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Improving the Network Lifetime in Wireless Sensor Networks Using Fuzzy Based Centrality Algorithm

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Abstract: Wireless Sensor Networks (WSNs) is partitioned into clusters to save energy, advance network scalability and resourceful routing. Residual energy, cluster node distance that is related to a node with respect of its structural position in the network is used for electing cluster heads. However for choosing cluster head the optimal numbers of nodes that may belong to a cluster are not taken into consideration. The latest centrality metric "Cluster Optimal Degree Centrality"(CODC) proposed in our paper addresses residual energy of individual nodes, distance between the potential cluster head and particular member nodes to ensure better cluster head selection and cluster quality. Finally based upon the distinct centrality metric, the Fuzzy Inference System based cluster head selection method has been proposed, which takes input as Expected Residual Energy and CODC. Though the clustering can improve QoS in wireless sensor networks, the proposed method can effectively prolong the network lifetime, since lifetime is directly related with the energy of the nodes optimizing this energy consumption is very important. The simulation results show that the proposed method performs better than LEACH resulting in high throughput and QoS.

Keywords: Cluster head selection; cluster optimal degree centrality; energy efficiency; fuzzy inference.

I. INTRODUCTION

A Wireless Sensor Networks (WSN) consists of small low power nodes with sensing, computational and wireless communication capabilities that can be deployed randomly or deterministically in an area from which the users wish to collect data. Energy efficiency and scalability are the prime factors in designing WSN system, which requires load balancing, improving the bandwidth and network lifetime.

Nodes in WSNs can be divided into a number of small groups called Clusters. The cluster formation process eventually leads to a two-level hierarchy where the Cluster Head (CH) nodes form the higher level and the cluster-member nodes form the lower level. The sensor nodes sporadically transmit their data to the corresponding CH nodes. CH nodes aggregate the data (as a result decreasing the total number of relayed packets) and transmit them to the base station (BS) either directly or through the intermediate communication with other CH node. Current clustering approaches often use two methods selecting cluster heads with more residual energy and rotating cluster heads periodically.

In this paper, we have considered the Expected Residual Energy [1], which is the predicted remaining energy for being selected as a cluster head and also a new clustering parameter, "Cluster Optimal Degree Centrality" [1] which considers both optimum member node degree for a cluster as well as distance of member nodes to their respective CH. The simulation results have shown that the proposed clustering method has resulted in enhanced network lifetime and individual cluster characteristics.

This paper is prepared as follows. Section II presents related work. Section III presents the system assumptions of our work. In Section IV the implementation of the proposed work is presented. In Section V application part is included. The simulation and result analysis are shown in Section VI and VII. Conclusion is given in Section VIII.

II. RELATED WORK

Clustering of sensor nodes has already been widely used in WSNs. Though the clustering can improve scalability in WSNs, it has some intrinsic problems. CH selection and cluster formation procedure should generate the best possible cluster; as a result energy consumption will be irregular. On the other hand they should also preserve the number of exchanged messages and the total time complexity should (if possible) remain constant independent to the growth of the network. In order to overcome this problem, most of the research focuses mainly on rotation of CHs. The first major approach towards rotation of CHs is LEACH (Low Energy Adaptive Clustering Hierarchy) protocol [10]. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decision without any centralized control. All nodes have an opportunity to become CHs to balance the energy spent per round by each sensor node.

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LEACH has also some comprehensible drawbacks. Since the decision on CH election and rotation is probabilistic, there is still a superior chance that a node with very low energy get elected as a CH. Due to the same reason, it is possible that the elected CHs will be concentrated in one part of the network (good CHs distribution cannot be guaranteed) and some nodes will not have any CH in their range. It cannot be used effectively on networks deployed in large regions. Fuzzy logic, due to its comparatively less computation burden and processing demands, has also been extensively used in WSNs for clustering intention. Fuzzy Clustering Algorithm uses fuzzy logic for blending different clustering parameters to elect CH. In centralized approach of Gupta [2], three parameters are considered: Node concentration, Residual energy and Node centrality. At this juncture CH is elected at the base station and it forwards the election results to entire network. The main drawbacks are overheads and control communication resulted from centralized method would be very high and unsuitable for energy constrained WSNs. Simulation is designed for electing only one CH per round. In distributed approach of Kim [3], also known as CHEF (Cluster Head Election mechanism using Fuzzy logic) uses two fuzzy descriptors: Residual energy and Local distance. In this approach node degree is not taken as a selection parameter; hence for nodes having equal residual energy, a node with less number of neighbour nodes has more chances to become CH and hence may result in inefficient clustering. In CHEATS [4] approach the distance of a node from base station and remaining energy of a node is taken for CH selection.

