Cluster Based Routing in Wireless Sensor Networks using Betweenness Centrality

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ABSTRACT: In recent days, wireless sensor networks emerging as a promising and fascinating area. There are two types nodes used in wireless sensor network for communication which are homogeneous and heterogeneous nodes. A hundred to thousands of nodes can be deployed in the sensing region to sense the environmental conditions. These nodes work cooperatively and send sensed information to the sink node. Network lifetime is the key parameter for wireless sensor network protocols. In this regard, finding an optimal communication path in the network becomes challenging. In this paper we proposed an algorithm for finding a cluster based routing for communication in WSN using betweenness centrality measure.

Keywords: Wireless sensor networks, data aggregation, clustering, routing, betweenness centrality

1. Introduction

A Wireless sensor network can be considered as a network of devices which includes sensor nodes that can communicate the information gathered from a monitored field through wireless medium. All sensor nodes are deployed with a sensor which is a device that responds and senses several types of input from both the physical or environmental conditions, such as pressure, heat, light, etc. The output of the sensor is normally an electrical signal that is broadcast to a controller for further processing. The data is forwarded through several nodes, and with a gateway to the base station. In recent years, designing an efficient routing protocol for a Wireless Sensor Network has become a leading area of research.

1.1 Data aggregation in sensor network:

In several applications of WSNs, knowledge collected by many sensors is based on common phenomenon, and therefore there's a high likelihood that this knowledge has some redundancy or correlation. Due to the correlation present within the sensors' readings, it's expected that communication approaches the base station in conjunction with this correlation. To avoid this, data aggregation and in-network process, are going to be used that surpass ancient approaches [4]. The main idea of the data aggregation and in-network process approaches is to mix the information arriving from completely different sources (sensor nodes) at certain aggregation points (or cluster heads) in route, eliminate redundancies by simple straightforward process at the aggregation

points, and minimize the whole quantity of knowledge of information for transmission before forwarding data to the external base station. Removing redundancies ends up in transmission fewer numbers of bits, and therefore reduces energy consumption and will increase the sensor nodes' lifetimes. Variety of studies that compared aggregation scheme concluded that increased network turnout and more potential energy savings are extremely possible using data aggregation and in-network processing in sensor networks.

1.2 Routing in sensor network:

Aside from the task of efficient design of data aggregation algorithms, the task of finding and maintaining routes for communication in WSN is additionally nontrivial, particularly once it includes the choice of aggregation points and routing through those points [8, 9].One of the main design goals of WSNs is to hold out data communication attempting to extend the lifetime of the network and prevent connectivity deprivation by using suitable energy management techniques. The design of routing protocols in WSNs is influenced by several difficult factors. These factors should be overcome before efficient communication will be achieved in WSNs. In general, routing in WSNs may be divided into flat-based routing, hierarchical-based routing, and location-based routing depending on the network structure. In flat-based routing, all nodes are usually assigned equal roles or practicality. In hierarchical-based routing the nodes are organized in different levels. Routing algorithms based on completely different geographical locations are classified as location-based routing. In [10] authors proposed, a hierarchical tree-based algorithm that is totally self-organized and distance efficient with vertex subset degree preserving minimum spanning tree as a routing tree.

1.3 Routing using Vertex Subset Degree Preserving Spanning Tree:

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 , by the authors in [5]. The minimum spanning tree problem with an additional 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) was also studied in [5]. In [10], an algorithm for multi-clustering in sensor networks using such A-DPMST is proposed. The sensor network can be modeled as a graph whose vertices are the sensor nodes, the base station, and the links between them as the edges. Now if the collection of cluster heads be A which is a nonempty subset of the vertex set of the graph then 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 any spanning tree every other node is either connected directly to the cluster head or having a path to the head, routing will be complete. Such routing could be made optimum by deploying higher energy nodes as the heads of the clusters.

2. Related Works

A major technical challenge for WSNs, however, lies on the node energy constraint and its restricted computing resources, which can create a fundamental limit on the network lifespan. Therefore, innovative techniques to eliminate energy inefficiencies that might otherwise shorten the lifetime of the network are extremely required. In this regard, some of the concepts of social networks are employed in WSN.

2.1 Social Network Analysis:

Graph connectivity measures are extensively studied in field of social network analysis (SNA) [11] and are popular choice among researchers to search out the importance of node in a network. In SNA, to locate the individuals which are most central or are most connected is very important. Also, the relation of individuals with each other is one of the fundamental problems in the social networks, certain measures like centrality and connectivity have been proposed, which allow characterization of the structures and properties of large networks and make predictions about their behavior [6, 7].

