A STUDY ON COVERAGE MAINTAINING PROTOCOL FOR CLUSTER HEAD ELECTION

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ABSTRACT

Clustering is an efficient method for saving energy in Wireless sensor networks by providing role of data relaying and aggregation to nodes called cluster heads. These are selected from all nodes on the basis on certain criteria that vary from technique to technique. Moreover, for evenly distributing load, the CHs are re-elected after certain intervals. Recently, for CH election, nature-inspired techniques for optimization are being used through creation of appropriate objective functions. But these types of global objective functions need information of entire network and generate much overhead. This paper proposes local objective functions so that a distributed control algorithm can be designed and local election is performed and coverage is also maintained by using activation scheduling.

Keywords: clustering in WSNs, cluster head, data aggregation, energy-efficient, wireless sensor networks

I.INTRODUCTION

Advancements in the techniques of micro-electrical and mechanical systems have made it possible to have small-sized sensor devices [1]. These sensor devices are capable enough of sensing their environment and record quantities like pressure, temperature, humidity etc. Moreover, the sensor devices are also endowed with a communication circuitry that is able to interact with similar type of devices through radio or wireless communication. The sensor nodes sense the data and link to each other to construct an ad-hoc network so that all the data can be paved and transferred to the Base station (BS). This network is known as wireless sensor network. Wireless technology is much better than wired one in the way as it does not require any preliminary establishment for deployment. With least construction cost and flexible anatomy and self-organization, a WSN is very useful for applications that involve monitoring of harsh terrains and environment.

The sensor nodes of the WSNs are very tiny devices that are operated by power batteries. Their deployment is in such a environment that is very harsh or impossible to replace power batteries when they are consumed. Hence, if the nodes use all their energy, the network becomes disconnected and failure may occur in the application. So there is a requirement of saving energy of sensor nodes as much as can be saved in such a way that operation of the network is not affected. Often, for duplicity purposes, a number of nodes are established in a specific region. And, a sleeping schedule is maintained so that only few out of all are activated at a time and rest are sent into sleeping mode such that RoI is covered. The nodes that are in sleep mode can save their energy. Yet, there is always a firsthand need of saving energy of the sensor nodes in order to increase lifetime of network.

The energy of sensor nodes is spent in three main operations: sensing, interacting and directing paths. Designing communication and routing protocols in such a way that energy is saved as much as possible is a very first research topic related to WSNs. Few sensor nodes are assigned an extra role of cluster head (CH). Other nodes that are not CH, join the CHs as member nodes of their clusters. The member nodes transmit the sensed data to their CH only and not to the BS. As CH is much closer than BS to member nodes, energy is saved. Also, CH can perform the data aggregation collected from the member nodes and decrease the actual data load to be transmitted to the BS. This again saves energy. Though, energy of the CH can be consumed faster in this way. That's why, researchers have advised to elect CH repeatedly and alter them in such a way that the load is distributed evenly in the network.

Heinzelman et al [2] proposed the innovative work for clustering in WSNs. They provided a probabilistic approach for electing CH nodes and performed rotation to them to get energy consumption evenly in the network. The protocol called LEACH doesn't select CH on the basis of any criteria hence does not work well, yet it is famous as the basic approach with which performance can be compared. There have been a number of improvements to LEACH like LEACH-C[3], TL-LEACH[4], LEACH-FL[5], LEACH-FS[6] etc. Other famous energy-efficient protocols for clustering and routing in WSNs are HEED[7], EECS[8], SEECH[9] etc. Every method advises some criteria for CH election, mostly the residual energy of the sensor node and its distance from BS. Recently, some nature-inspired algorithms have been given that set an objective function that must be minimized or maximized in a way to find the best candidates for CH election. But all such algorithms need global information of the network and that require a lot of data collection and thus overhead is increased and energy consumption is also increased. Hence, it is better to form some cost functions on the basis of local information and decisions can be taken with lesser interaction between the sensor nodes.