The protocol named as LEACH-ERE (LEACH Expected Residual Energy) Energy Prediction methodology [6] in clustering using fuzzy logic with fuzzy descriptors as input: residual energy and expected residual energy. ERE is predicted by using the Expected Energy Consumption (EEC). During CH election phase, a constant number of candidate nodes are elected and compete for CHs according to the nodes residual energy. The candidate nodes broadcast its residual energy within a predefined radio range. If candidate finds a candidate with additional residual energy, it will furnish in the competition. Or else it will become the CH. The main drawback is that it is only limited to homogeneous sensor nodes.

Most of the fuzzy based clustering algorithms stated above are based on LEACH and taken residual energy and some local parameters while electing CHs. In the proposed method apart from energy metric and local parameters, we have taken optimal node degree centrality for calculating fitness of a node to become CH. It also decreases excessive load handling problems of CHs during local intra cluster communications.

III. SYSTEM ASSUMPTIONS

We consider a WSN with a large number of sensor nodes randomly deployed over a 2-D planer area. All the sensor nodes are identical in computational capabilities and have the same amount of initial battery energy. The sensor nodes can communicate with each other through short-range radios. The received signal strength is measurable and hence node can adjust their transmission range. Nodes transmit and receive packets with Omni-directional antennas. Further the following assumptions have been made:

1) Wireless sensor nodes and the base station are stationary after initial deployment.
2) All sensor nodes are energy constrained i.e. Battery recharges or substitution is not possible.
3) All member sensor nodes can communicate directly with their respective CHs.
4) Links are symmetric. Thus, two nodes can communicate using the same transmission power.

IV. IMPLEMENTATION

a) Excepted Residual Energy:

ERE of a member node is expected remaining energy of a node after executing a steady-state phase (the data gathered from cluster-member nodes is aggregated at CH and transmitted to base station).

The expected residual energy can be represented as

$$E_{exp\ residual}(l,d_{toBS},n)=RE_{new}-E_{exp\ consume} \qquad (1)$$

Where l-packet size
d-distance to base station
n-number of nodes

b) Cluster Optimal Degree Closeness Centrality:

The centrality is calculated by taking into consideration (X,R) weighted graph which represents the topology of WSN, where X is the total number of sensor nodes and R is a relation that represent any distance metric between two nodes like actual distance.

The CODC can be calculated by

$C^k(x_i)=eng[x_i]/n_\alpha$

Where C^k-measure of closeness centrality upto k nodes
n_α-distance of member nodes

c) Neighbor node distance:

This parameter improves the data deliverance. It is calculated by the formula:

d= √((x2-x1)^2+(y2-y1)^2))

d) Fuzzy Inference System:

It blends different clustering parameters for electing cluster-head. Fuzzy "if-then" mapping rules is used to achieve the fitness computation. The fuzzy inference technique used here is Mamdani method [9] because it is the most frequently used technique. The fitness value will alter according to the values ERE and CODC.

Table 1. Fuzzy Inference Rules For the Proposed Method

Sl.no.	ERE-energy	CODC-weight	Fitness
1	Low	Low	Low
2	Low	Optimal	Low
3	Low	Very high	Low
4	Medium	Low	Low
5	Medium	Optimal	Medium

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6	Medium	Very high	Medium
7	High	Low	Medium
8	High	Optimal	Very high
9	High	Very high	Medium
10	Very high	Low	High
11	Very high	Optimal	Very high
12	Very high	Very high	High

The implementation is completed using NS2 simulation. Initially thirty nodes are considered in the network, and the results are compared with LEACH.