2.2 Betweenness in sensor networks:

Betweenness centrality of a vertex (node) is defined as the number of the shortest paths from all vertices to all other vertices that pass through it in a graph or network [11]. In [1] author introduces a technique for more improvement within the network lifetime by considering network connectivity beside energy potency for the choice of data transmission routes. The network lifetime is increased by preserving highly connected nodes at initial rounds of data communication to confirm network connectivity throughout later rounds. In that algorithm, connectivity factor of a node is calculated on the basis of Betweenness centrality of a node and energy efficient routes are found by using fuzzy logic and ant colony optimization. In wireless sensor networks due to random deployment, there are certain nodes that are connected to relatively higher number of nodes and are members of large number of network paths. Early energy depletion of those nodes

might cause network partitioning and reduce overall effective network lifetime. In [3], it has been proposed that the network lifetime of the WSN may be further increased by conserving the energy of these highly connected nodes. Among the various energy efficient paths, the first priority is given to paths which have lesser number of those highly connected nodes. This successively ensures that highly connected nodes are preserved resulting in delay of the partition of network. The on top of mentioned concept has been implemented using graph connectivity measures for coming up with the routing algorithm. In [3], Betweenness centrality measure has been used to find the connectivity share of a node in the network. Further, depending upon the value of Betweenness centrality, each node is classified into h (low), X (moderate) and g (high) connectivity domains. In [2], at the time of route selection, energy efficient routes of nodes falling under low connectivity domain are preferred, which in turn ensures that the connectivity of the network is prolonged with the presence of highly connected nodes in later rounds.

3. Proposed Algorithm:

In this paper we proposed a new cluster based routing in wireless sensor networks using betweenness centrality. Initially, a square region with fixed side is assumed and the required number of nodes say 'n' are generated randomly. Then a random network is formed on these n nodes. The betweenness centrality measure is calculated for all nodes in the network and the nodes are arranged in descending order of their measures. Accordingly, they are considered for being cluster heads. The routing tree is obtained as a vertex subset degree preserving spanning tree where the vertex subset is the cluster head set.

3.1 Assumptions made:

The following are the assumptions made under this algorithm.

- The area of the network is fixed and n-nodes of the network are randomly placed in that region.
- The distances from the base station to all the nodes in the network are known.
- The distances between the nodes can be calculated.

3.2 ALGORITHM RoutingTree

1. /* Initialize all the parameters*/
2. List X $\leftarrow$ ϕ /* List of eligible nodes*/
3. A $\leftarrow$ ϕ /* List of cluster heads in the final tree*/
4. T $\leftarrow$ ϕ /* Final forest whose components are different clusters*/
5. E_T $\leftarrow$ ϕ /* The edge list of the forest T*/

6. X ← getEligible (w_{bi})
7. for each $v_i \in X$
8. $C_b(v_i) = \frac{\sum_{s \neq v \neq t} \frac{\sigma_{st}(v_i)}{\sigma_{st}}}{(n-1)C_2}$ /* σ_{st} is the number of shortest paths from s to t and $\sigma_{st}(v_i)$ is the number of shortest paths from s to t passing through v */
9. $C_B(v_i) = b[i]$
10. end for
11. X ← sort(X) /* The vertices in X are arranged in non decreasing order of their b[i]*/
12. for each $i \in X$
13. {A, E_T } ← addVertex (i) /* Build the degree preserving trees using eligible nodes*/
14. end for
15. R ← E - E_T /*Remaining edges of the network*/
16. R ←sort(R)
17. for each $i \in R$
18. T ← insert (i)
19. end for /* Inserting remaining edges to form the spanning tree*/
20. return (A, T)

3.3 Functions used in the algorithm:

The following are the functions defined and used for the purpose.

- getEligible(w_{bi})
- sort(X)
- addVertex (i)
- insert (i)

which are defined as follows:

Edge Weight Assignment

Procedure **getEligible (w_{bi}):** returns the eligible nodes to the set X whose distance from the base station is less than or equal to the threshold value t which is calculated using the formula, $t = \frac{1}{n}\sum_{i \in V} w_{bi}$

Shortlisting Eligible nodes

For each node v in X we calculate the weight $C_B(v_i)$, using the formula $C_b(v_i) = \frac{\sum_{s \neq v \neq t} \frac{\sigma_{st}(v_i)}{\sigma_{st}}}{(n-1)C_2}$ where the vertices in X are arranged in non-decreasing order of their weights using the function **sort(X)**.

Formation of Clusters

- 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 plays the role of **cluster heads.**

Building a Routing Tree

- 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 excluding edges 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.