We suggest here a method of clustering in which a cost function can be set and this can be calculated by using only local information. Based on this cost function, a CH is elected in each neighbouring region. We use activation scheduling for maintaining coverage so that no inactive node loses its energy and can save energy of these nodes for further use and network lifetime is also increased. Simulation results show the performance of our proposal.

Rest of the paper is organized as follows. Section II discusses those previous works that have set a cost function or an objective function to decide CHs and previous activation scheduling algorithms for coverage maintenance. Section III describes the proposed cost function, proposed coverage maintenance protocol and the clustering method. Section IV presents the results of simulation in graphical form.

II. RELATED WORK

With the first method as LEACH, there have been many methods proposed in the literature for clustering. Here we discuss the methods that have used some kind of cost functions to use for CH election.

In DEGRA [10], Cluster head are elected on the basis of the density of each node, calculated as

$$Den(s_i) = \sum_{0<x\leq N \,\&\, d(s_i,s_x)\leq R} l$$

The concept of density represent number of nodes located within a circle transmission region of neighboring nodes with itself as center. Where R=radius, s_i= the i-th node and $d(s_i, s_x)$= distance between s_i and another node s_x. Thereafter, a utility function of each node is computed as:

$$U_i = \frac{E_{residual}(s_i)}{E_{total\_cost}(s_i)/Den(s_i)}$$

Where, $E_{residual}$= residual energy for one node.

E_{total_cost}= Total energy consumption of its Den neighbourig nodes

$E_{total\_cost}(s_i)/Den(s_i)$= average energy consumption among its neighbor node, a standard of average cost of energy in its cluster.

In EEDUC[11], the nodes are needed to wait for various time lengths to transmit a competition message. The message is transferred within the competition radius. Time of waiting is calculated as:

$$[(1-\alpha) \times N_i/N_{MAX}] + [\alpha \times V_{random}]$$

Where N_i=number of neighborhood nodes of node i

N_{MAX}=number of total sensor nodes

V_{random}= random number between 0 and 1

α=constant coefficient between 0 and 1. During round 0, each node has same energy with other nodes

Competition radius of HELLO message:

$$R_{comp} = [1 - w_1\left(1 - \frac{TS_i}{TS_{MAX}}\right) - w_2\left(1 - \frac{E_i}{E_{MAX}}\right) - w_3\left(1 - \frac{N_i}{N_{MAX}}\right)]R_{MAX}$$

Where, TS_i= distance between node I and base station.

TS_{MAX}= maximum distance between sensor node and the Base Station.

E_i=residual energy of node i.

E_{MAX}=maximum energy of sensor node

R_{MAX}=maximum cluster size

w_1, w_2 and w_3= constant coefficient between 0 and 1.

Oladimeji et al [12] have given an objective function that is optimized by using a genetic algorithm. They have word their protocol as DLSACH for dynamic local search-based algorithm for clustering hierarchy. The objective function is

$$F(i) = 0.9 * \frac{AvgENCH}{AvgECH} + 0.1 * R$$

Here, $AvgENCH$ is the average energy of all non-CH nodes and $AvgECH$ is the average energy of all CH nodes. R is calculated as the risk penalty if the number of elected CHs are greater or less than optimum range. It is a global objective function that is computed with different probabilities of CHs and then the best CHs are elected. Each time a random selection is made and a genetic mutation and combination operator is performed to obtain a better selection.

III. PROPOSED CLUSTERING TECHNIQUE AND COVERAGE MAINTENANCE

The main objective of clustering is to elect CHs and balance the energy consumption load in such a way that no node is dead prematurely by leaving the network disconnected. Here we first set the goals of our clustering algorithm as:

a) Reduction in energy consumption by limiting the information used in CH selection. Much energy is consumed in data collection and if this information is varying like in case of residual energy then overhead increases energy consumption. So, if some global information is needed then it must be static otherwise local information must be used.

b) Establishment of cost function in such a way that the nodes with higher energy and more central position among its member nodes must be given higher chance of being elected. The cost function should have a variable random input so that various nodes are elected as CH at different rounds and balance is also maintained. We can also consider distance from BS

c) In case of duplicate deployment, coverage of the region must be maintained. And all extra nodes be put in sleep mode for energy saving. Thus, making duplicate nodes into sleep mode is also an aim in our algorithm.

d) Ensuring network coverage all the time is a condition to be met.