Fuzzy Based Centrality Algorithm
INPUT
N- Communication network N at time T
s- a sink node
n- neighbor nodes
cv- cost value of node
c(i)- clusters
n_α-distance of neighbor node

OUTPUT
F - fitness of the node
CH- cluster head for each cluster

1) N←30
2) (N is divided to 5 clusters, N/5);
3) Broadcast (Energy, cost value);
4) s← (ERE, cost value); // The node which has high energy and cost value in c(0)
5) CODC← (eng[i]/n_α); // The distance from node s[0] to i
6) high-cluster energy← (comparing CODC)
7) if(ERE,CODC== F)
8) the nodes will become cluster-head
9) else
10) the nodes will become member-nodes
11) end if
12) if(cluster-head==true)
13) broadcast(CH message, n)
14) cluster members send data aggregation message to cluster head;
15) cluster head passes aggregation message to the base station;
16) end if

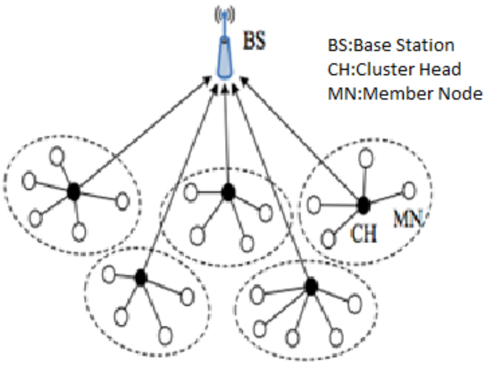

Fig1. Cluster Based Architecture in WSN

V. APPLICATIONS

Sensors integrated into structures, machinery, and the environment, coupled with the efficient delivery of sensed information, could provide tremendous benefit to society. The applications for WSNs are varied, typically involving some kind of monitoring, tracking, or controlling. Some important applications are as follows:

Disaster prevention: In addition to the warning system, sensor networks can be used for hazardous workspaces like underground mining, steelworks and refineries. Wireless sensor networks can be deployed in underground mining for surveillance of deteriorating grounds, toxic gases, and unstable grounds. In refineries, sensors can be used to track workers which can facilitate to alert an operator if someone accidentally enters a temporary hazard zone or to guide fire fighters to the people in danger.

Intelligent buildings: The sensors used in this application reduce energy wastage by proper humidity, ventilation, air conditioning (HVAC) control.

Intelligent bridges: It monitors the condition of bridge infrastructure and improves the efficiency of inspection, repair, and rehabilitation efforts.

Surveillance: VigilNet is a military wireless sensor network that acquires and verifies information about enemy capabilities and positions of hostile targets. It has been successfully designed, built, demonstrated, and delivered to the Defence Intelligence Agency for realistic deployment.

Green house monitoring: Sensors are used for saving heat energy in green houses. It is done by accurate measurement of temperature with high spatial resolution, horizontal as well as vertical in order to achieve reliable and consistent results.

Agricultural field: Precision agriculture is one of the most promising application domains where WSN may deliver a feasible or even a optimal solution. Fraunhofer IMS instrumented a field with sensor nodes equipped with sensors for measuring air temperature, relative humidity and soil moisture. The main objective is to indicate when the field or specific parts of the field are at risk of developing fungal diseases.

Animal Rearing: Installing a WSN near animals help to optimize their rearing conditions.

VI. SIMULATION

NETWORK SIMULATOR (NS2) is a discrete event driven simulator developed at UC BERKELEY. The goal of NS2 is to support networking and education. It is suitable for designing new protocols, comparing different protocols and traffic evaluations. It is distributed freely and an open-source software.
Simulation Tool:

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In this study NS-2.35 is used. NS2 is built using object oriented methods in C++ and OTCL (Object oriented Tool Command Language). The user writes simulation as a OTCL script, plumbs the network components together to complete the simulation. The new network components are easy to set up and implement by the user. The event scheduler acts as the other major component besides network components that triggers the events of the simulation (e.g, sends packet, starts and stops tracing).

VII. RESULT

The performance of the algorithm is evaluated through NS2 simulation and it is compared with LEACH. A random network deployed in an area of 900m*800m is considered and the proposed method shows better results than LEACH.

A. Number of Alive nodes

The energy efficiency is evaluated by calculating the network life time. Compared to LEACH proposed method shows better results and therefore highest operational network life. The network lifetime is shown by plotting time versus energy. It is shown in Fig2

B. Throughput

It is the average number of packets received per second at the base station. It is depicted by the graph as shown in the Fig3. It is calculated by using

Throughput=Number of bits received / (Simulation time*millisecond)

C. Packet Delivery Ratio

It is defined as the ratio of packets that are successfully delivered to the destination compared to the number of packets that have been sent out by the sender. It is shown in the Fig4.