4. Simulation Results

The above algorithm is implemented in NetSim by interfacing with MATLAB and tested for different user input values for the number of nodes. The following are the sample outputs obtained by running our coding. Figure 1(a) depicts the 500 m X 500 m square region in which 20 nodes were deployed randomly. Figure 1(b) is the random network generated on 20 nodes. Figure1(c) is the network in which the nodes are clustered with different cluster heads, and the cluster heads are connected to the base station, so that any node can communicate to the base station through the corresponding cluster head. Two more sets of outputs (Figure 2(a, b, c) and Figure 3(a, b, c)) are given which are obtained in other runs of the program.

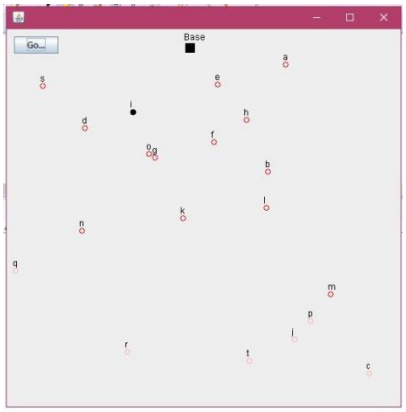

Figure 1(a)

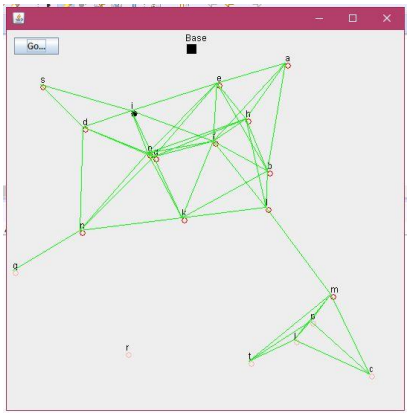

Figure 1(b)

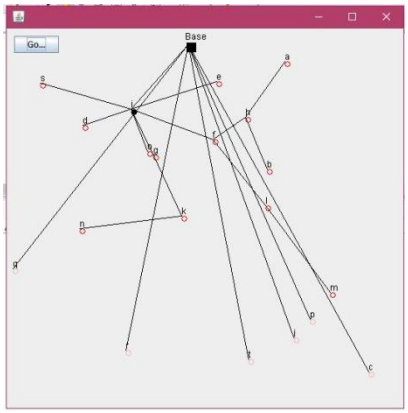

Figure 1(c)

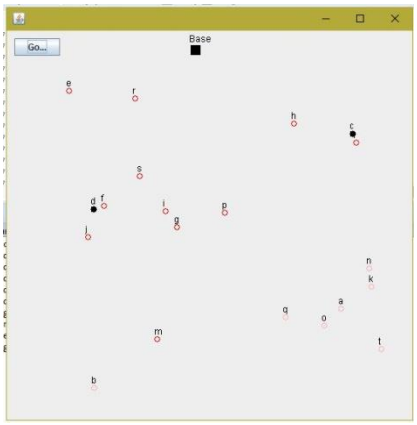

Figure 2(a)

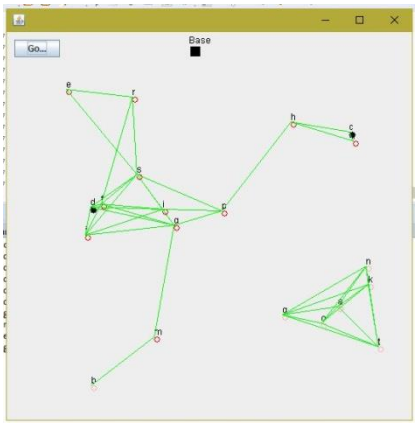

Figure 2(b)

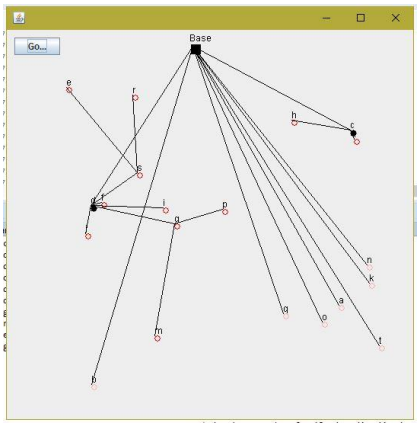

Figure 2(c)

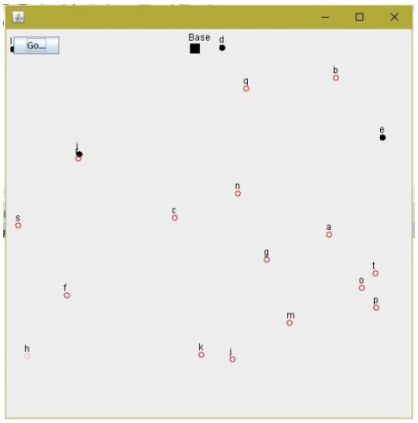

Figure 3(a)

