Current Trends in Technology and Science
ISSN : 2279-0535. Volume : 04, Issue : 01 (Dec.- Jan. 2015)

An Energy-Balance, Cluster Based Routing Algorithm Using Vertex Subset Degree Preserving Spanning Trees For Wireless Sensor Networks

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Abstract - The past few years have witnessed increased interest in the potential use of wireless sensor networks (WSNs) in a wide range of applications and it has become a hot research area. Based on network structure, routing protocols in WSNs can be divided into two categories: flat routing and hierarchical or clustering routing. Owing to a variety of advantages, clustering is becoming an active branch of routing technology in WSNs. Other than this energy conservation is more important in most applications in that all sensor nodes are constrained with energy which is directly related to network lifetime. In this paper, we propose a cluster based routing algorithm using vertex subset degree preserving spanning trees in which energy is also taken into account for the formation of clusters & heads after the first round of transmission. We describe and analyze the algorithm. Finally, we conclude the paper with some future directions.

Keywords - clustering, graph algorithms, networks, routing, spanning trees.

1. Introduction

Wireless Sensor Network (WSN) consists of a large number of tiny sensor nodes distributed over a large area with one or more powerful sinks or base stations (BSs) collecting information from these sensor nodes. All sensor nodes have limited power supply and have the capabilities of information sensing, data processing and wireless communication. Routing is one of the critical technologies in WSNs. A major technical challenge for WSNs, however, lies in the node energy constraintand its limited computing resources, which may pose a fundamental limit on the network lifetime. Therefore, innovative techniques to eliminate energy inefficiencies that would otherwise shorten the lifetime of the network are highly needed. In many applications of WSNs, data collected by many sensors is based on common phenomena, and hence there is a high probability that this data has some redundancy or correlation.

The main idea of the data aggregation and in-network processing approaches is to combine the data arriving from different sources (sensor nodes) at certain aggregation points (or simply aggregators) in route, eliminate redundancies by performing simple processing at the aggregation points, and minimize the total amount of data transmission before forwarding data to the external base station (BS). Removing redundancies results in transmitting fewer numbers of bits, and hence reduces energy consumption and increases the sensor nodes lifetimes.

And an aggregation scheme concluded that enhanced network throughput and more potential energy savings are highly possible using data aggregation and in-network processing in sensor networks. Aside from the task of efficient design of data aggregation algorithms, the task of finding and maintaining routes is also nontrivial, especially when it includes the selection of aggregation points and routing through the points. One of the main design goals of WSNs is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques. We are implemented a hierarchical tree-based algorithm is proposed which is completely self-organized and energy efficient with vertex subset degree preserving minimum spanning tree as routing.

Sensor nodes are organized into local clusters with one node in each cluster as cluster head. The cluster head receives data from all other sensors in the cluster, aggregates data, and transmit the aggregated data to the BS.

2. Routing In Sensor Networks

Based on network structure, routing protocols in WSNs can be roughly divided into two categories: flat routing and hierarchical routing. In a flat topology, all nodes perform the same tasks and have the same functionalities in the network. On the other hand in a hierarchical topology, nodes perform different tasks in WSNs and typically are organized into lots of clusters according to specific requirements or metrics. Generally, each cluster comprises a leader referred to as cluster head (CH) and other member nodes (MNs) or ordinary nodes (ONs), and the CHs can be organized into further hierarchical levels. In general, nodes with higher energy act as CH and perform the task of data processing and information transmission, while nodes with low energy act as MNs and perform the task of information sensing.

3. Related Works

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The typical clustering routings protocols in WSNs include Low-energy Adaptive Clustering Hierarchy (LEACH) [4], Hybrid Energy-Efficient Distributed clustering (HEED) [15], Distributed Weight-based Energy-efficient Hierarchical Clustering protocol (DWEHC) [3], Position-based Aggregator Node Election protocol (PANEL) [2], Two-Level Hierarchy LEACH (TL-LEACH) [8], Energy Efficient Clustering Scheme (EECS) [14], Energy-Efficient Uneven Clustering (EEUC) algorithm [13]. Energy Efficient sensor Network protocol (TEEN) [9], The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) [10], Two-Tier Data Dissemination (TTDD) [16], Concentric Clustering Scheme (CCS) [6]and *etc*. Clustering routing is becoming an active branch of routing technology in WSNs on account of a variety of advantages, such as more scalability, data aggregation/fusion, less load, less energy consumption, more robustness, *etc*.

In the last few years, a relatively large number of clustering routing protocols have been developed for WSNs [1, 5, 7]. The concepts of graph theory relevant to wireless sensor networks are discussed in [11].This paper is to introduce energy –balance cluster based routing algorithm for WSN using the graph theory concept vertex subset degree preserving spanning trees.

