message.

Step 4 : Management
Member nodes of each cluster sends data to CH.
CHs collects the data.
CHs send the collected data to the leader through the chain.
Leader node sends the final gathered data to BS.

Step 5 : Header Switch
If E(CH) < E', the first candidate becomes a new header.
If E of the three candidates is greater than E', go to Step 2.

Figure 2 Pseudo code of the proposed algorithm

In the Step 1, the BS sends a message to each node in the network, including the CHs(Cluster Headers) and the member nodes, to demand them to reply with their location and remaining energy information, and the nodes transfer the requested data to the BS. This process is the equivalent as the one in LEACH-C.

Next, in the Step 2, the BS selects the headers based on the remaining energy information transferred in the Step 1. The selected headers spread the TDMA schedule to the neighbor nodes. This procedure is basically alike the one in LEACH-C, however our new mechanism selects one header and three candidates, and hereafter when a new header needs to be selected, one of the candidates becomes a header without re-running the header selection algorithm.

The Step 3 is a process to form a chain along the headers decided in the previous steps. For this, we use the Greedy Algorithm used in PEGASIS. The chain is formed in the order from the furthest to the nearest node from the BS, and nearer nodes have better opportunities to be the leader.

In the Step 4, through the chain of the headers formed in the Step 2 and 3, the collected data from the member nodes of each cluster are transferred by the their header, and the headers pass the data to their leader.

Continuously in the Step 5, when a header needs to be switched with another, due to its exhaustion, a new header is selected using the header selection method explained in the chapter 3.1. In other words, our new mechanism can reduce the overhead from header selection by allowing a candidate take over the responsibility of the header instead of executing the costly header selection algorithm.

Alike the suggested protocol in this paper, BCDCP[8] determines the routes using the techniques in both LEACH-C and PEGASIS. However, since this protocol assumes that every node has the ability to directly transfer its data to the BS and that nodes have no mobility, it is realistically ineffectual.[9][10] Opposingly, our new protocol can guarantee the mobility of the nodes as it periodically re-arrange the clusters over the whole network and the headers continuously report the state of their clusters to the BS. Furthermore, CBERP can significantly reduce the overhead caused by selecting new headers since it selects a multiple of candidate nodes and appoints one of them the header whenever the original header is unavailable.

4 Test and Evaluation

4.1 Environment

For evaluation, we used NS-2(ns-2.27) and tested CBERP and other referred routing protocols, such as LEACH, LEACH-C and PEGASIS. But, we assumed the following during the test.

1) The BS(Base Station) has powerful operation and data communication capabilities.
2) Every node has sensors and a transmitting device of the equivalent performance with each other.
3) The BS has the location information of all nodes.
4) Every node knows the distance to its neighbor nodes from itself.
5) The distance for transmission of every node is 100m.

Name	Value
Initial Energy for a Node	25kJ
Transmission Power	200mW/110mW
Consumed Energy for Transmission per bit	20μJ(Tx)/11μJ(Rx)

Chart 1. System environment settings

As the Chart 1 shows, each sensor node spends 20μJ per bit for transmitting in 10kbps and 11μJ for receiving. Therefore, a node spends 0.02J and 0.001J relatively for transmitting and receiving 128 byte data.

4.2 Performance

In the Figure 3, we displayed the result of the experiment that tested the nodes in the field of 100m * 100m varying the number of the nodes from 50 to 200. With the low density of nodes CBERP showed greatly better performance than PEGASIS, yet it was slightly better than PAGASIS as the density grew.

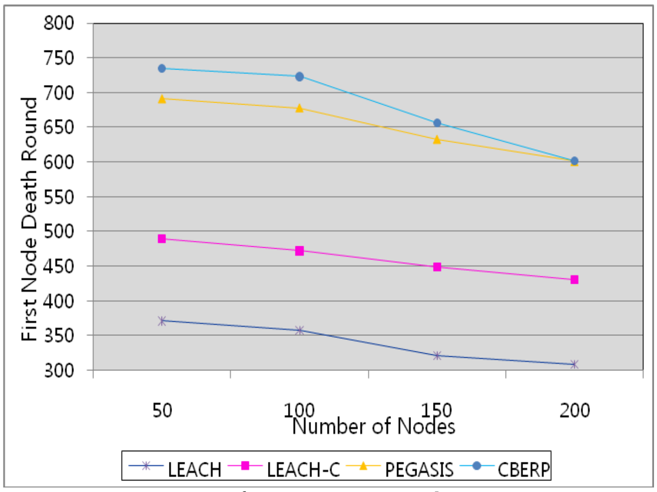

Figure 3 Performance test upon node count

	Node Count:100	Node Count:200
	Round when a node dies at the first	
LEACH	359	254
LEACH-C	477	331
PEGASIS	679	402
CBERP	727	491

Chart 2. Comparison of Rounds when a Node Dies at the First

We indicated in the Chart 2 more specifically how many rounds the first exhausting node appears after in the field of 100m * 100m changing the number of the nodes from 100 to 200. CBERP showed 48% better performance than LEACH, 33% better than LEACH-C and 7% better than PAGASIS when the numbers of nodes are 100, and 49% better than LEACH, 34% better than LEACH-C and 18% better than PEGASIS when the nodes are 200.

5 Conclusion

Among all protocols for sensor networks, LEACH-C and PEGASIS are known as the most energy-efficient algorithms. In LEACH-C, the cluster headers collect the data from their member nodes. The headers thus spend a great amount of energy and they die earlier than other nodes.

PEGASIS, an improved protocol of LEACH-C, does not use clustering and forms a chain linking along all nodes to reduce energy consumption. However, as the number of nodes grows and the chain become lengthy, the data transmission time from the source to the sink node, which is the BS, and the nodes close to the BS die earlier than others. Moreover, if a certain number of nodes move, it uses more energy since it has to repeat chaining the nodes.

In this paper, we tried solving the problems by mutually combining PEGASIS and LEACH-C. More specifically, CBERP divides nodes into clusters and selects the headers that gather and transmit the data from their member nodes as in LEACH-C. However, CBERP advances the header selection mechanism by utilizing a number of candidate nodes to reduce the overhead. After selecting the headers in this way, it forms a chain of the headers and send data through the chain as in PEGASIS. Thus, with the new protocol suggested in this paper we could overcome the drawback of PEGASIS since the number of nodes forming the chain is smaller in CBERP, and could minimize the overhead while clustering.

For the future work, our research will focus on how many header candidates should be selected for more effective performance. Depending on the number of nodes and the size of the field, the optimizing value is expected to be varying, and we are planning to get the distribution of the values by conducting many experiments.

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