2012 International Conference on Information and Network Technology (ICINT 2012)
IPCSIT vol. 37 (2012) © (2012) IACSIT Press, Singapore

Relay Node and Cluster Head Placement in Wireless Sensor Networks

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Abstract. Wireless Sensor Networks (WSNs) have enjoyed considerable interest from the research community due to their varied applications and unique challenges. They have found applications in military use for enemy tracking, battlefield surveillance, and target classification as well as other applications including traffic monitoring, cross-border infiltration detection, military reconnaissance, habitat monitoring, etc. Due to the low manufacturing costs of WSN nodes, they can be deployed in large numbers yielding challenges in network management such as routing, topology control, and data management protocols. These challenges are only complicated by severe energy constraints and the inherently unreliable nature of wireless communications which have yielded work in increasing network efficiency and augmenting protocols with varying degrees of fault-tolerance. So our main objective is to increase the tolerance level and decrease the complexity of the wireless sensor network. We have to place the nodes in such a way that the complexity and cost of the network should be minimized. In this way the tolerance level of the network is increased as the relay node placement and number of cluster heads is minimized and life time of the network is increased. In this paper we present two different models for effective relay node and cluster head placement in wireless sensor network.

Keywords: WSNs, relay node, cluster head.

1. Introduction

Wireless sensor network (WSNs) is a most popular research area in world now a daze. WSNs have received significant attention in recent years due to their potential applications in military sensing, wildlife tracking, traffic surveillance, health care, environment monitoring, building structures monitoring, etc. WSNs can be treated as a special family of wireless ad hoc networks. A WSN is a self-organized network that consists of a large number of low-cost and low powered sensor devices, called sensor nodes, which can be deployed on the ground, in the air, in vehicles, on bodies, under water, and inside buildings. One important characteristic of sensor networks is the stringent power budget of wireless sensor nodes [1, 2]. Since the sensor nodes are prone to failure, fault tolerance should be seriously considered in many sensor network applications. Actually, extensive work has been done on fault tolerance and it has been one of the most important topics in WSNs. There are still many technological hurdles to overcome before wireless sensor networks can be widely deployed [6].The individual sensor nodes are resource constrained. They have limited battery resources, processing capabilities, and communication bandwidth [8, 9, and 10]. An energy-efficient and scalable routing protocol plays an essential role to facilitate data dissemination from the source nodes to the sinks.

The reminder of this chapter is as follows, section 2 discusses the related works. Section 3 describes the existing algorithms, section 4 discusses proposed work. Section 5 describes the simulation and results. Finally references are mentioned in section 6.

2. Related Works

Wireless sensor networks are commonly deployed in harsh environment and are susceptible to innumerous faults in several layers of the system. [3, 4].Communications which is proven to be much less energy consuming than the long range The short range communication between the nodes implies localized interaction in the network. There is a need to model the different components of a sensor network. Sensor networks are often abstracted and mapped into a graph, where each vertex of the graph corresponds to a wireless node and there is an edge corresponding to the communication between two nodes. If the communication between the nodes is bidirectional, the mapped graph of the network will be non-directed. However, if the communication between the nodes is asymmetric, then the mapped graph becomes directed. The communication model between the nodes can be either one-to-one, or one to- many. In the one-to many communication models, each message sent out by a node can be heard by all of its neighbors.

Providing a reasonable and practical model for sensors and actuators is a much more complex task. This is due to the great variety of different sensors, both in terms of their functionality and in terms of their underlying technologies. There are a lot of potential applications that are envisioned for sensor networks. For example, they can be used in a battlefield, where they can detect and spy on the enemies or they can support the positive forces. Also, they can be used in intelligent security systems in buildings and security critical applications. [6, 7] They can be used for habitat monitoring applications where they can monitor and study the changes in phenomena for a long time. However, it can be reduced to the same placement problem in two-tiered architecture by setting uniform communication ranges for both sensor nodes and relay nodes. So, we focus on relay node placement problem in two-tiered networks in this section. Generally speaking, the problem can be described as follows. Given a set of sensor nodes that are randomly distributed in a region and their location, some relay nodes are needed to be placed on the region for forwarding data to the sink, such that each sensor node is covered by at least one relay node. The objective is to minimize the number of relay nodes that make the network k-connected (usually 2-connected is desirable).

