Efficient Cluster Head Selection Method For Wireless Sensor Network

Manjusha M S[1], K E Kannammal[2]

[1] PG Scholar, Department Of Computing Science, Sri Shakthi Institute Of Engineering And Technology Tamilnadu, India,

[2] Associate Professor, Department Of Computing Science, Sri Shakthi Institute Of Engineering And Technology Tamilnadu, India

ABSTRACT:

A WSN (Wireless Sensor Network) consists of over hundreds of sensor nodes which have limited energy, process capability and memory. The applications of WSN in some extreme environment make sensor nodes difficult to replace once they use up the battery resource. Since the wireless transmission is the most energy consuming operation, how to design an energy efficient routing protocol becomes the main goal for the wireless sensor network. LEACH is considered as the most popular routing protocol which has better performance in saving the energy consumption. However, the selecting formula neglecting the change of nodes' energy will make the nodes acting as cluster heads too many times which leads to the death of the cluster head early by consuming excessive amount of energy. Also, the frequent reclustering wastes certain amount of energy. This paper presents a new version of LEACH protocol referred to as VLEACH which aims to reduce energy consumption within the wireless network.

KEYWORDS: *Clustering*, Cluster Head, *LEACH protocol, Routing, V-LEACH, Vice Cluster Head, Wireless sensor networks*

I. INTRODUCTION

Wireless sensor network consists of hundreds and even thousands of small tiny devices called sensor nodes distributed autonomously to observe physical or environmental conditions like temperature, pressure, vibration and motion at different locations such as landslides [5]. Every node in a sensor network usually equipped with one sensor, a wireless communications device like radio transceiver, a small microcontroller, and an energy supply, a battery. Since the nodes are battery operated energy plays a vital role. The application of the WSN involves several fields, like military battleground, fire detection, and other extreme environments. In these situations, it is troublesome to replace the dead nodes caused by energy's depletion with new ones to provide energy for the system. Therefore, making sensor nodes operating as long as possible is the main method to maximize the lifespan of the sensor network. Because the energy's consumption of sensor node primarily originates from the long distance transmission of data, an efficient routing protocol can have a good impact on the energy's consumption. Thus how to design an energy efficient routing protocol becomes the main goal for the wireless sensor network [6].

The basic objective on any routing protocol is to make the network useful and efficient. A cluster based routing protocol group sensor nodes where each group of nodes has a Cluster Head (CH). Sensed data is sent to the CH rather than send it to the BS; CH performs some aggregation function on data it receives then sends it to the BS where these data is needed. LEACH [7] is considered as the most popular routing protocol that use cluster based routing in order to minimize the energy consumption. Leach divides the communication process into rounds with each round including a set-up phase and a steady-state phase. In the setup phase, some sensor nodes are selected as CHs according to certain rules and other nodes join in the clusters as member nodes. Within the steady-state phase, the CHs collect the data coming from their own cluster members and aggregate them before transmitting to the BS [4]. However, due to the inherent characteristic of LEACH, the unnecessary energy consumption caused by the

unreasonable choosing formula and the high frequency of reclustering among sensor nodes will cause the uneven energy distribution and waste a certain amount of energy in the whole network. Supported the ideology of traditional LEACH, we modify the selecting formula by considering the dynamic change of sensor nodes' energy and establish a Vice cluster head for every cluster during the communication process, that aims to diminish the energy consumption spent on the reclustering and prolong the time of being in a steady-state phase.[2]

II. LEACH PROTOCOL

Low Energy Adaptive Clustering Hierarchy (LEACH) [3, 8] is the first hierarchical cluster-based routing protocol for wireless sensor network that partitions the nodes into clusters, in each cluster a special node with extra privileges referred to as Cluster Head (CH) is responsible for creating and manipulating a TDMA (Time division multiple access) schedule and sending aggregated data from nodes to the BS where these data is needed using CDMA (Code division multiple access). Remaining nodes are cluster members. Figure 1 shows the LEACH protocol. LEACH is divided into rounds; each round consists of two phases.

