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Energy Efficient Hierarchical Based Routing Protocol for Mobile Wireless Sensor Network

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Abstract
Many researches in wireless sensor network aims to minimize energy consumption, as energy is the primary life factor of a node. In this paper, hierarchical protocol, i.e. clustering concept is used to minimize energy consumption. The proposed protocol is a mobile data collector based architecture which is an improvement of LEACH-C (Low energy adaptive clustering hierarchy-centralized) protocol. In this variable round time method is used instead of constant round time method, which provides multi-hop communication between node and base station. Mobile data collector architecture typically can be used for large geographical regions. The proposed protocol is simulated by using NS2 simulator. This shows the improvement of energy utilization and throughput compared with existing protocols like LEACH-C and LEACH-M.
Keywords: *Wireless sensor network, Cluster, Cluster Head and LEACH, Routing etc…*

1. Introduction

Current wireless technology provides advantage that allows the manufacturing of small and low cost sensors that can connect to each other wirelessly. The sensing devices are used to observe different kinds of atmospheric conditions like temperature, pressure, humidity etc., and convert them into electrical signals, but these sensing devices depends mainly on battery for its operation. Thus the minimum usage of energy increases the network lifetime. But in some applications it is very critical to replace the battery if it is totally drained off, which leads to network failure or messages cannot be reached to the user. More energy is needed when the node is transferring data to the user. Keeping all this in mind, many routing protocols have been developed [1].

Routing in Wireless sensor network is classified into three different types; 1) Flat based routing: Here, each node typically plays the same role and sensor nodes combined together to perform the sensing task; 2) Location based routing: sensor nodes are addressed by means of their locations; 3) Hierarchical based routing: The scheme of hierarchical routing is to manage efficient energy utilization by multi-hop communication. The data aggregation and fusion is to reduce the amount of messages transmitted towards the base station [2].

Clustering technique is usually used to reduce the energy consumption of the sensor nodes. In each cluster a node is nominated as a cluster head, which is responsible for collecting the data from member nodes and aggregates this data to the base station. Cluster based architecture has some special advantages compared to others like scalability and efficient communication. Figure 1 shows the Hierarchy of a cluster model.

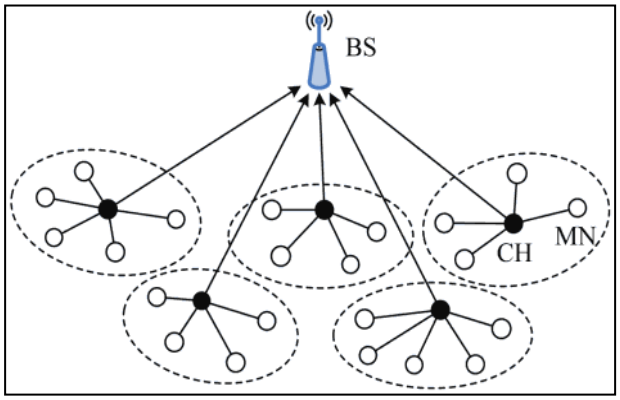

Figure 1: Hierarchy of a cluster model

Heinzelman et al. [3] proposed low energy adaptive clustering hierarchy (LEACH) protocol a well-known clustering protocol but, it does not consider round time for nodes in the operation. To solve this problem LEACH-C protocol was proposed that uses constant round time for nodes in which it calculates the round time based on initial number of nodes and applies for entire network lifetime. But use of constant round time makes the network load unbalanced. Since, sensor nodes are dynamic in nature, if new nodes are added into the network or any node may die because of lack of energy after the round time has been decided, then the round time is not enough to complete the operation because of the addition of nodes. To overcome this variable round time method is used, where the round time is decided based on the number of active nodes with its remaining energy level.

Many clustering protocols proposed for Wireless sensor network assume that nodes are stagnant. The reason for sensor nodes to be taken as stagnant is the assumption of simple network topology. Clustering protocols may reduce signalling overhead since they do not have to manage the mobility pattern or location information of sensor nodes. As a result, it allows nodes saving more energy leading to a longer network lifetime. However, with some applications such as animal tracking, search and rescue activities this assumption is not very realistic, hence there are raising demands for clustering protocols to support mobile nodes [4].

