Energy Efficient Multihop Routing scheme with in Network Aggregation for WSN

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Abstract

This paper introduces an energy efficient, multi-hop routing scheme, with in-network aggregation. The technique uses clustering as the base of our algorithm. Ant Colony Optimization (ACO) is implemented over clustering algorithm for multi-hop routing. This reduces amount of direct transmissions from CHs to BS. The technique work in three phases: (a) clustering, (b) intra-cluster communication, (c) inter-cluster communication. LEACH is implemented for clustering, which generates randomly distributed clusters. Then cluster members send data directly to their cluster head. Ant Colony Optimization algorithm (ACO) is used for communication between cluster-heads and base-station. Use of clustering minimizes the transmission of redundant data by data aggregation at the cluster-head level. ACO tends to search shortest and energy efficient route. The results shows lower power consumption and lower average cost (distance) and thus longer lifetime.

Keywords: *ACO, clustering, multi-hop routing, WSN.*

I. INTRODUCTION

In recent years, with continuing advances in the technologies of microelectronics, digital signal processing and wireless communication, there has been more and more attention to the large-scale and low-cost wireless sensor networks (WSN) which can be used to get information from dangerous zones and remote areas [1]. A wireless sensor network (WSN) is composed of a large number of sensor nodes and a base station (BS). The BS typically serves as a gateway to some other networks. It provides powerful data processing, storage centre, and an access point to the sensor nodes in its network. The objective of WSN is to sense their environment, collect sensed information and transmit it to the BS.

A Wireless Sensor Network is a resource constraint network. Designing an efficient routing protocol for such a network is considered as a problem. To achieve an efficient and robust routing operation, major features of typical WSNs are needed to be taken into consideration [2]. First, failures in communication nodes are more probable in WSNs than classical networks, as nodes are often located in unattended places and they use a limited power supply. Therefore the network should not be affected by a node's failure and should be in an adaptive structure to maintain the routing operation. This is performed by sustaining different paths alive in a routing task. In WSN main objective of sensor nodes is to transmit sensed information to the base-station. If direct transmission is used, then nodes that are farther away from base-station get their power source drained much faster than those nodes that are closer to the base-station. Solution is to use multi-hop routing scheme.

Second, nodes in WSNs present stringent energy constraints. They consume much more energy when they are in communication. So the energy levels of the nodes should also be considered as well as the length of the route while designing a routing protocol. Average lifetime of network would increase by choosing nodes having more energy. Even with using Minimum energy multi-hop routing scheme [3], node's energy resource get rapidly drained, since these nodes engage in the forwarding of a large number of data messages (on behalf of other nodes) to the base station. Thus solution is to use multi-hop communication with in-network aggregation of correlated data.

Third, the bandwidth of wireless links in WSNs is limited. It is important not to involve too much information about overhead of the routing task in the communications. This is also a means of preserving more energy.

Thus the routing scheme needs to be energy efficient, multi-hop routing scheme, with in-network aggregation.

Among different routing protocols to be used in wireless sensor networks, clustering is a method that has commonly been found in WSN [3]. Clustering is a process of dividing a network into non-overlapping groups of sensor nodes. Each cluster is managed by a chosen Cluster-Head (CH). Cluster members send data packets to the cluster heads which communicate with each other and send the aggregated packet to the Base Station (BS).Thus clustering can help us to use data aggregation methods [4]

In this work, we use clustering as the base for our algorithm. To further improve the routing algorithm, we use the ant colony optimization (ACO) to find the optimal route from the cluster heads to the base station. In comparison with the methods that use only ACO-based routing in WSNs with a large number of nodes, our algorithm leads to a shorter convergence time, less routing overhead and longer lifetime

The rest of the paper is organized as follows. In Section II, a review of the previous works related to clustering algorithms and ACO-based routing in WSNs is given. In Section III, the proposed cluster-based ant colony optimization algorithm is presented. The results are discussed in Section IV. Finally, the conclusions are given in Section V.