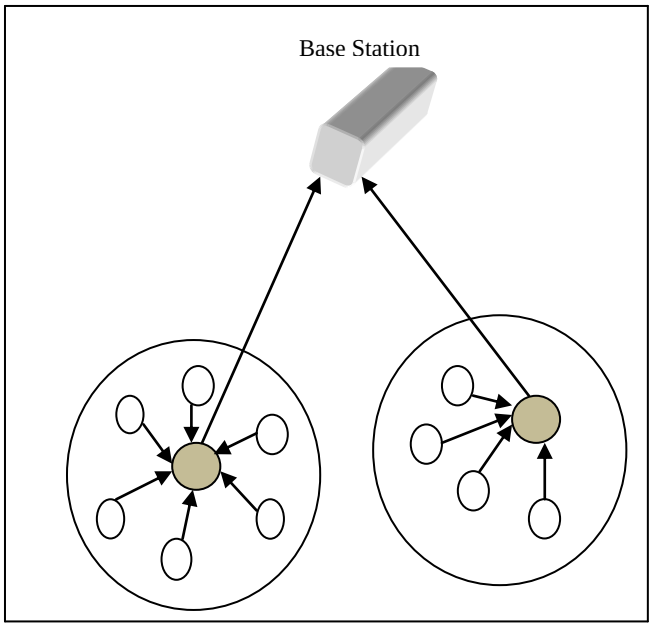

Figure 1. LEACH Protocol

2.1. Set-Up Phase. After finishing the deployment of sensor nodes, each node within the monitor field decides independently of other nodes whether or not it can become a cluster head in the current round. Throughout the phase, every node generates a random number between zero and one [1] and then compares it with the threshold value T (n).

$$T(n) = \begin{cases} \frac{p}{1-p\cdot\left[r \bmod \left(\frac{1}{p}\right)\right]}, & n \in \\ 0, & n \end{cases} \qquad (1)$$

Where p is that the percentage of cluster heads over all nodes within the network, r is the number of rounds of selection, and G is that the set of nodes that haven't been selected as cluster heads in round $1/p$. The node whose number is larger than the threshold can choose itself as a cluster head so broadcasts the message to its surround sensor nodes. During this phase, a node could receive more than one broadcast message from completely different cluster heads, however the node will decide its distance to a cluster from the strength of received broadcast signal; the stronger the signal, the nearer to a cluster. So the node whose number is smaller than threshold will only send request message containing its ID to the cluster that has the strongest signal strength for saving energy spent on the transmission distance. Once the cluster head receives request message returning from one node, it records the node's ID and decides it as its member node. Once the message exchanges between cluster heads and normal nodes, every CH gets its own member nodes' information regarding IDs and every normal node gets that cluster that it belongs to. Based on the message it records, a

TDMA schedule is created by the CH and broadcasts it to the cluster members. So all the member nodes of that CH gets their idle slots for data transmission. Then the steady-state phase starts.

2.2. Steady-State Phase. The establishment of a cluster head in every cluster during the set-up phase provides a guarantee for the data transmission in the steady-state phase. In normal cases, member nodes can put off their radio till they sense the required surrounding environment data. If there are some data in need for transmission, they will send the data to CH during the idle slots recorded within the TDMA schedule table. As for the CHs, they need to keep up communication status at all times so as to receive the data from different member nodes. Once receiving all the data from their members, CHs will aggregate these data's and then send them to BS. As a result of some sensor nodes may sense similar environment data, the aggregation on the cluster head will diminish excess bandwidth cost and communication traffic that includes a positive reflection to the energy's consumption. Also, the transmission distance becomes shorter comparing with transmitting to BS on an individual basis for each member node, which can save energy for the member nodes. However, the heavy tasks on CH will result in an excessive amount of energy consumption. So as to avoid making the CHs die early and cause the cascade result within the network, a new round begins and new clusters are going to be rebuilt in the whole network.

Although the LEACH protocol acts in a very sensible manner, they also suffer from several drawbacks just like the following:

[1] CHs' selection is random, that doesn't consider the residual energy of every node or want the support of BS.
[2] The high frequency of reclustering wastes a certain quantity of energy.
[3] It can't cover a large area.
[4] CHs aren't uniformly distributed, where CH may be settled at the edges of the clusters.

III. PROPOSED SYSTEM -VLEACH

Motivated by the initial LEACH and different improvement protocols [2, 3] we tend to propose a modification to the cluster head selection method to reduce energy consumption. For a small sensor network, we make the following assumptions.

[1] The base station (BS) is located at a fixed location which is far from the sensors and is immobile.
[2] All nodes within the network have limited energy with an indentify ID.
[3] All the nodes are able to reach BS and can communicate with one another.
[4] CH perform data compression and aggregation function.

