Energy Efficient Zone Division Multihop Hierarchical Clustering Algorithm for Load Balancing in Wireless Sensor Network

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Abstract— **Wireless sensor nodes are use most embedded computing application. Multihop cluster hierarchy has been presented for large wireless sensor networks (WSNs) that can provide scalable routing, data aggregation, and querying. The energy consumption rate for sensors in a WSN varies greatly based on the protocols the sensors use for communications. In this paper we present a cluster based routing algorithm. One of our main goals is to design the energy efficient routing protocol. Here we try to solve the usual problems of WSNs. We know the efficiency of WSNs depend upon the distance between node to base station and the amount of data to be transferred and the performance of clustering is greatly influenced by the selection of cluster-heads, which are in charge of creating clusters and controlling member nodes. This algorithm makes the best use of node with low number of cluster head know as super node. Here we divided the full region in four equal zones and the center area of the region is used to select for super node. Each zone is considered separately and the zone may be or not divided further that's depending upon the density of nodes in that zone and capability of the super node. This algorithm forms multilayer communication. The no of layer depends on the network current load and statistics. Our algorithm is easily extended to generate a hierarchy of cluster heads to obtain better network management and energy efficiency.**

Keywords- routing protocol; WSN; multihop; load balancing; cluster based routing; zone division.

I. Introduction

WSNs consists of more than hundreds of small spatially distributed autonomous devices using sensor called sensor nodes to monitor the physical and environmental situations such as sound vibration, temperature, pressure, motion and intensity of light at various place. Energy is most concentrate term in WSNs because it determines the aliveness of wireless sensor node. One of the most design objectives of WSNs is to minimizes node energy consumption and maximize the network life time [1][2]. So preserving the consumed energy of each node is an important objective that must be considered when developing a routing algorithm for wireless sensor networks. In WSNs each node tries to perform computation on data locally, so data to be forwarded condenses because computations is less expensive than data transmission in WSNs. e.g. to calculate the mean value of data sample at node is much efficient than to transmit sample data and calculate the mean value at base station. Due to the short range of the radio communication and the fact that consumption of energy is proportional to the square of the distance making communication multi hop instead of direct communication will save energy.

The rest of this paper is prepared as follows segment II briefly describes the applications of the WSN in different areas, Segment III describes the problem formulation, Segment IV gives general key issues of the various routing algorithms, Segment V includes a detailed study of the related research. The proposed algorithm is discussed in segment VI, segment VII discusses the simulation and its results and lastly concludes the paper.

II. Application

Here we describe a few areas where WSNs can be used effectively. According to [3] WNs are able to supervise wide range of applications which include Intensity of light, Temperature, Humidity, Pressure, existence of objects, size and motion of objects. Usually applications include inspection and battle space monitoring [4] by military, agricultural and environmental. Engineering applications include maintenance in a large industrial plant, regulation of modern buildings in terms of temperature, humidity etc. Other applications include greenhouse monitoring, land slide detection, forest fire detection, flood detection etc. [5].

III. Problem Formulation

Broadcasting is the process in which a source node sends a message to all other nodes in the network that's deal with energy [18]. The energy factors lead to the cost increase of WSN continuation, specifically for the networks deployed in out-of-the-way areas.

Thus, the problem of WSN long-term operation is of vital significance. The lifetime problem is a complex problem of WSN and cannot be resolved one-sidedly. The problems have to be introduced at three main categories [8][15][16]:

Design **-** application, modeling, simulation;

Hardware **-** hardware machinery, technology, maximum power point tracking, energy scavenging technology;

Software **-** energy saving techniques, communication protocol, middleware.

At the design level the full network operation depends on the application. This application may decide the hardware architecture and power management approach of the sensor node and network. As well, earlier to hardware implementation of the node it should be modeled and the full network has to be simulated.

The lifetime problem at the hardware level includes the correct HW machinery choice along with energy storage. Energy scavenging technology may significantly increase the WSN lifetime, but for the maximum efficiency it is desirable to apply it with the maximum power point tracking (MPPT) technique [6].