A minimal coverage can satisfy the last two aims. We design an activity schedule such that coverage is ensured. Now, we design a cost function that involves all possible criteria with minimal exchange of information among the nodes.

Assuming a circular coverage by every sensor within the radius equal to its effective sensing range the area covered by a sensor can be computed as the area of circle. That is, every *i-th* sensor node covers an area equal to

$$A_i = \pi R^2$$

Whenever areas sensed by two sensors overlap, the common area is computed as

$$A_{i \cap j} = 2R^2 \cos^{-1}\left(\frac{d}{2R}\right) - \frac{1}{2} d\sqrt{4R^2 - d^2}$$

Where R is the radius (range) and d is the distance between two centres or two sensors. Subtracting the common area covered, actual covered area can be obtained. That is, the effective area coverage by any sensor is computed as

$$Aeff_i = \pi R^2 - \sum_{\forall j} A_{i \cap j}$$

In any sub-region only minimum required sensor nodes should be kept active so that the coverage is maintained. The total coverage is observed through a matrix called the Coverage matrix. It captures the overlapped areas of every *i-th* node with *j-th* node as the (i,j) entry in the matrix. This allows identification of nodes that can be sent into sleep mode without affecting the coverage since there will be other nodes covering part of the selected node's area. We compute the sum of region being effectively covered by all active nodes. And keep nodes active mode until the maximum effective coverage is achieved.

The selective activation of nodes according to the coverage effect is formally listed as the Selective Activation with Coverage Maintenance (SACM) protocol in Fig 1.1. All nodes having energy higher than the average energy of nodes alive in the network are considered to be the candidates for being in active list. Among all the candidates we pick only those nodes that can cover most of the other nodes' region. Thus, sum of overlap areas in the coverage matrix (CM) is compared for all neighbouring candidate nodes. And the node with maximum coverage is selected for active list. Thus, for any candidate sensor node i, if the following condition is satisfied, it is removed from the active list

$$\sum_{j} CM_{ij} > 1.5 * \sum_{k} CM_{jk}, \forall j, d(i,j) < R$$

Proposed SACM Protocol

Compute the residual energy, E_{Res} of each node.
Compute the average energy of all node, E_{Avg}.
Generate a candidate list for nodes with $E_{Res} > E_{Avg}$.
Generate sub-matrix of CM using rows and columns only of candidate nodes
For all i in candidate list
Compute condition (5)
If true, remove i from the candidate list.
Compute the reduced CM by removing i-th row and column
end if.

Fig 1.1 Proposed Selective Activation with Coverage Maintenance Protocol

We develop a local objective function to be a function of energies of a node and its neighbors and number of times a node has been elected as a CH. The function is:

$$F(i) = \alpha * \frac{AvgEN_i}{energy_i} + (1-\alpha) * freq_i$$

The weight has been included to decide the contribution or importance of a factor towards making a node a CH. Generally, value of 0.8 or 0.9 is suitable so that the energy of the node has more importance as selection criteria as compared to the frequency of CH role. $Avgl$ is the average energy of neighbor nodes of i-th node. It has to be viewed in proportion to the energy of i-th node itself at current round. The number of times i-th node has been continuously CH, that is the number of rounds since when i-th node was CH is fr.

IV. SIMULATION AND EXPERIMENTS

We simulate a WSN using MATLAB. The radio model of [12] is considered. The member nodes of a cluster transfer the sensed data to the CH using single-hop communication and so does the CHs to transfer to BS. The sensor nodes can have two power levels for transmission. For distances smaller than the threshold distance , free-space power level is used. For larger distances, the signal is amplified and multi-path power level is used. The parameters used for energy dissipation computations in our experiments are listed in Table 1.