I. RELATED WORK

In this section, we briefly review some of the clustering methods and ACO-based routing methods proposed in the field of WSNs.

W. R. Heinzelman et al.[5] proposed LEACH (Low Power Adaptive Clustering Hierarchy), an algorithm used for clustering in WSN. For LEACH, in each round, some nodes become cluster heads randomly, and the other nodes respectively decide to which cluster them belong in order to minimize the communication energy with the associated cluster head. Then cluster nodes take turns to transmit data to associated cluster head, the aggregated data will be delivered to BS by cluster heads directly. . It has two main weeknesses –1. It is possible no or lots of CHs are selected. 2. CHs are not selected in a distributed manner; it is possible that too many CHs are located in a specific area.

O. Younis and S. Fahmy [6] proposed new clustering algorithm called HEED as an improvement over LEACH.
In HEED (A Hybrid, Energy-Efficient, Distributed Clustering) several iterations are needed to choose a cluster head.All nodes assume the initial probability to become a cluster head as follows:

$$\mathbf{CH_{prob}} = \mathbf{C_{prob}} \times \frac{\mathbf{E_{residual}}}{\mathbf{E_{max}}} \quad (1)$$

At the beginning of each round all uncovered nodes decide to be cluster heads with probability CHprob. If a node decides to be a cluster head, it broadcasts a message to other nodes. In this message if CHprob is less than 1, the node introduces itself as a tentative cluster head. If CHprob is equal to or greater than 1, the node introduces itself as a final cluster head. At the end of each iteration all nodes double their CHprob. A node assumes itself covered if it is covered by at least one tentative or final cluster head. If at the end of a round, a certain node isn't covered by any tentative or final cluster head, it reveals itself as a final cluster head. Then each node joins a cluster which generates the lowest cost for it. Unlike LEACH, HEED creates well-balanced clusters

Hong-Chi Shih et al.[7] proposed an ant colony optimization (ACO) based routing algorithm to reduce power consumption. They modify ACO and join ladder diffusion to scheme the node routing for sensor networks. First, a grade table is built using ladder diffusion and referred to generate several possible routing paths. Then, the ACO explores these paths to reduce the power consumption of the nodes. This algorithm obtains more balanced transmission among the nodes and reduces the power consumption of sensor network.

M. Shamim Hossain et al.[9] proposed an Ant Based Routing Algorithms for Resource Constrained Networks. 1. At some interval, forward ants are created at the source node and sent towards the destination. They move in parallel but independent of each other in finding the destination.2. Forward ants select the least cost path joining the source and destination. The next node is selected according to a link probability distribution 3. Forward ants maintain a list of nodes already visited. Before moving forward towards a node, the forward ant checks if that node exists in the list. If it exists, the forward ant selects the next link to an unvisited node with the least probability distribution.4. If a forward ant reaches a node from which all neighbouring nodes exist in the list, it dies. 5. Once the destination is reached, a backward ant is created and sent back along the same path to the source node updating the link probability distribution at every hop. The pheromone value is updated for each link. Once backward ant reaches the source node, it dies.

Ali-Asghar Salehpour1 et al.[10] proposed an energy efficient routing protocol for cluster based WSN using Ant Colony Optimization (ACO). In this protocol LEACH is implemented as the base protocol. ACO is implemented over LEACH for multi-hop routing. This protocol is implemented in rounds. Each round has following three phases:1.Clustering, 2. Intra-cluster communication, 3. Inter-cluster communication.

In Clustering phase, Leach [5] is implemented to generate random clusters. Intra-cluster communication is established by implementing TDMA protocol over MAC layer. For inter-cluster communication, multi-hop routing protocol ACO is implemented. AntNet 1.0 is implemented for ACO. This protocol considers remaining energy of nodes to decide the next-hop node.

Proposed work is an enhancement over LEACH-ACO protocol.