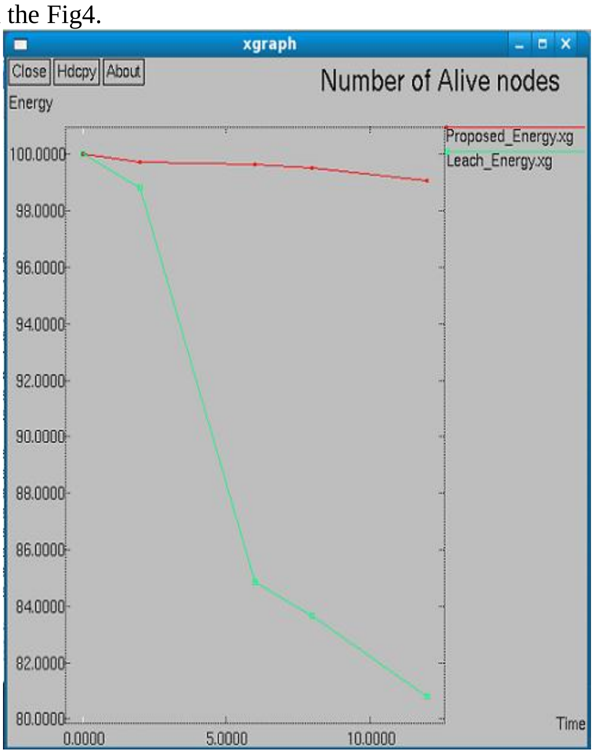

Fig2. Number of Alive nodes

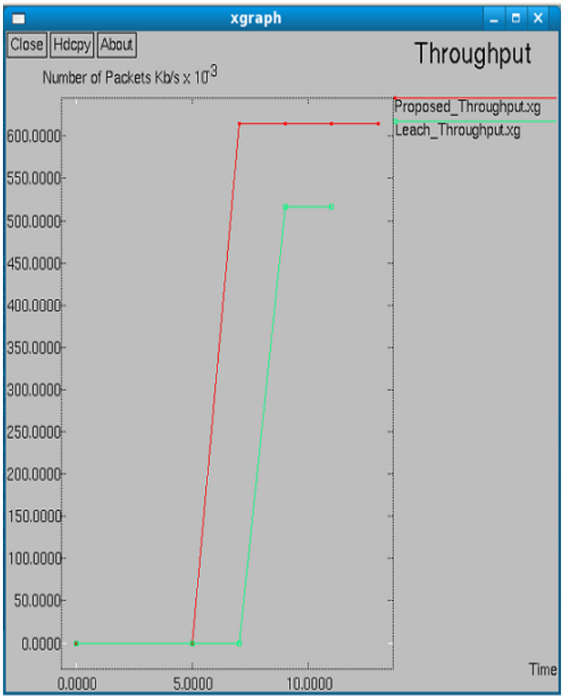

Fig3. Throughput

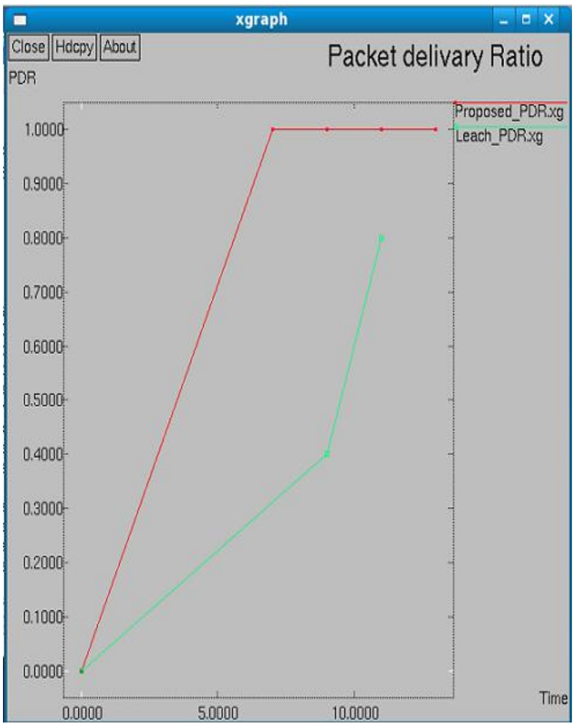

Fig4. Packet Delivery Ratio

VIII. CONCLUSION AND FUTURE WORK

In this paper, we have implemented a new method of clustering called Fuzzy Based Centrality Algorithm based upon Cluster Optimal Degree Centrality and Expected Residual Energy. It has been compared with LEACH and it shows better results in terms of network lifetime, individual cluster QoS and intra cluster communication. A further direction of this work will be to apply the implemented technique for multi-hop routing and can also be extended for optimal placement of sink as well as relay nodes.

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