The rest of this paper is organized as follows: Section-2 gives the brief discussion about hierarchical protocols like LEACH, LEACH-C and LEACH-M. Section-3 presents the proposed protocol with discussions. Section-4 includes proposed methodology. Finally, the conclusion is drawn in Section-5

2. Recent Works

LEACH and LEACH-C are the basic hierarchical routing protocols. The idea proposed in LEACH has inspired many other hierarchical routing protocols

2.1 LEACH

Low energy adaptive clustering hierarchy is an energy conserving routing protocol for WSN [3]. LEACH is a self adapting clustering routing protocol. In order to distribute the energy between the sensors, LEACH uses randomization. Here, nodes are organized as clusters where one node acts as a cluster head and is selected by using distributed algorithm, the function of the CH is to aggregate the data to the BS, LEACH uses TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collision. The operation of the LEACH is divided into rounds. Where each round starts with a setup phase to organize the clusters, next is the steady state phase to transmit the data to the base station. Here, steady state phase is longer compared to set-up phase in order to minimize the overhead condition.

2.2.1 Operation of LEACH

When clusters have been created, each node decides whether or not to become a cluster head for the present round. Here node “n” chooses a random number between 0 and 1. If the number is less than a threshold T (n), then the node becomes cluster head for the current round. This decision is based on the desired percentage of cluster heads for the network and the number of times the node has been a cluster head. The threshold is calculated as

$$T(n) = \begin{cases} \dfrac{P}{1 - P * (r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where *P* is the desired percentage of cluster heads, *r* is the current round time and G is the set of nodes that not have been selected as a cluster heads in the last 1/P rounds.

Each node that has been elected as a cluster head for the present round, it broadcast an advertisement messages to the remaining nodes, the non-cluster head nodes keep their receiver to receive this message of all the cluster head nodes, then each non-cluster head node decides the cluster to which it will belong for this round, then non cluster head node send join request to the CH. The CH node receives the entire message for the nodes that would like to be included in the cluster. After this it assigns a schedule, which informs each node that when it has to transmit the data. Which is based on TDMA, after creating clusters and assigning time slots, the steady state operation is divided into frames, where nodes send their data to the cluster head at most once per frame during their allocated time slot. After cluster head receives data from nodes, it aggregates the data and send to the base station. Then, the network again goes backs to the set up stage. Each and every cluster uses different CDMA codes, where each node has a unique code. Combining DS-SS ideas with a TDMA schedule reduces inter-cluster interference and increases the network lifetime.

2.2.2 Disadvantages

- The node with low residual energy has the same probability to become cluster head as high residual energy.
- In order to communicate with the base station it uses a single hop which makes it cannot be used for large geographical region

2.2 LEACH-C

LEACH-C is an enhancement of LEACH protocol that uses centralized clustering algorithm. However, using a central control algorithm to form cluster, which may produce better clusters by dispersing the CH nodes throughout the network [5].

During the setup phase of LEACH-C, each node sends information about its current location and energy level to the base station and it ensures that all nodes energy is evenly distributed. The base station computes the average node energy and the node which have energy below this cannot become cluster heads for the current round. Base station finds clusters using Annealing algorithm. The algorithm minimizes the energy consumption of non-cluster head nodes to transmit their data to the cluster head.

Once the cluster head and the associated clusters are found, the base station broadcasts a message that contains the CH-ID for each node. If ID of that node matched with the cluster head ID, then the node is selected as a cluster head, else the node determines its TDMA slot for data transmission and goes to sleep until it's time to transmit the data. The main advantage of LEACH-C is selection of the CH is based on energy level that reduces the failure of CH. which in turn increases the network lifetime [6].

The unequal clustering of problem in sensing environment this leads to overload energy utilization problem. Due to this, clusters are divided into minimum sized and maximum sized cluster. This minimum sized cluster will transmit greater number of frames to all cluster head than maximum sized cluster. Since it has fewer nodes so, this makes the CH always busy in aggregation of data to BS, leads to the cluster head death.

2.2.1 Disadvantages

- Round time is kept constant.
- Node movement is not supported in LEACH-C.

2.3 LEACH-M

LEACH-M is an enhancement of LEACH to support mobility [4]. The displacements of mobile nodes are random, hence some of them probably move to the areas that are not covered by any cluster-head. So idea is to divide the sensing area into sub-areas and try to optimize location of cluster-head in these sub-areas.

During the Setup phase of LEACH-M, each node sends its information about its locations, velocity and energy level to BS. Based on the received information, In LEACH-M cluster-heads are

elected on the basis of attenuation model. Optimum cluster-heads are selected to lessen the power of attenuation. Other criterion of cluster-head selection is mobility speed. Node with minimum mobility and lowest attenuation power is selected as cluster head LEACH-M.