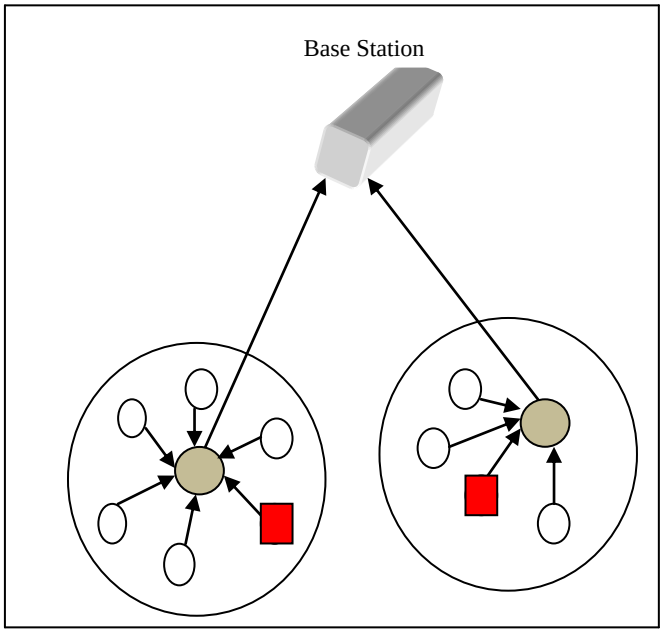

Figure 2. Proposed VLEACH

In the improvement, we also make use of the hierarchical clustering ideology and divide a round into a set-up phase and steady-state phase. The set-up phase will use a modified formula for selecting the appropriate

CHs which are responsible for collecting data from their member nodes and transmitting them to BS. CHs will consume more energy than member nodes because of the heavy tasks so in order to avoid making the CHs die early, LEACH take the measure of beginning a new round and rebuilding the clusters. However, in the proposed system we will make use of the information about the member node which is achieved dynamically by cluster heads in the steady phase to choose the vice cluster heads (VCHs). VCH take over the role of cluster heads in the later period of steady state phase. Figure 2 shows the VLEACH protocol. Comparing with the normal LEACH, the VCHs proposed will diminish the frequency of reclustering in the same interval and extend the time of being in steady-state phase, which is able to prolong the lifecycle of the whole network.

3.1. Selecting Cluster Heads (CHs) in the Set-Up Phase. Based on the fact that LEACH does not take into account the residual energy of the nodes during the selection of cluster heads in the set-up phase, we tend to develop the present energy and also the times being selected as CH or VCH. We first consider about the threshold $T(n)$ and are modified to the following equation:

$$T(n) = \begin{cases} \frac{p}{1-p*\left[r \bmod \left(\frac{1}{p}\right)\right]} \times \left[\frac{E_{n_{current}}}{E_{n_{init}}} + \left(1 - \frac{E_{n_{curr}}}{E_{n_{ini}}}\right) \right. \\ \left. \times \frac{p}{(CH_{times}+VCH_{times}+1)} \right], & n \in \\ 0, & n \notin \end{cases} \quad (2)$$

Where p is that the percentage of cluster heads over all the nodes within the network, R is the number of round of selection in current time. G is that the set of nodes that haven't been selected as cluster heads in round $1/p$. $E_{n\ cur}$ is the residual energy of the node and E_n is the initial energy of each node. CH times (VCH times) is that the times of being selected CH (VCH times) once. Deducing from (2), we can able to get that the larger the $E_{n\ cur}$ larger the $T(n)$. So we can infer that the node that has lot of energy will have a much bigger probability to become the cluster head within the current round. But at the same time, if a node acts as CH or VCH for an excessive amount of time, the energy it consumes are going to be larger than other sensor nodes. However, the improved equation can lower the probability of a node acting as CH or VCH too many times to become CH again. We are able to observe that the improved formula adds some useful determinacy factors within the choice of cluster heads that is helpful to the stabilization of clusters. If there are too many selected cluster heads in the deployed area then it will cause some unnecessary energy consumption. For limiting the cluster heads' number to a reasonable range, we tend to develop the simulated annealing algorithm to form appropriate numbers of cluster heads which is about 4%-5% of the overall sensor nodes. Once finishing the choice of cluster heads within the set-up phase by using the improved equation and simulated annealing algorithm, begin the steady-state phase of a round.