Software plays a vital responsibility in WSN lifetime as well. e.g. the adaptive duty-cycling algorithm [7] allows the utilization of up to 58% more environmental resources in comparison to the systems without this technique.

IV. Design Issue of Routing Protocol

WSNs pose various challenges to design. This segment summaries some of the major challenges faced while clustering the wireless sensor network.

A. Network scability

The number of sensor nodes deployed in the sensing area may be in the order of hundreds, thousands or more. When a WSN is deployed, sometime new nodes need to be added to the network, so routing algorithm must be scalable enough to respond to actions.

B. Mobility

Wireless node have the propriety of mobility, Mobility of nodes is an significant issue in mobile ad-hoc networks (MANET). Nodes in MANET move from one network to another separately or in group. In single node mobility scheme every node performs registration individually in new MANET whereas in group mobility method only one node in a group.

C. Network deployment

Node deployment in WSNs is either fixed or random depending on the purposes where it will be used. In fixed deployment the network is deployed on preset locations whereas in random deployment the resulting distribution can be uniform or not uniform. In such a case careful managing the network is necessary in order to guarantee full area coverage and also to guarantee that the energy consumption is also uniform across the network.

D. Multihop or Singla hop communication

The communication model of wireless sensor network may be formed as single hop or multi hop. Energy consumption in wireless systems is directly proportional to the square of the distance; single hop communication is costly with respect to energy consumption. Most of the routing algorithms use multi hop communication model since it is more energy efficient with respect to energy consumption in contrast, with multi hop communication the nodes which are nearer to the cluster head.

E. Cluster dynamics

Cluster dynamics describes how the unlike parameters of the cluster are determined e.g., the number of clusters in a particular network. In some cases the number might be pre assigned and in some cases it is dynamic. In case of dynamic, there is an option of forming unbalanced clusters. While limiting it by some pre-assigned, minimum distance can be effective in some cases. Also cluster head selection can either be centralized or decentralized which both have advantages and disadvantages. The number of clusters might be fixed or dynamic. Fixed number of clusters cause less overhead in that the network will not have to repeatedly go through the set up phase in which clusters are formed.

V. Related Works

Routing in WSNs is a tricky task because of data source from multiple paths to single source, data redundancy and also because of energy and computation factors of the network [9]. The usual routing algorithms are not efficient when applied to WSNs. The performance of the existing routing algorithms for WSNs varies from application to application because of various demands of various applications.

Generally the routing protocols are classified into two classes one is based on the network structure and the second is based on protocol operation. The network structures are further classified as flat network routing, hierarchal network routing and location based routing. The protocol operation can be classified as negotiation based, query based, multipath based, coherent based and QoS based routing. Rest of section shortly describes the routing protocols based on network structure and more specifically the hierarchal routing algorithms.

Cluster based routing in WSNs comes under the class of hierarchal routing. Hierarchal routing comprise the formation of clusters where nodes are assigned the task of sensing which have low energy and transmission task to nodes which have higher energy. The cluster heads may be extraordinary nodes with higher energy or ordinary node depending on the algorithm and application. The cluster head also performs computational functions for instance data compression and data aggregation in order to decrease the number of transmission to the base station in this manner saving energy of that node. Load balancing and redistribution (LBR) technique for adhoc networks in general and wireless sensor networks in particular cases have been described in [19]. A Genetic Algorithm (GA) [20] is used to generate energy-efficient hierarchical clusters. Static clustering techniques [21] and MTE routing is also increase the efficiency of the network life time. The multi-hop technique with a backoff [22]-based clustering algorithm to organize sensors. By using an adaptive backoff strategy, the algorithm not only realizes load balance among sensor node, but also achieves fairly uniform cluster head distribution across the network.

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical cluster-based routing protocol for wireless sensor network which divided the nodes into clusters, in each cluster a dedicated node with extra privileges called 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). Rest nodes are cluster members [10].