Then selected cluster-heads broadcast their status to all nodes in transmission range. Non-cluster-head nodes compute their willingness from multiple cluster-heads and select the cluster-head with maximum residual energy. In steady state phase, if nodes move away from cluster-head or cluster-head moves away from its member nodes then other cluster-head becomes suitable for member nodes. It results into inefficient clustering formation. To deal this problem LEACH-M provides handover mechanism for nodes to switch on to new cluster-head. When nodes decide to make handoff, send DIS-JOIN message to current cluster-head and also send JOIN-REQ to new cluster-head. After hand-off occurring cluster heads re-schedule the transmission pattern [7].

3. Methodology

The proposed protocol is an enhancement of LEACH-C protocol called VR-LEACH-M, which is used to overcome the power consumption problems and to increase the network lifetime. The protocol is based on variable round time, where the value of the round time is set in accordance with the changes in the network. The round time is calculated based on the number of active nodes and it also supports the mobility of the cluster head and the non cluster head nodes, which makes it usable for several applications.

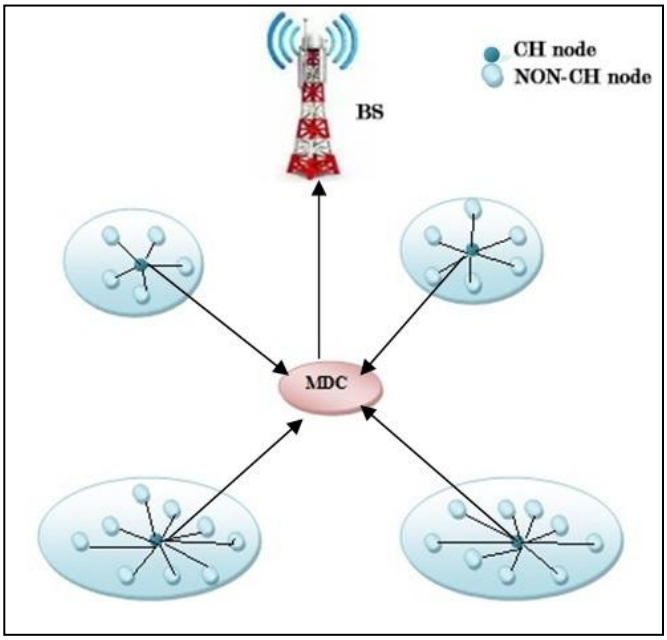

Figure 2: Architecture of Proposed Protocol

The Figure 2 shows the architecture of VR-LEACH-M, Here we assume that the Base station is stagnant. The entire operation of VR-LEACH-M is divided into Set-up and Steady state phase, set-up phase it is the same as LEACH-C, where each node transmits its location and energy level to the Base station. Then, Base station divides the network into different clusters and the Base station will fix the round time to be used for the present round i.e., Tcurrent. The round time *Tcurrent* is defined at the beginning of a current round and *Rcurrent* that mainly depends on the minimum cluster size and the maximum cluster size.

The frame time *Fmin* for the cluster C*min* which is having the minimum size that is minimum number of nodes *Mmin,* is calculated (Eq. 2) as follows:

$$Fmin = Mmin * \sigma + \lambda \quad (2)$$

Where, λ is time required to send data to base station and σ constant time slot.

After knowing the frame time we can calculate the present round time *Tcurrent* is as follows:

$$Tcurrent = NFavg.\ Fmin \quad (3)$$

Where, *NFavg* is the average number of frames for a cluster with the size N/k. Thus from the above equation indicates that CH of the minimum sized cluster must not transmit more frames than the average number of frames *NFavg* for the entire

round which will reduce the overload power utilization of the Cluster Head of the minimum sized cluster head *Cmin*, but this apply for only minimum sized cluster the remaining clusters in the network can transmit more frames than the average number of frames *NFavg* [8].

After deciding the round time for the current round, the Base station will transmits the information's i.e., round time to the clusters. So, sensor nodes will decide which cluster it belongs to and at what time slot it has to transmit data. Next is the steady state phase, which is similar to LEACH-C. Here, the calculated round time depends mainly on the number of active nodes with remaining energy level in the network. But as the process continues energy level in each node depleted and based upon the energy level, if the round time decided is very small, then it results in frequent re-clustering. Hence, when the number of active nodes is less than the round time then it is fixed as the half of the previous round time such that the round will be completed as well as avoids frequent re-clustering. Figure 3 shows the proposed variable round time scheme. This approach makes the clustering algorithm adaptive to network changes [9].