3.2. Establishment of Vice Cluster Heads' (VCHs') during the Steady-State Phase. In the steady-state phase of LEACH protocol, the cluster heads will consume more energy than member nodes. As a result they need to take the responsibility of aggregating and relaying data to remote BS for their member nodes. So as to avoid making the cluster heads die early when undergoing certain amount of communication time, a new replacement round begins to reorganize the nodes into clusters and reselect the cluster heads. So, all the nodes go to judge themselves and rebuild the cluster heads so as to campaign for new cluster heads. So, it consumes some energy spent on recompleting the cluster heads and shortens the full time of being in steady-state phase. Thus we propose a new scheme to extend the time of being in steady phase and diminish the frequency of recluster. The new scheme works as follows. During the data communication in steady-state phase, as a result of all member nodes send the data sensed from environment to their own cluster head, the cluster head will have the chance to find out the status information of its members. Based on this, the cluster head will record the information of various member nodes dynamically in the format like <id, E>, which refers the member node *id* has residual energy *E*. Through this fashion, the CH can have global energy information about its member nodes. So as to extend the time of being in steady-state phase and delay a new round's coming; CH can appoint a member node which has the utmost energy in cluster to take over the role of it if it consumes too much energy in the later steady-state phase of current round. Thus we can call the member node which is appointed by the CH as a vice cluster (VCH). So as to make the rest of member nodes get the VCH's *id*, the CH broadcast this message containing the VCHs *id* to various other member nodes. Then from that, the CH itself will become a standard member node because of the too much energy consumption and the establishment of VCH in a cluster. Since then, all the member nodes can send their data to VCH, which send the compressed data to the BS. We are able to observe that the establishment of VCH in cluster can prolong the communication time of being in steady-state phase and it also delay the coming of a new round. But the problem is that after a certain time,

VCH also consumes more energy than the member nodes due to the heavy tasks undertaken as previous CH. To avoid the chances of being the VCH die early, start a new round for selecting CHs among all the sensor nodes in the set-up phase. So we can call the whole communication in our improved protocol as the cycle of "CH-VCH-CH." It can be described using the Figure 3.

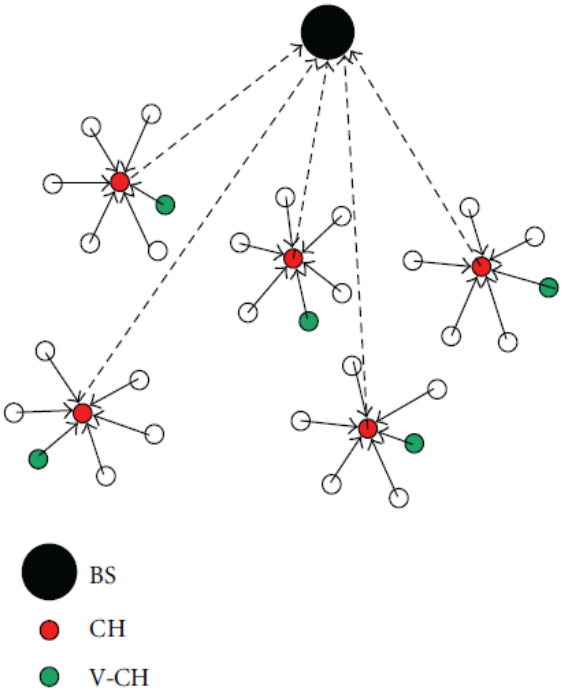

Figure 3. Improved hierarchical protocol working process

In the proposed protocol, we have taken the measure of choosing a VCH for every cluster in the later period of the steady-state phase in a round by using the energy information achieved by CH, which may diminish the frequency of reclustering and extend the time of being in steady-state phase. Within the whole communication phase of a round, CH and VCH have similar roles such as collecting data from member nodes and relaying the aggregated data to the BS. The distinction is that the CH takes the responsibility within the earlier stage of the steady-state phase, while VCH replaces the CH and works in the later stage of the steady phase of the current round. Also, the CHs choice originates the competition among all the nodes within the set-up phase. However, CH directly establishes the VCH within the later stage of the steady-state phase in a round. We are able to get that the method of establishing VCH is easy and speedy comparing with the generation and cooperation of random numbers within the set-up phase. Thus all of them have a good benefit to the saving of energy in the whole network.

IV. SIMULATION RESULT

We examine the improved protocol through simulations in matlab. A network consists of 100 nodes is deployed in an area of 100m × 100m with BS at (50, 50). For comparing the advantages of the improved VLEACH protocol we use the number of dead nodes as simulation parameter. The simulation results are shown in Figure 4. From the simulation we can observe that in our proposed VLEACH node starts to dead earlier than the normal LEACH protocol.