TABLE I. SIMULATION PARAMETERS

Parameter	***Description***	***Value***
L	No. of transmitted bits	4000
E_{elec}	Energy consumed in transmission and reception	50 nJ/bit
ε_{fs}	Energy dissipated in free space propagation	10 pJ/bit/m^2
ε_{mp}	Energy dissipated in multipath propagation	0.0013pJ/bit/m^4
Data Packet Size	Size of a data packet	500 bytes
Control Packet Size	Size of a control packet	25 bytes
d_0	Threshold distance	87 m

The performance of the proposed algorithm is compared with the work of [12], upon following metrics:

a) Rounds – The number of rounds taken in execution before the network is dead.

b) FND – First Node Die is the number of rounds completed before first node is dead.

c) HND – Half Node Die is the number of rounds completed before half of the nodes are dead.

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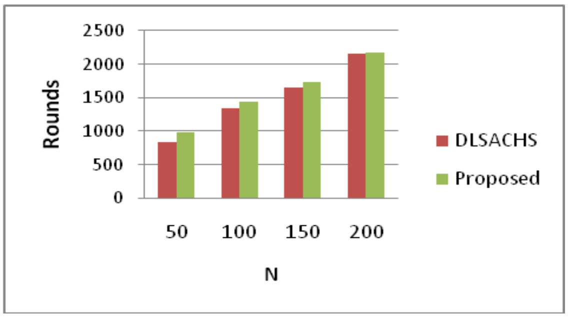
V. RESULTS

Fig 1, 2 and 3 show the number of rounds recorded by the proposed algorithm as compared to the work of [12]. In all conditions, the number of rounds of the proposed algorithm is higher or nearly same. When area is increased and number of nodes fixed. The density of nodes in any region reduced, and the distance between the nodes increases. This implies that communication cost and energy consumption increases. So, the number of rounds is reduced if area is increased as shown in Fig 3. Yet, in work of [12], the communication overhead is more, hence energy consumption is faster. So number of rounds of the proposed protocol is greater.



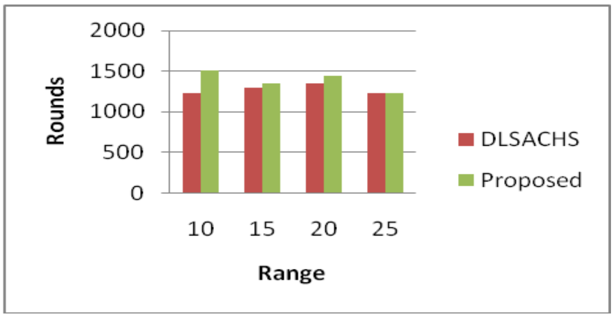
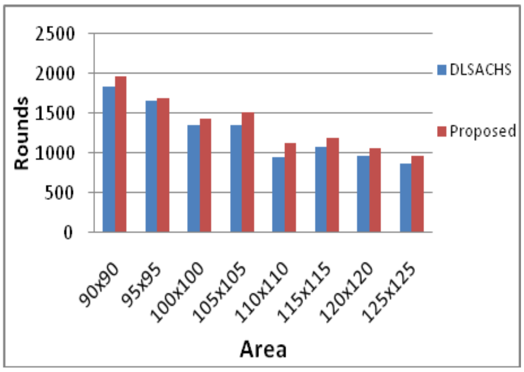