The LEACH and LEACH-C, which uses a single hop communication. Hence, these protocols cannot be used for larger geographical regions. In order to solve this, T mobile agent is used, called a Mobile Data Collector (MDC) [10] this moves between network and collects the data from the cluster head nodes and moves towards the base station to dump the data. These protocols can be used in larger geographical region sensor networks with the MDC architecture, which reduces the energy consumption of the sensor nodes and increases traffic received at base station. It has a multi-hop communication for data aggregation and transmission from sensor nodes to base station with minimum energy consumption [11]. This approach enhances the network scalability for large scale environmental applications. After the cluster formation CH set up the Time Division Multiple Access (TDMA) schedules every node to send data towards CH. Then, MDC transmit a beacon message to all CHs to update their current position. When MDC received the data from any CH, it will direct the data towards the base station [12]. In the next round each node transmits its energy level and location to the base station then each node takes random movement which allows supporting mobility features, after this CH has been selected by BS based on the remaining energy levels similar to LEACH-C.

Actually sensor nodes are deployed in region to perform monitoring mission in the region of interest. Because of the dynamic changes of the events and hostile environment a pure static sensor node could face the problem, By introducing mobility to some or all the nodes in a WSN, we can enhance its capability and flexibility to support multiple missions like location tracking, health monitoring, security surveillance etc.,

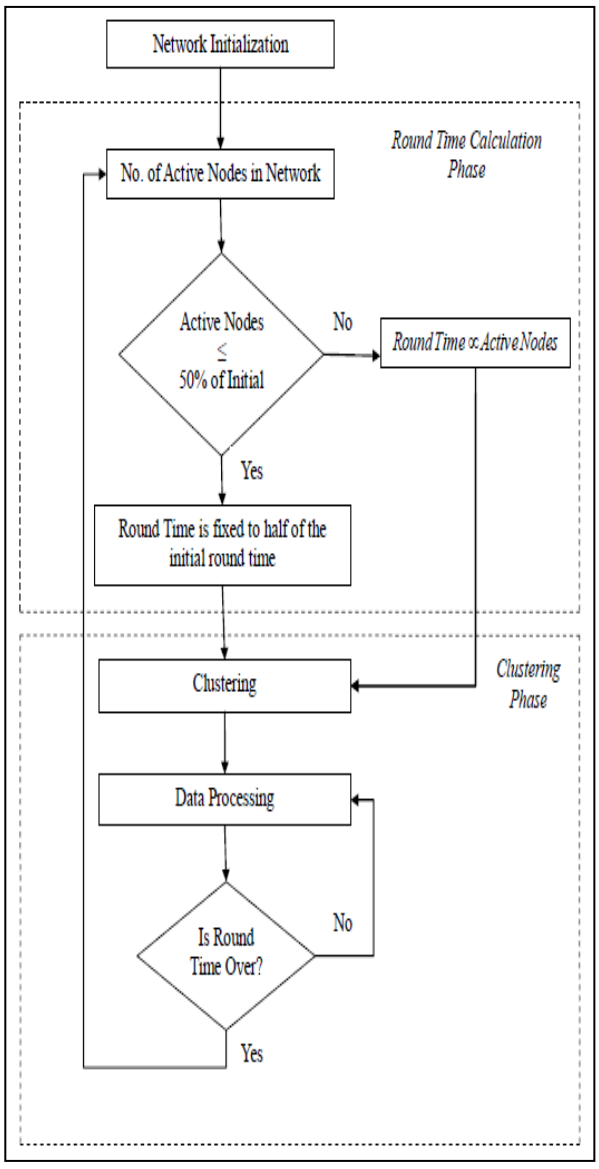

Figure 3: Proposed variable round time approach

4. Simulation Results

The table 1 shows the parameters along with its values and types used for simulating the WSN.

Table 1: Parameters used to simulate the WSN Environment

PARAMETERS	VALUES
NETWORK AREA	1500*1000
NUMBEROF NODES	35
PROPOGATION MODEL	Propogation/TwoRayGround
NEWORK INTERFACE	Phy/Phywireless
MAC INTERFACE	MAC 802.11
ANTENNA TYPE	Antenna/OmniAntenna
INTERFACE QUEUE TYPE	CMUPriQueue
APPLICATION	CBR
INTERFACEQUEUE LENGTH	1000
INTIAL ENERGY	100 J
RX POWER	1.0 WATT
TX POWER	2.0 WATT
STOP	24.0 S
ROUTING PROTOCOL	DSR

4.1. Performance Parameters

4.1.1. Energy Consumption

Figure 4 shows the simulation result of comparison of proposed protocol with existing LEACH-M and LEACH-C.