LEACH cluster head is chosen using a threshold $T(n)$

$$T(n) = \begin{cases} \dfrac{p}{1 - p(r\ \boldsymbol{mod}(1/p))} & n \in G \\ 0 & others \end{cases}$$

Where, p is the percentage of cluster heads over all nodes in the network, r is the number of rounds of selection, and G is the set of nodes that are not selected in round 1/p.

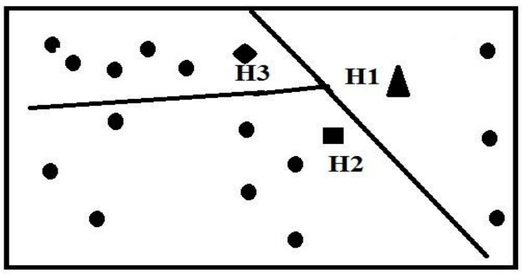

Figure 1. Randomly generated Cluster head using threshold function

WSNs are autonomous networks. Sensor nodes are independent with each other. The coordination between nodes is done through wireless communication, which costs much. This is one of the major reasons that the LEACH protocol selects cluster heads randomly. In Figure, H1,H2 and H3 are three cluster heads; symbolizes as anodes ▲,■ and ♦ respectively. H1, H2 and H3 are very closely located. According to data communication model, the energy that a cluster head consumes is the sum of that consumed in receiving data and that in sending data, as described in equation:

$$E_{ch} = lE_{elec}\, N_{mem} + lE_{DA}\,(N_{mem} + 1) + lE_{elec} + l\varepsilon_{mp}\, d_{toBs}$$

Lin SHEN and Xiangquan SHI [11] describes in there paper, when multiple cluster heads are randomly selected within a small area, a big extra energy loss occurs. The amount of lost energy is approximately proportional to the number of cluster heads in the area. When perform long time, it will experience unbalanced remaining energy among nodes. Blind nodes will appear and the network life and routing efficiency will be decreased.

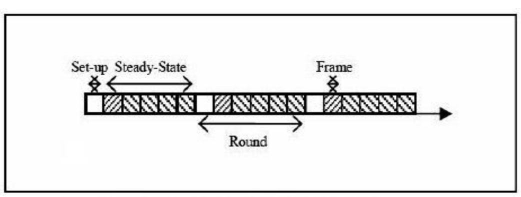

Figure 2. Phases of LEACH Protocol [12]

The operation of LEACH is broken up into *rounds*, where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase. The phase of LEACH protocol is divided into two sub groups:

Set-up Phase: (1) Advertisement Phase (2) Cluster Set-up Phase
Steady Phase: (1) Schedule Creation (2) Data Transmission

Since LEACH has many shortcomings, many researchers have been done to improve this protocol. Loscrì [17] proposed two-level Leach. In this protocol, CH collects data from other cluster members as original LEACH, but rather than transfer data to the BS directly, it uses one of the CHs that lies between the CH and the BS as a relay station. Some improve version of LEACH are as follows: E-LEACH, TL-LEACH, M-LEACH AND V- LEACH etc [14].

VI. Zone Division Multi hop Hierarchical Clustering For Load Balancing

Our proposed algorithm consists of two different phases, the setup phase and steady phase. During the setup phase Super nodes known as Cluster Heads and Vice super node as known as temporary cluster heads are chosen followed by the steady phase. The steady phase is the data transmission phase and is longer than the setup phase. In the setup phase, initially the algorithm divide the full region into four zone and also find the centre area of that region, make a set of temporary super node and also select a node super node . The zone may be or not divided again that's depending on efficiency of super node.