I. PROPOSED ALGORITH

Proposed approach EECA (Enhanced Energy Efficient Cluster base Routing based on ACO) is an enhancement over LEACH-ACO protocol. LEACH-ACO used just remaining energy of nodes for taking decision of next hop. We combined the distance as well as energy as parameters to take decision. The proposed approach has following steps:

1. Selection of CH's and the members of each cluster are specified according to Leach [5]. With Leach it is possible that no CH is chosen.

2. Each CH assigns a TDMA schedule to its nodes. Then nodes within a Cluster send data to its CH within their assigned time-slot. When one TDMA schedule finishes CH perform data aggregation.

3. Route setup where each node finds the optimal route to base through CH's. If the node is not CH, it sends its data directly to its CH. At CH, after data aggregation, data is send to BS by multi-hop transmission using AntNet1.0. If a node is not included in any cluster, it sends its data directly to BS.

4. If no clusters are generated then whole network uses multi-hop ACO to send data to BS.

EECA Algorithm:

EECA's algorithm is given below:

```
Algorithm(n)
/* n is the no. of nodes in the network, Each node is defined by Node(i) */
{
For i=1 to n
{
Node(i).E=0.5;
Node(i).T='N';
}
/* Initially no node is cluster head and energy level is equal to 0.5J*/
For (i=1 to r)
/* perform the multihop routing for r no. of rounds*/
For i=1 to n
{
/* a random value rand is generated for node. Required threshold value is given by
```

$$T(n) = \begin{cases} \dfrac{p}{1 - p \bmod (r, round(\frac{1}{p}))} \quad if G <= 0 \\ \end{cases} \qquad \text{Eqn. (2)}$$

```
It is independent of node's energy and position.*/

For(rand(i)< REQ_THRESH)
{
Set Node(i).T='C';

If(Node(i).E<0)
{
Dead++;
/*Set Node I as the Dead Node*/
}
Node(i).E=Node(i).E- Distance * EnergyRatio;
}
For i=1to n
{
If (Node(i).T='N' and Node(i).E>0)
{
Select cluster head with minimum transmission distance. If no cluster head found, then send data directly to BS. If node become member of a cluster, send data directly to CH.
}
If (Node(i).T='C')
{
set TDMA schedule for cluster members and after one frame aggregate their information to form one packet.
}
}
/* use multihop routing for transmission through CHs to BS.*/
Call antoptimization(); /* pass CHs as variables*/
If (no node is of type 'C')
Call antoptimization(); /* pass all nodes as variable*/
}
}
Function AntOptimization()
{
```

{Initialization}

Initialize $\tau \in (0,1)$, $\eta \in (0,1)$ and $\lambda \in (0,1)$.

$$\eta_{ij} = \frac{e_j}{\sum_{n \in N_i} e_n} \quad \text{and} \quad \lambda_{ij} = \frac{1}{d_{ij}}$$

{Construction}

a. For each node k (currently in state ι) do

i. repeat

1. choose node with max probability as next node to move i

$$P_{ij}^{k} = \begin{cases} \dfrac{[\tau_{ij}]^{\alpha} \bullet [\eta_{ij}]^{\beta} \bullet [\lambda_{ij}]^{\sigma}}{\sum [\tau_{ij}]^{\alpha} \bullet [\eta_{ij}]^{\beta} \bullet [\lambda_{ij}]^{\sigma}} & \forall\ j \in N_j \text{ and } j \notin M^k \\ 0 & \text{otherwise} \end{cases}$$

2. append the chosen move to the k-th node's set tabu list M_k.

ii. until node k has completed its solution and reached BS.

b. end for

{Trail update}

c. For each ant move do

i. compute Δτ

ii. update the trail matrix.

$$\tau_{ij} = (1-\rho)\tau_{ij} + \delta\tau_{ij} \quad \text{where} \quad \delta\tau_{ij} = \frac{1}{\sum d_{ij}}$$