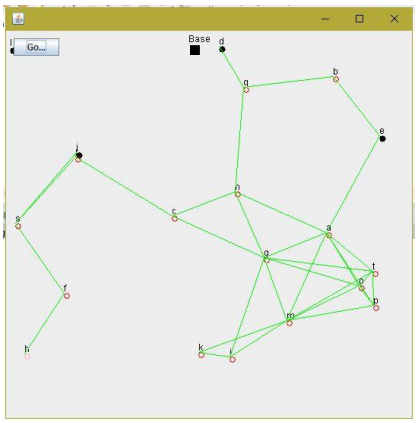

Figure 3(b)

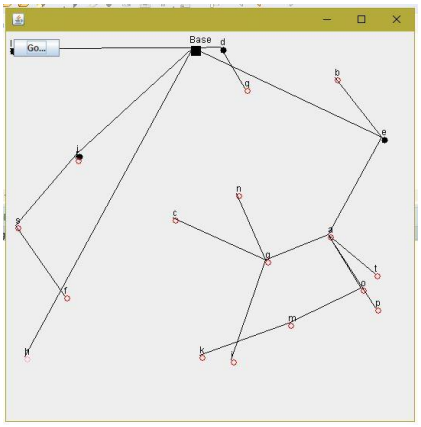

Figure 3(c)

5. Application of the proposed algorithm

The past few years have witnessed increased interest in the prospective use of wireless sensor networks (WSNs) in applications such as disaster management, border protection and security surveillance. Sensors in these applications are expected to be remotely installed in large numbers and to function autonomously in unattended environments. To sustain scalability, nodes are often grouped into disjoint and mostly non-overlapping clusters.

For example, consider the military network depicted in Figure 4. In this network the sensor nodes are deployed randomly in a surveillance area. And the nodes are grouped into four clusters with the cluster heads which are denoted by red circles. In such military network command nodes which are present in the country, send the commands to the cluster heads and in turn head nodes will communicate them to the other nodes belonging to the corresponding cluster. It will collect the information from the sensor nodes, aggregate and communicate it to the base station. Command nodes then receive the necessary information from the base station and act accordingly.

To achieve such communication in a military network , our cluster based routing algorithm for WSN using betweenness centrality could be applied.

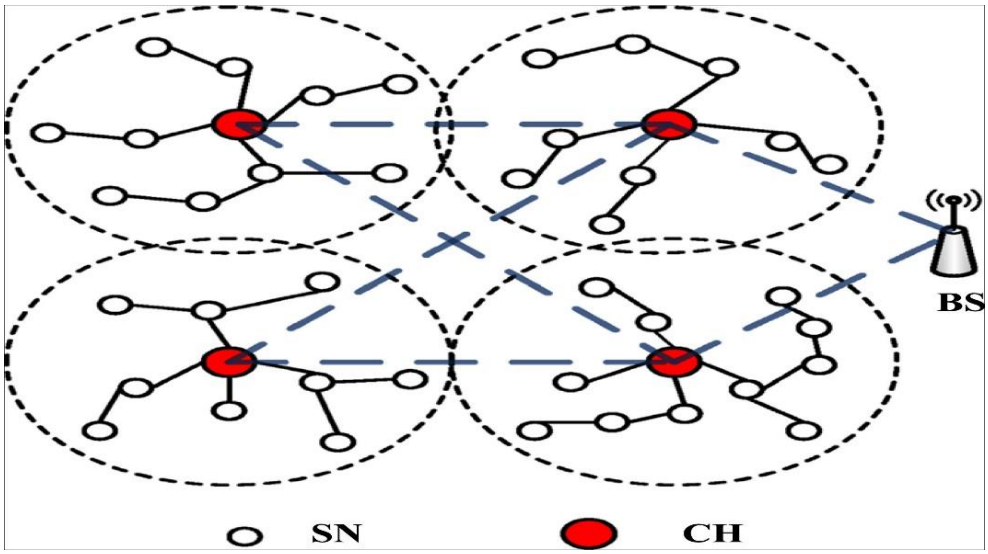

Figure 4

6.Conclusion

In this paper, a new cluster-based routing algorithm for wireless sensor networks is proposed. This work combines two different concepts of graph theory and social network for serving the purpose. In this approach, betweenness centrality measure is calculated for all nodes in the network, and they are arranged in descending order of their betweenness centrality and hence considered for being cluster heads. The routing tree is obtained as a vertex subset degree preserving spanning tree where the vertex subset is the cluster head set. Proposed algorithm is implemented in NetSim by interfacing with MATLAB and tested for different user input values for the number of nodes. This is a distance-based algorithm. In future, it is feasible to incorporate energy too for finding the routing path for further rounds after each transmission in the network. Further, this algorithm could be compared with other existing algorithms of a similar kind by fixing the common parameters.

7. References

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