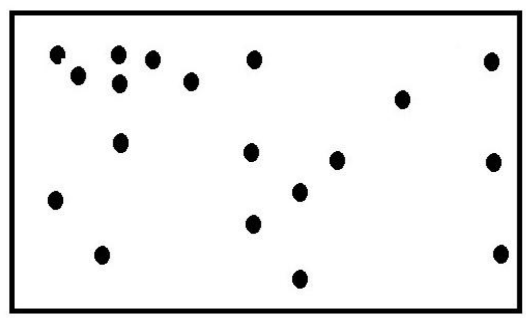

Figure 3. Random deployment of node in network

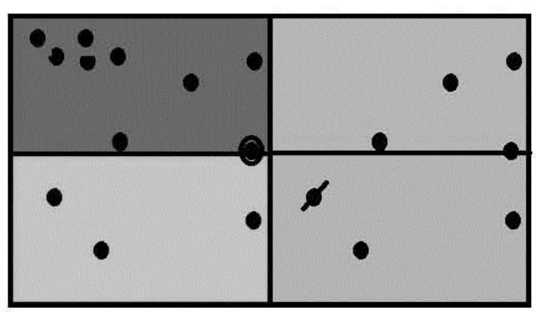

Figure 4. Top layer

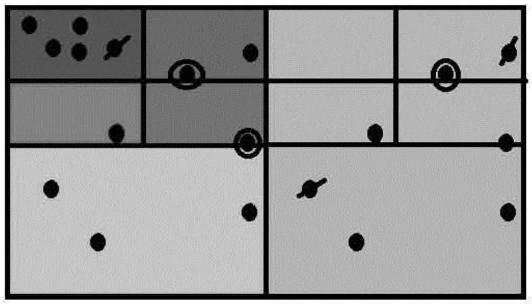

Figure 5. Middle layer

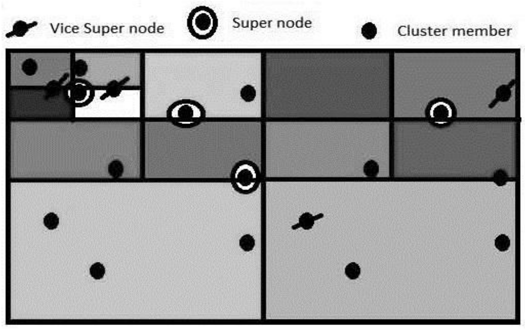

Figure 6. Bottom layer

Figure 3 shows the random deployment of nodes in a network; Figure 4, Figure 5 and Figure 6 shows how cluster are formed with super mode and vice super node by zone division. Zone division helps us to make cluster balanced.

When the super node will be dead the vice super node act as a super node. After finishing the setup phase the steady state phase will start and nodes transmit data. When all the nodes within the cluster finish sending data the super nodes performs some computation on it and sends it to base station using multihop communication.

PROPOSED ALGORITHM:

Setup phase:

1. Measure the region and find the centre of region.
2. Find nodes as close as centre is called set of super node, store the set and specify a super node from the set on the basis of energy level of the node.
3. ID of super node is stored in to the table of previous super node and vice versa.
4. This super node broadcast a message to the all node of that zone and receives **reply message [a]** from the node.
5. If the location or distance and no of node is more than the **efficiency [b]** of super node then divide the region into four (4) equal Zones and go to step 6.

Else

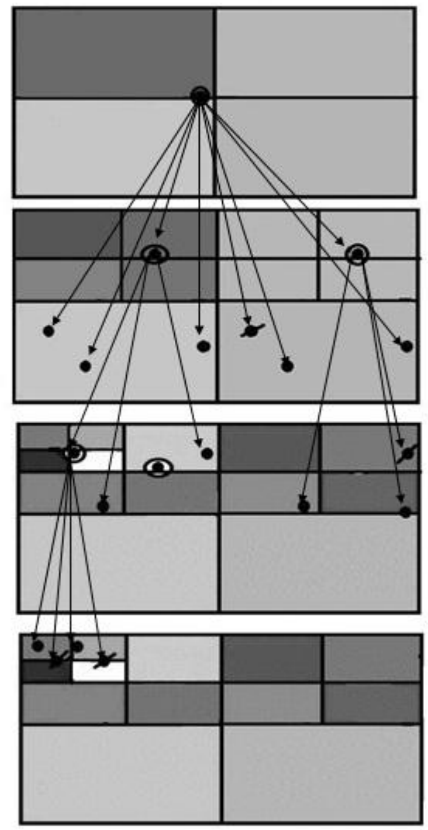

Figure 7. Hiearchical Structure

go to step 7.