4. Vertex Subset Degree Preserving Spanning Trees

A new class of spanning trees called Vertex Subset Degree Preserving Spanning Tree (A-DPST) is defined as a spanning tree T of the graph $G(V,E)$ such that $\deg_T(v_i) = \deg_G(v_i)$ for all v_i in A which is a nonempty subset of V[12]. The minimum spanning tree problem with an added constraint that the vertices of A should preserve their degrees in the spanning tree which can be termed as A-Degree Preserving Minimum Spanning Tree (A-DPMST).We are using an algorithm for multi-clustering in sensor networks using such A-DPMSTis proposed.

The sensor network is considered as a graph whose vertices are the sensors along with the cluster heads, the base station, and the links between them as the edges. Now the collection of cluster heads say A is a nonempty subset of the vertex set of the graph and the construction of the routing tree for the sensor network becomes the problem of finding A-Degree Preserving Spanning Tree in the graph. Because in the sensor network this A-DPST will be a minimally connected subnetwork in which all the links to the cluster heads are maintained. Since in the tree every other node is either directly connected to the head or having a path to the head, routing will be complete. Such routing could be made optimum by deploying higher energy node as the sensor heads of the clusters.

5. Proposed Algorithm

One of the important issues in design consideration of a sensor network is nodes lifetime. Our goal is to find solution to this issue. All nodes are given specific grades. All the nodes that can be connected by the sink node can be defined as the *1*st-grade nodes, and then the nodes in the *1*st-grade nodes' radius are defined as the *2*nd-grade nodes. Then divide these nodes in this way, and all nodes will have a certain grade. Our assumption is that the life time of the WSN is until one of the node's energy is consumed completely, so one way to reach the goal is to keep the balance of nodes' residual energy. From, the nodes which are close to the sink node consume more energy and die earlier than others. In order to avoid this we should consider the energy balance of the system when designing the routing algorithm. And thus the WSNs life time is extended.

5.1 Node weight assignment

Our routing tree algorithm starts with getting the energy of all nodes and getting the distances of all nodesfrom the base station and also among the nodes. These distances are given as weights on the corresponding edges. Let E_{bi} denotes the energyof node v_i and w_{ij} denotes the distance from node v_i to the node v_j which is assigned as the weight to the edge joining the nodes $v_i$and v_j. Then the procedure getEligible (w_{bi}) returns the eligible nodes to the set X whose energy is greater than or equal to the threshold value "t" which is calculated using the formula, $t = 1/n \sum_{v_i \in V} E_{bi}$ Now X is a subset of V the set of all nodes in the network.

5.2 Formation of clusters

For each node v in X we calculate the node weight $w(v)$, using the formula $w(v) = 1/k \sum_{e \in E(v)} w(e)$, where $E(v)$denotes the set of all edges having one end vertex as v and $k=|E(v)|$. Now the vertices in X are arranged in non decreasing order of their weights. The function addVertex(i) decides whether a node from the sorted eligible set X can be included along with its neighbors to the tree, even after maintaining the disjointness of the clusters and restricting the formation of circuits. The degree preserving nodes in the routing tree constructed play the role of cluster heads.

5.3 Building a routing tree

Our routing tree construction is based on the idea of Kruskal's algorithm with some modification. The function insert (i) checks whether the sorted remaining nodes can be included in any one of the clusters by means of minimum weight edge without forming any circuit and exclusive of connectivity between the clusters formed. Then, all the cluster heads are attached to the base station and hence a complete routing for the sensor network is obtained.

5.4 After a transmission

The node from where we want to pass data to the base station is stored in name. Then by using findeligible(name) function we will get all the nodes(Y) which are having an edge with the given node name in the spanning tree. We can select a particular node from the set of nodes by using the function choose(Y) and energy is reduced from that chosen node. This procedure is continued until we reach the cluster head. Finally from cluster head the data will be transferred to the base station, Then again the routing tree is constructed.

Current Trends in Technology and Science
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Algorithm
Procedure RoutingTree(Wbi,Wij)
/*Initialize all the parameter*/

```
List    X ← ∅   /* List of eligible
        nodes*/
        XX ← ∅        /*List of all nodes*/
        A ← ∅         /* List of cluster heads
                in the final tree*/
        T ← ∅         /* Final forest whose
        components are different clusters*/

      E_T ← ∅         /* The edge list of the
                      forest T*/
      Y ← ∅            /*Set of all node connected
with a given node in a spanning tree*/
X ← ∅   getEligible(Wbi)
for each v ∈ X
        w(v) =1/k∑_{e∈E(v)} w(e)
end for
X ← ∅    sort(X)
        for each i ∈ X
                {A,E_T } ← addVertex(i)
        end for

R ← E - E_T
R ← sort(R)
        for each i ∈ R
        T ← insert (i)
        end for
return (A,T)
name=gettext( )
Y=findeligible(name)
choose(Y)
```