Fig 1 Number of rounds when nodes are increased

Fig 2 Number of rounds when range is increased



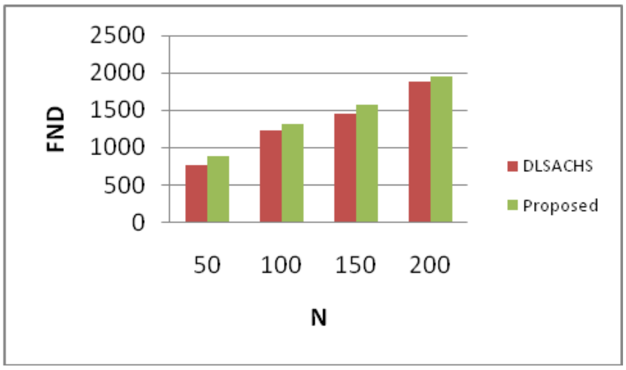
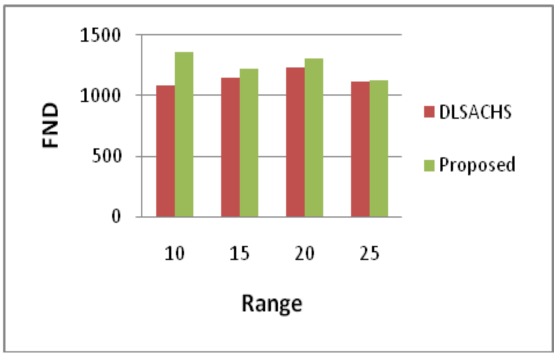


Fig 3 Number of rounds when area of sensing field is increased

Fig 4 Value of FND when nodes are increased



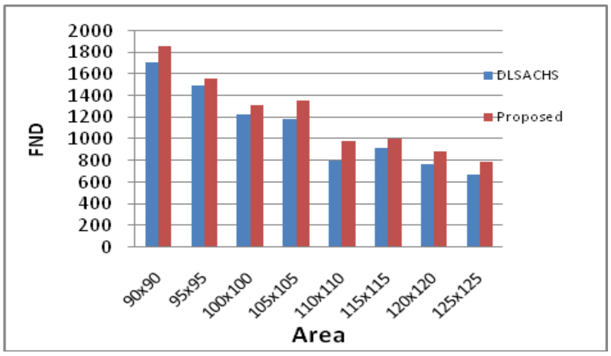


Fig 5 Value of FND when range is increased

Fig 6 Value of FND when area is increased

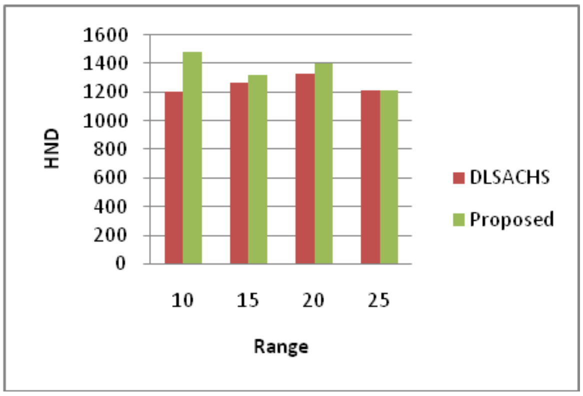


Fig 7 Value of HND when number of nodes is increased

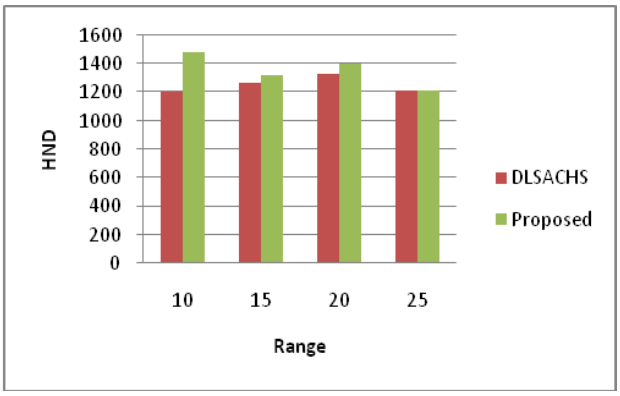


Fig 8 Value of HND when range is increased

The values of FND and HND are more for the proposed protocol. This shows that there is even distribution of load.

VI. CONCLUSION

Wireless sensor networks have a number of applications. Since the devices are limited in energy source, the demand of energy-efficient algorithms increases. There are many algorithms in literature that select CHs on the basis of some criteria which are coupled together as accost function or through fuzzy logic or through some nature-inspired technique of optimization. Many such proposals require global information about all nodes to determine exact values of the cost functions. We have given a cost function that includes only local information and hence saves the energy. Simulation results represents that the performance of the proposed work is better than the previous work.

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