6. Find the centre of zone and repeat step 2.
7. The node id is stored in the super node and vice verse,(The super node sends a message about the information of all neighbor nodes of that zone to the node.

Or

Node sends a hello signal to the neighbor nodes.)
Update the neighbors table.
Steady state Phase:

8. **Node to super node communication:** Nodes sensing and transmitting data to the immediate super node in their allotted time slot. The super node collects data and processes the data. After that the super node transmission is start. All super nodes do the same task.

When the data reach to base station **the steady state is repeated.**

a: Reply message contains the energy level.

b: Efficiency of super node is measured by the super node energy level ,signal receiving time and delay of access .

VII. SIMULATION AND RESULT

We calculate the performance of the proposed algorithm in this segment using OMNeT++ simulator. It has been developed by András Varga [13]. It is an object-oriented modular discrete event network simulator. It model consists of hierarchically nested modules. Modules can have their own parameters. Parameters can be used to modify module activities and to parameterize the model's topology.

In our case the sample deployment of the network is shown in Figure 2, Figure 3 shows the top layer of the network with super nodes, Figure 4 shows the middle layer and Figure 5 shows the bottom layer of the network. After formation of layers, clusters are formed and steady state phase starts.

TABLE I. DADED NODE COMPARISION

Time	No of Dead Nodes		
	Proposed algorithm	***VLEACH***	***LEACH***
5	3	7	9
10	6	8	13
15	6	10	18
20	7	11	22
25	8	11	25
30	9	13	27
35	11	16	29
40	12	17	30

TABLE II. REMAINING ENERGY CONSUMPTION COMPARISON

Time	Remaining Energy		
	Proposed algorithm	***VLEACH***	***LEACH***
5	295	292	255
10	293	240	215
15	280	230	205
20	272	226	180
25	270	222	173
30	263	200	150
35	254	175	143
40	249	171	135
45	241	168	131

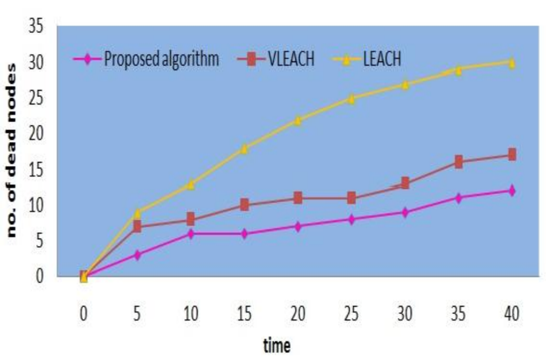

Figure 8. Dead node comparison in network (w.r.t TABLE I)

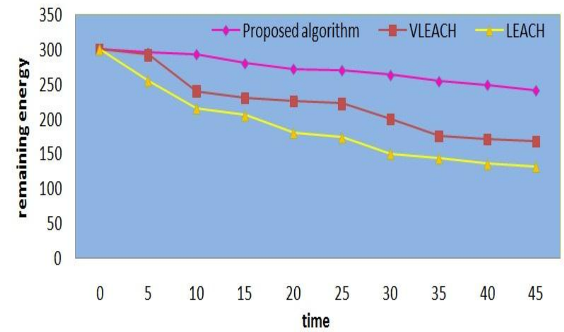

Figure 9. Remaining energy comparison in network (w.r.t. TABLE II)

VIII. CONCLUSION AND FUTURE WORK

It is clear from the simulation outcome that by utilizing the density property of the WSNs it is possible to enhance the network life time and also efficiently balance the energy consumption load across the network. The energy consumption of the network becomes uniform. That mean the proposed algorithm is efficient than the other version of LEACH protocol. The future work includes network with some mobility in the network.

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