Procedure getEligible(W_{bi})

```
List    X ← ∅
        t = (1/n) ∑_{i=1}^{n} E_bi
       for each v_i∈ V
        {
        if(E_bi>=t)
                X=X ∪ v_i
        }
        end for
return(x)
```

Procedure addVertex(i)

```
List E_i ← edges(i)
for each j∈E_i
                if(end node of j is in A)
                return;
                else if(both the end nodes of j are
                                in A)
                return;
                else
                A=A ∪ i
        end for
return (A,Ei)
```

procedure insert (i)

```
if (both end nodes of the edge i are in T)
        return;
else if (none of the end nodes of i is in T)
        return;
else
        return i;
```

procedurefindeligible(name)

```
        for each i∈ XX
                if end node of name is an end node of i
                        Y=Y ∪ i
                end if
        end for
        return Y
end
```

procedure choose(Y)

```
        temp=energy(first element in Y)
        for each j ∈ Y
                if energy j > temp
                        reduce_energy(j)
                        findeligible(j)
                else
                        reduce_energy(temp)
                        findeligible(j)
                end if
        end for
end
```

Procedure reduce_energy(i)

```
        for each i
                i=i-10
        end for
end
```

5.5 Description and complexity analysis

In the first phase, the algorithm produces a forest first. Initially it includes the node with minimum weight to the cluster head set A and along with its adjacent nodes to T. Then the procedure addVertex (i) includes the other possible head nodes. It never chooses an edge that completes a cycle. Also it will not choose the edge which connects the components already existing. By maintaining these two properties it includes the other nonhead nodes through the procedure insert (i). At each stage the nodes are included to T using possible minimum weight edge. And hence the forest will be near minimum. To finish all the cluster heads are joined to the base station which completes the routing in the network. Then it returns the routing tree and the set of cluster heads A.

In the second phase, after a transmission over, the nodes belongs to the path of transmission are identified and their energy are reduced according to formulas used. Then in the resultant network, the routing tree is constructed by giving preference for being cluster heads to the nodes having higher energy. The time complexity of the above algorithm is O (n^2).

5.6 Simulation and results

In this section, performance result of the proposed routing algorithm is presented. This algorithm is

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simulated in Java-based custom simulator. It was considered that a node can transmit a data packet to its adjacent nodes in the network and to the base station. Experiment was conducted in a network area 500m × 500m. To simulate the performance, after fixing the base station the nodes are arbitrarily generated and network is randomly formed. The following table shows the node ID as well as the random generated *x* and *y* coordinates. The results of the coding are displayed with Figs. 1–4. The base node is fixed at (250, 50).

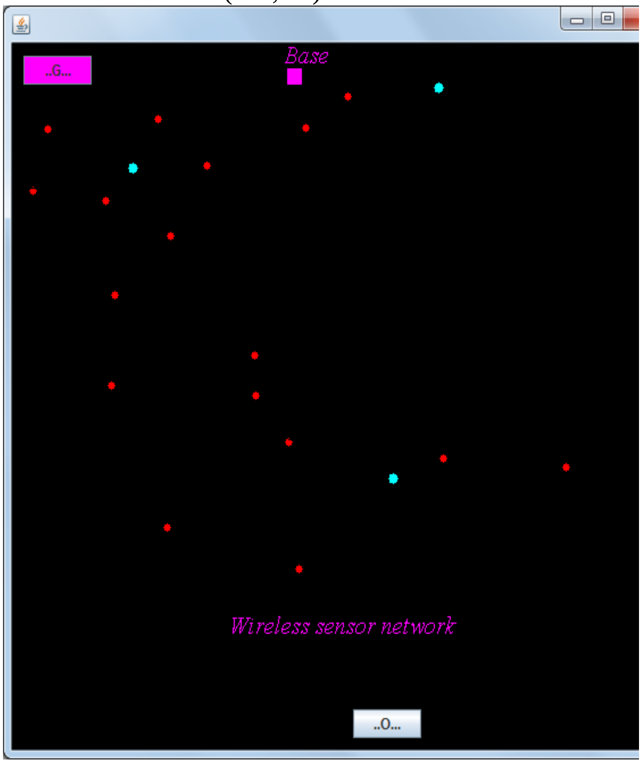

Fig. 1.The arbitrarily generated nodes inside of the network with a range of 500m× 500m.