3. Existing Algorithm

3.1. Algorithm for node placement

Algorithm MRP-1 scheme is utilized for creating the wireless sensor network of relay nodes and sensor nodes where sensor and relay nodes are connected. The solution is based on two fundamental works. First is for a given number of points we have to find out the minimum number disk set with prescribed radius to cover all the points, for finding the solution in polynomial time approximation scheme(PTAS),for any given error €,the ratio of solution is not larger than (1+ €) and € is fixed.[5] The other problem is Steiner tree problem with minimum number of Steiner points,(STP-MSP).Given set of terminals in the Euclidean plane, the problem is to find the Steiner tree such that each edge in the tree has length at most d and number of Steiner points is minimized.MRP-1 is composed in two steps. In step one, for any give error ε, we use min-disk-cover scheme to find a set of relay nodes that cover all sensor nodes. Note that the network of these relay nodes may not be connected if distance between them is larger than d. In order to connect these relay nodes, more relay nodes are needed. In step two, using STP-MSP algorithm and place additional relay nodes to get a Steiner tree. Finally, the Steiner tree and the sensor nodes form the connected network.

3.2. Algorithm for node placement in two tired wireless sensor network

Here algorithm of node placement and MRP-2 scheme is utilized for making the network 2 connected and more relay nodes are adding to the network.MRP-2 requires the network is 2-connected. It means that when one relay node fails, the network is still connected and data packet gathering operation can be carried out. Main idea is to add some backup nodes to the communication circle of each relay node r in R, such that the whole network is 2-connected.First condition is, the backup nodes should cover all nodes in the communication circle of r. The first purpose of this condition is to make any node in the circle can switch to one of the backup nodes when r is out of service [5]. The other purpose is to make at least one of the backup nodes communicate with outside when r is out of service. The first is for collecting messages purpose and the second is for forwarding messages purpose. Second condition is, the backup nodes in the communication circle of r should communicate with each other. This is because that condition 1 only guarantees there exist at least one backup node can communicate with outside, but some other nodes in the circle may not communicate with outside if r is out of service. That is, the purpose of this condition is to make all nodes in the circle can communicate with outside. We call the above two features 2-connected conditions.

4. Proposed work

4.1. Minimal Relay Node placement in Wireless sensor network

Table. 1: Simulation Parameters for relay node placement in Wireless sensor network

Parameters	Values
Network area	5000m*5000m
Number of nodes	100
Communication range of sensor node	600m
Communication range of relay node	1000m
Base station position	500m*1750m

Step-1: Distribute all the sensor nodes in the wireless sensor network randomly and find the Euclidian distance of each node.

Step-2: Using the coverage criteria i.e. minimum disk cover scheme, find the minimum number of disks to cover all the nodes present in the network, which node cover more number of nodes within its communication range, that node is select as the relay node for that wireless sensor network, the relay nodes do the job of the cluster head, that means they forward the collected information from the sensor nodes to the base station.

Step-3: Define the number of relay nodes to place in the network. Then by using descend order sorting we get the id of the relay nodes.

Step-4: To represent the relay nodes as circle to visualize them as different from the sensor nodes, we use the circle function.

Step-5: For checking all the sensor nodes present in the network are covered by the relay nodes, check there is a link between the nodes or not, if there is a link, value is 1 and that sensor node is connected to the respective relay nodes and direct connection with the neighboring sensor nodes, for relay nodes value is set to 0.

Step-6: If any sensor node is not covered by the predefined number of relay nodes, then redefined the number of relay nodes and check that the sensor nodes which are not connected to any relay node, they are connected to any sensor node or not, repeat the process till all the sensor nodes are covered by the currently defined relay nodes and the network is connected.

4.2. Dynamic selections of cluster head using leach protocol

Table. 2: Simulation Parameter for Dynamic Cluster head selection

Parameters	Values
Network area	100m*100m
Number of Nodes	100
Initial Energy	0.5J
Base Station Position	50m*175m
E_{elec}	50nJ/bit
$E_{tx=}E_{rx}$	50nJ/bit
E_{amp}	10pJ/bit
Packet size	2000bit
Rounds	700

Step-1: Distribute all the sensor nodes in the network, energy level sent to the base station and geographically group data

Step-3: Node with highest energy level select as cluster head for the network.

Step-4: Cluster head status is broadcasted and the number of cluster heads is found out. The distance of cluster heads from the base station is found out.

Step-5: Received signal strength indication (RSSI) is checked

Step-6: Join request send by the node to cluster head and acknowledgement message send by the cluster head to sensor node to join as the member of the cluster and RSSI value is calculated. If energy of a node is zero, then the node is dead. The energy spent for choosing new cluster head is calculated. The amount of data is transmitted between the nodes is calculated according to the number of nodes present in the network.