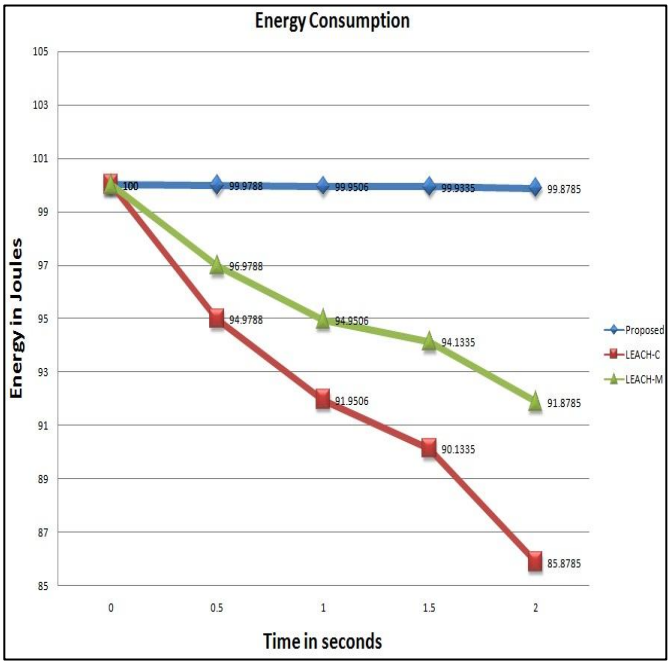

Figure 4: Energy in Joules Vs Time

It can be observed from the graph that as the time increase the energy in the sensor node decreases, our proposed protocol. on the other hand our proposed protocol consumes less energy comparing with other protocols.

4.1.2 Throughput

Throughput is defined as the sum of the data rates that are delivered to the base station.

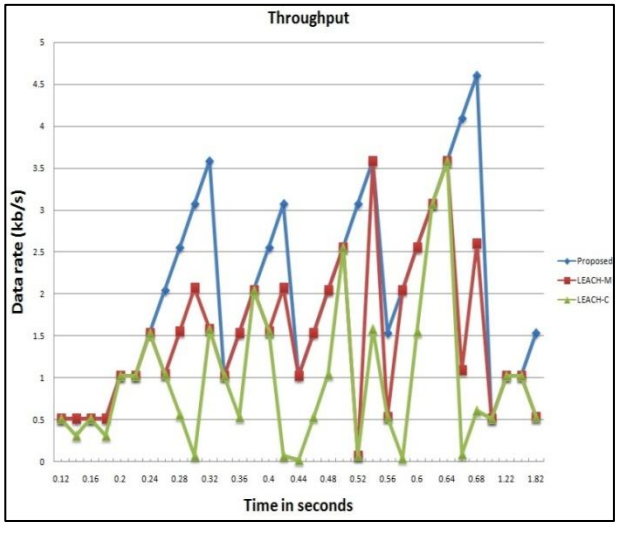

Figure 5: Data rate (kb/s) Vs Time

The figure 5 shows that as the time increases data rate also increases. It can be observed that the proposed protocol has better throughput compared to other protocols.

4.1.3 Packet delivery ratio

Packet delivery ratio is defined as the no. of packets received to the no. of packets sent.

Figure 6: Packet delivery ratio Vs Time

The figure 6 shows the proposed protocol has superior packet delivery ratio compared with existing protocols LEACH-M, LEACH-C

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5. CONCLUSION

The process of reducing energy utilization of sensor node is an important task in the wireless sensor network. Since sensor nodes are deployed in a region for sensing environmental conditions like temperature, pressure, humidity, where it is difficult for us to go and repair or recharge the sensor nodes which is a battery oriented device for its operation. In order to overcome this many researchers aims to minimize energy. A similar effort has been made in this work to develop an energy efficient routing protocol. NS2 has been used for the simulation of this work. The two hierarchical based routing protocols has been compared with the proposed protocols for the performance parameters like energy consumption, throughput and packet delivery ratio for two rounds, which shows the proposed methodology provides the better results compared to the other two and using mobile data collector based structure it can be used for large geographical regions.

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