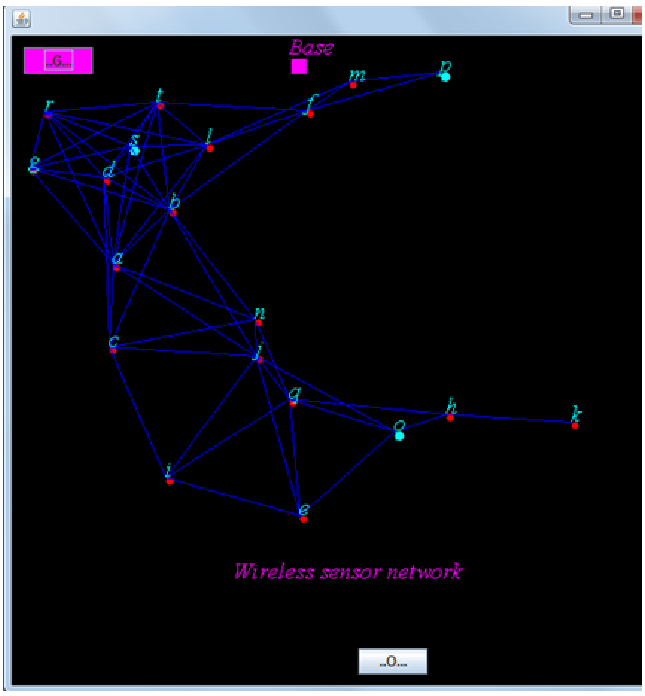

Fig. 2.The randomly generated network.

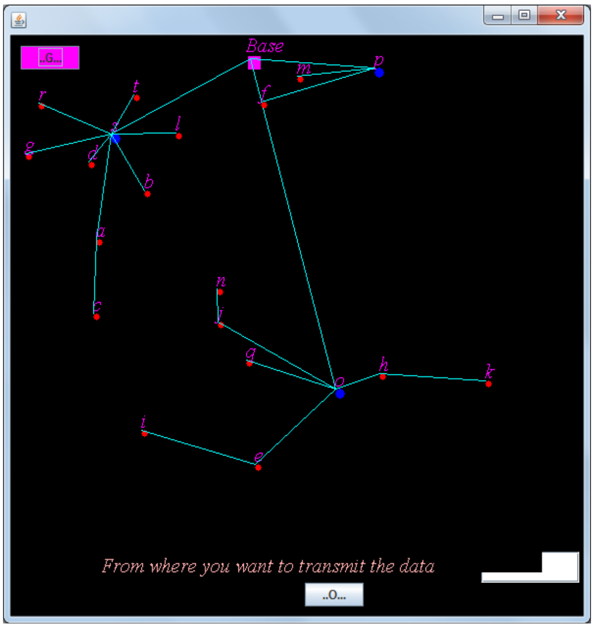

Fig. 3.Clustered routing tree constructed

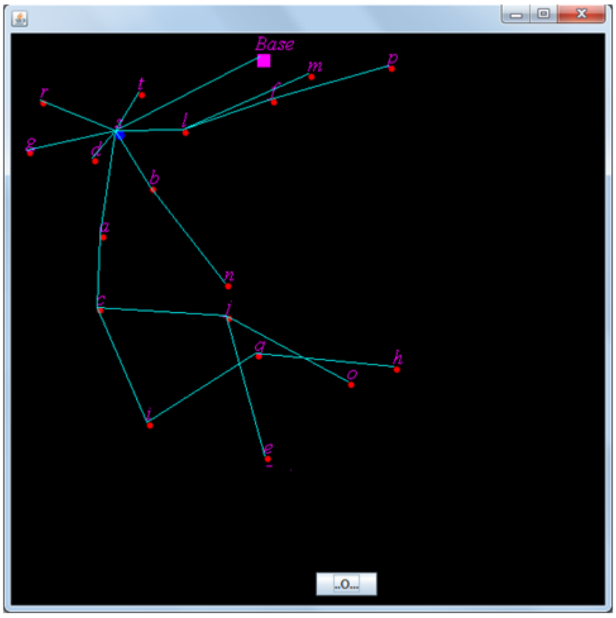

Fig. 4. Second round routing after a transmission

6. Conclusion

A new energy-based routing algorithm using degree preserving spanning tree is proposed for effectively collecting the data in a sensor network. In cluster based routing the sensor nodes transmit data to their cluster heads, which transmit the aggregated data to the base station.In the proposed algorithm, the cluster heads are chosen from the eligible node set which satisfies the condition that their energies are greater than or equal to the threshold value calculated. While forming the clusters also the energiesof the nodes are considered and routing could be made optimum by deploying higher energy node as the sensor heads of the clusters. Therefore, the complete routing tree obtained for the network will be almost optimum. We have implemented the algorithm which gives the solution for the problem of multi-cluster formation along with their heads.From this design of the algorithm, the network lifetime is improved.

ACKNOWLEDGEMENT

The authors are appreciative to G.Packiya Lakshmi and K.Yogeswari, MCA students, PSG College of Technology, who did their project under the guidanceof Dr.K.Sangavai,for their support in implementing and testing the algorithm proposed.

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