5. Simulation and Results

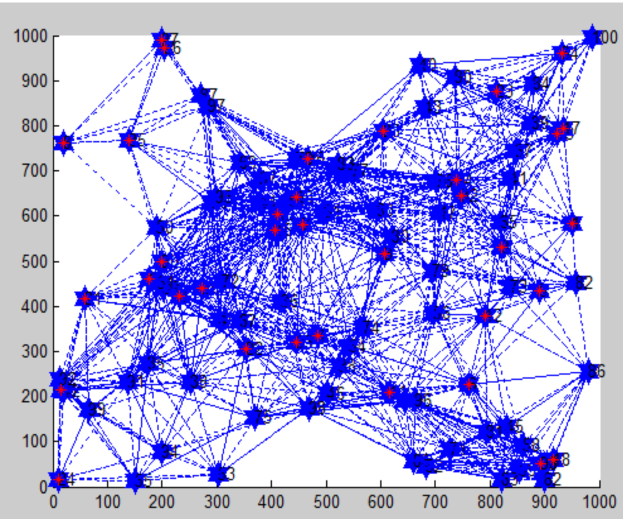

Fig. 1: Single tired Wireless sensor network

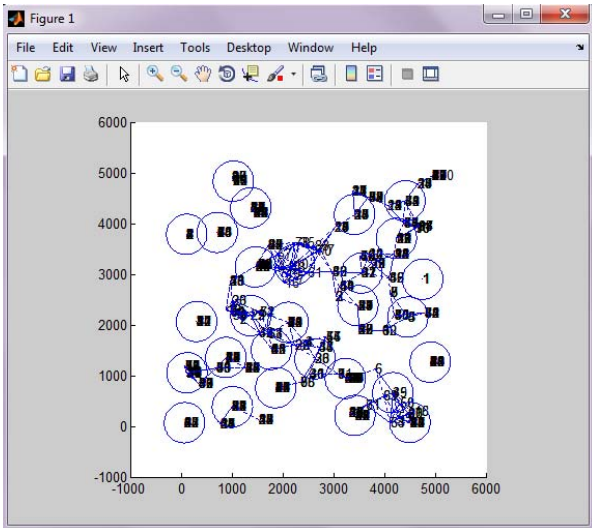

Fig. 2: Relay node placements in Wireless sensor network

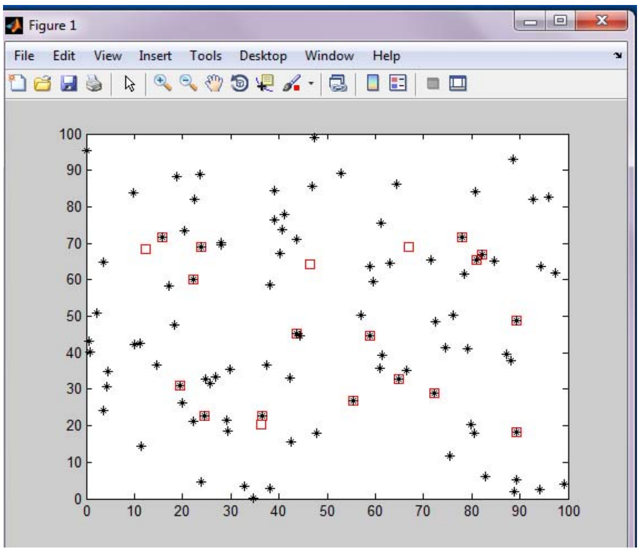

Fig. 3: Dynamic cluster head selection for 100 nodes

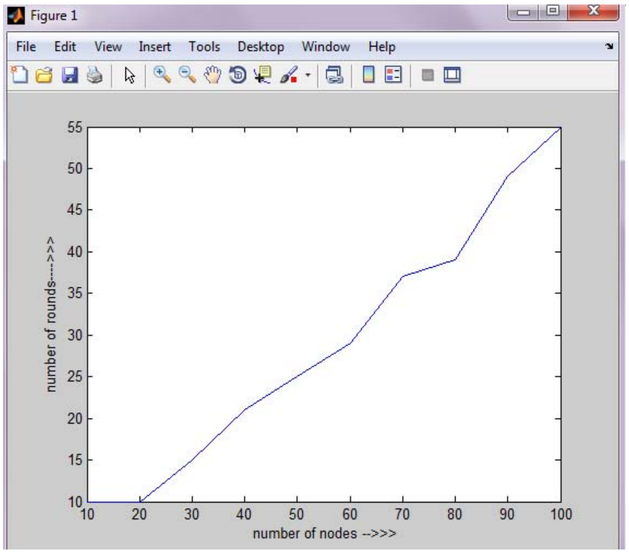

Fig. 4: Simulation time graph for wireless sensor network

Here (Figure 4) we taking number of nodes in the x-axis and simulation time for different number of nodes as number of rounds in the y-axis. In the relay node complexity graph (Figure 5) we take the number of nodes in the x-axis and number of relay nodes required for different number of nodes in the wireless sensor network in the y-axis. We get the values by simulating our static model for different number of nodes.