$0 < \rho < 1$ is the pheromone trail evaporation rate.

d. end for

{Terminating condition}

If not(end test) go to construction phase}

IV RESULTS AND DISCUSSION

In this section, we assess the efficacy of the proposed algorithm. The reference network used in our simulations had 100 nodes in a 100 x 100 square field. Each node had 0.5 joules of initial energy. The packet size was 4000 bits and 0.01 percent of the nodes were selected as cluster heads

Simulations are performed using MATLAB. The algorithm is implemented using mathematical computation on MATLAB. We ran simulations for the random 100 node network. The base station was chosen at location (50,50) in network. For our experiments, depending on the transmission range, we have considered both the free space and the multi path fading channel models. If the distance is less than a threshold,d0 , the free space model is used; otherwise, the multi path model is used.

The energy consumption models of the transmitter and receiver separated by distance dist, transmitting or receiving a K-bit message for a K-bit message are respectively given by[11]:

$$E_t = \begin{cases} (ETX + EDA) * K + E_{mp} * K * dist^4 & \text{if dist} \geq d_0 \\ (ETX + EDA) * K + E_{fs} * K * dist^2 & \text{otherwise} \end{cases} \quad (9)$$

$$E_r = (ERX + EDA) * K \quad (10)$$

Where Et and Er are energy consumed by transmitter and receiver respectively. ETX and ERX is the energy consumed per bit to run the circuitry of transmitter and receiver, Efs and Emp are the power loss of free space and multi path models used. cost of data aggregation is modeled by EDA. Threshold transmission distance d0 is

$$d_0 = \sqrt{\left(\frac{E_{fs}}{E_{mp}}\right)} \quad (11)$$

ETX,ERX	**50nJ/bit**
E_{fs}	**10pJ/bit/m ^{2}**
E_{mp}	**0.0013pJ/bit/m^4**
K	**4000**
EDA	**5nJ/bit**

We studied mathematical implementation of proposed algorithm. To evaluate the advantage of using proposed approach, we have compared the proposed algorithm with LEACH-ACO. The results of simulation for the system lifetime as a function of round are shown in fig 1, and fig2..Fig 3 shows the comparison of lifetime of both approaches.

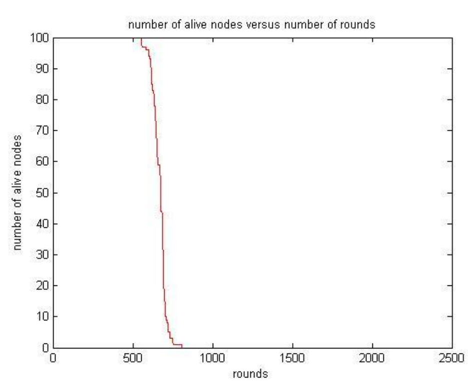

Fig 1: LEACH-ACO

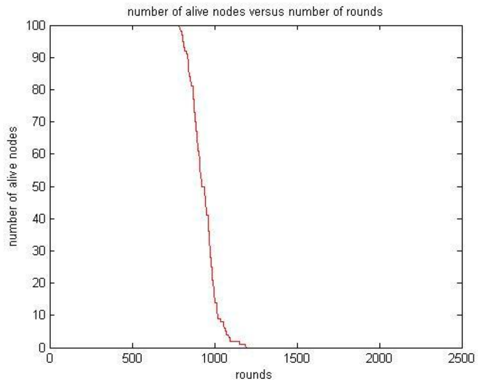

Fig 2: EECA

LEACH-ACO	EECA
810	1190

The proposed approach proved to increase lifetime of network.

V. CONCLUSION

In this paper, we proposed an energy efficient, multi-hop routing algorithm for the wireless sensor networks using the ant colony optimization. We compared the proposed routing method with two other algorithms which were ACO and LEACH-ACO. The simulation results showed a higher system lifetime for the proposed routing algorithm compared to these routing algorithms.

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