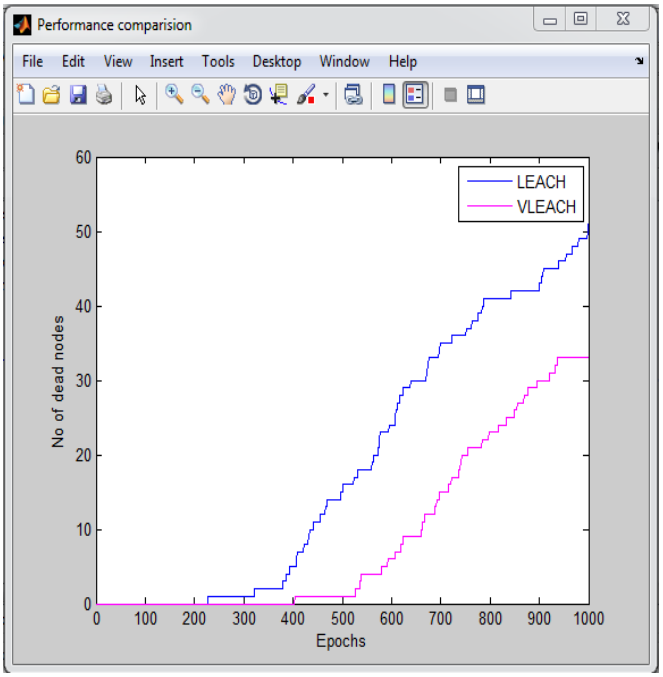

Figure 4: LEACH and VLEACH with 100 nodes

We also compare the LEACH and VLEACH with 200 nodes for showing that our proposed protocol also works in the case of dense networks also. The simulation result with 200 nodes is shown in Figure 5.

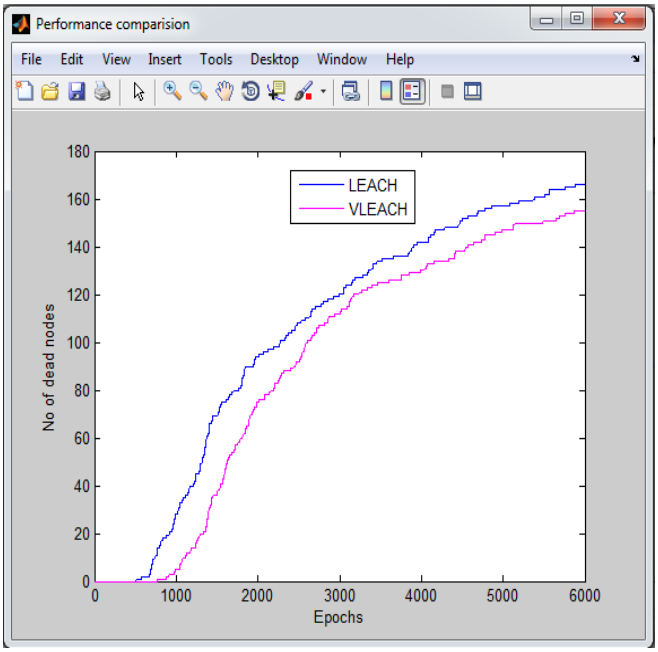

Figure 5: LEACH and VLEACH with 200 nodes

By the introduction of VCH, certain amount of energy spent on the reclustering and recomputing among different nodes gets reduced. From Figure 4 and 5, we can obtain that the number of dead nodes is reduced in our improved routing protocol than LEACH over the simulation rounds. This shows that our improved protocol consumes less energy. Also due to our modification to the steady-state phase, the times for selecting the cluster heads to each member node in the whole network become reduced. This results the remaining energy of the network using our improved protocol exceeds that of the original LEACH protocol.

V. CONCLUSION

In this paper, an outline of the original LEACH protocol is presented and proposed a new version of hierarchical protocol referred to as VLEACH. The proposed protocol obtains energy efficiency by the modification for selecting the cluster head formula and the steady-state phase. The modification to the choosing of cluster heads formula makes the CH or VCH have more opportunity to act as CHs. So the total energy of the whole network has more even distribution among different nodes. Thus the VCH introduction makes the frequency of reclustering more lowly and prolongs the time of being in steady-state phase; thus the energy used for calculating the formula on every node reduces.

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