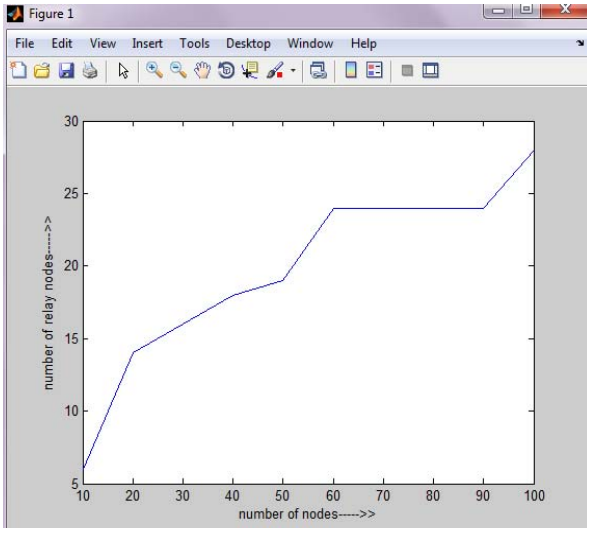

Fig. 5: relay node complexity for WSN (Static)

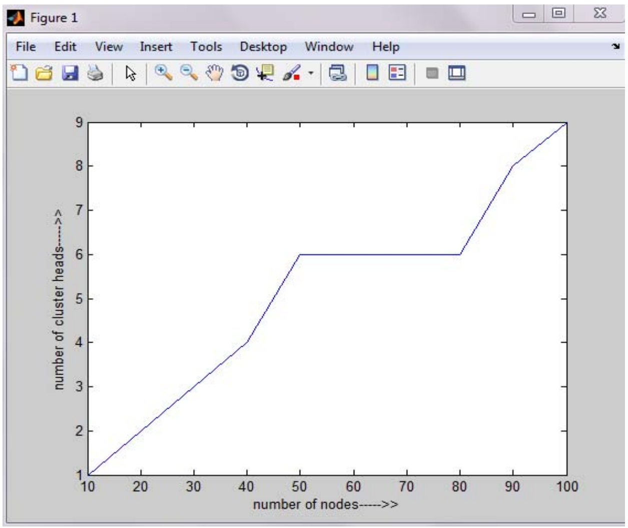

Fig. 6: cluster head complexity for WSN

In cluster head complexity graph (Figure 6) we show the number of cluster heads required for different number of sensor nodes in the wireless sensor network. Then we compare the two models we design, we show this comparison for cluster node requirement for different number of sensor nodes for wireless sensor network in Comparison graph (Figure 7).We show the number of relay node requirements with respect to same and different communication range for sensor nodes and relay nodes in Comparison graph (Figure 8).

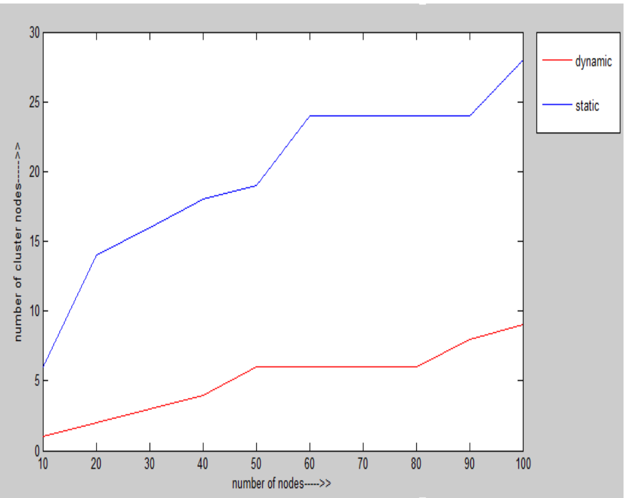

Fig. 7: Comparison of cluster node requirement in WSN (static/dynamic)

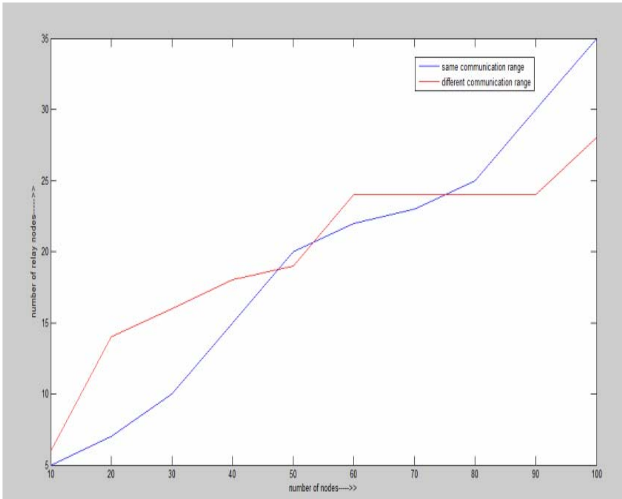

Fig. 8: Comparison of relay node requirement in WSN

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