Efficient Gateway Based Routing in Wireless Sensor Networks

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Abstract: The design and implementation of wireless sensor networks is a rapidly increasing research area, in recent years because of a large number of application years. A number of researchers have worked on improving the routing capability of the network so as to efficiently utilize the power consumption of the network. In this, research work, a gateway based routing technique has been presented. The proposed technique GEER acronym for Gateway based Efficient Routing uses a multi-hop and two-tier approach for packet forwarding from node to the base station. The nodes are divided into various regions depending on their energy and distance from the base station and gateway. The performance of the system is enhanced by cluster location and balancing the network loading among the clusters. The proposed protocol gives better results in terms of network lifetime, residual energy and throughput.

Keywords: Routing, Wireless Sensor Networks, Gateway, residual energy, network lifetime.

I. Introduction

The Efficient design and implementation of wireless sensor networks is a booming area for researchers in the recent years, due to the vast potential of the sensor networks to enable the applications that connect the physical world to the virtual world[1]. Potential applications for such large-scale wireless sensor networks exist in a variety of fields, including military operations medical monitoring, environmental monitoring, surveillance, home security and industrial machine monitoring. By networking large numbers of tiny sensor nodes, it is possible to obtain the data about physical phenomena that was difficult or impossible to obtain in more conventional ways. In the next coming years, as advances in micro-fabrication technology allow the cost of manufacturing sensor nodes to continue to drop, increasing deployments of wireless sensor networks are expected, with the networks eventually growing to large numbers of nodes. Different characteristics of sensor nodes includes the size, battery consumption, the power level, lifetime of the operation, movement characteristics (indicating whether nodes are stationary or mobile), position characteristics (indicating whether the nodes are embedded power Supply).[2]

Designing suitable routing algorithms for different applications, fulfilling the different performance demands has been considered as an important issue in wireless sensor networks. In these context many routing algorithms have been proposed to improve the performance demands of various applications through the network layer of the wireless sensor networks protocol stack [3, 4], but most of them are based on single-path routing. In single-path routing approach basically source selects a single path which satisfies the performance demands of the application for transmitting the load towards the sink. Though the single path between the source and sink can be developed with minimum computation complexity and resource utilization, the other factors such as the limited capacity of single path reduces the available throughput [5].

Secondly, considering the unreliable wireless links single path routing is not flexible to link failures, degrading the network performance. Finding an alternate path after the primary path has disrupted to continue the data transmission will cause an extra overhead and increase delay in data delivery. Due to these factors single path routing cannot be considered effective technique to meet the performance demands of various applications.

To overcome these performance issues and to cope up with the limitations of the single path routing strategy, multi-path routing strategy also known as alternate path routing came into existence. As the name suggests there will be multiple paths established between the source and the destination through which the data can reach the destination [6]. Now how these links are used are totally based on the individual routing strategy. Some routing algorithms use the best path to send the data, keeping the other alternate paths as a backup and use it if the primary path fails, some use all the paths concurrently to send data and so on. In the past few years gateway based routing approach is extensively used for different network management purposes, such as providing a fault tolerant routing, improving transmission reliability, congestion control and Quality of Service(QoS) support in the wired and wireless networks, but the unique features of the wireless sensor networks and the characteristics of the short range radio communications introduce a new challenges that should be addressed in designing the multi-path routing protocols.

II. Literature Review

In the hierarchical architecture, some higher-energy nodes can be used to process and send the information to the base station while lower energy nodes can perform the sensing in the target area. In other words, the network is partitioned into many clusters. In each cluster, a node is selected as a cluster head with some cluster members. A two-tier hierarchy is formed where cluster heads are in the higher tier while cluster members are created a lower tier. Cluster members sense the data from the physical environment and send it to their respective cluster heads. Cluster heads process the data and transmit it to the sink either directly or in the multi-hop manner. Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol has been proposed by Heinzelman et al. [6]. It is the first hierarchical clustering approach in WSN. In the LEACH protocol, the operation consists of many rounds. Each round has two phases; the set-up phase and steady-state phase. In the setup phase, the cluster is formed and in the steady-state phase, data is transmitted to the base station. The cluster head are elected based on the predefined percentage of cluster heads and how many times the node has been a cluster head in previous rounds. LEACH can balance the load among the cluster heads up to some extent.

Younis and Fahmy have proposed a Hybrid Energy Efficient Distributed clustering (HEED) routing protocol [7]. It is a multi-hop clustering algorithm for wireless sensor networks, which focus on efficient clustering by proper selection of cluster heads. The cluster head is selected based on criteria such as residual energy and intra-cluster communication cost. HEED is a fully distributed clustering method and provides uniform CH distribution across the network. The communications are in a multi-hop fashion

between CHs and the base station. However, it generates more CHs than the expected number, which decreases the network lifetime.

Directed Diffusion routing protocol has been proposed by Intanagonwiwat et al.[8]. It is a query based multipath routing protocol, where the sink initializes the routing process. The sink floods the interest into the network. During the interest message flooding all the intermediate nodes store the interest message received from the neighbors for later use and creates a gradient towards the sender node. During this stage, multiple paths can be discovered between each source-sink pair. Then the source transmits the data through the selected path. Further the sink continues to send low-rate interest message over the remaining paths, this is done to preserve the freshness of the interest tables of the intermediate nodes, and also maintain the discovered routes. If the active path fails, the data can be forwarded through the other available paths. Although, it provides fault-tolerant routing, it evolves all the nodes in route discovery. As a result, it affects the network lifetime.

Ye Ming Lu et al. [9] have proposed a distributed, scalable and localized routing algorithm . It discovers multiple node-disjoint paths between the sink and the source nodes. It also uses a load balancing algorithm that distributes the traffic over the multiple paths. When an event is detected, it selects a node from the event area as the source node. The source node then starts the route discovery process. The sink sends multiple route request messages to its neighboring nodes with distinct path id to build node-disjoint paths. After receiving the first route request message from the source node, the sink starts a timer. Any path discovered after the timer stops are discarded. The sink also optimally assigns the data rate for each path.

Wang et al. [10] have proposed an energy-efficient and collision-aware multipath routing protocol. It is a reactive routing protocol. It creates two collision-free paths between the source and the sink using the location information of all the sensor nodes. In this protocol, each node sends a route discovery message with proper power and node position information. It is assumed that all nodes have a transmission range of 0 to R, and all nodes know their neighbor information within that range R. Hence to decrease the chance of interference, all routing paths are built above this range. The broadcasting is used to detect collision, and the nodes that are overhearing from other routes cannot be in any route. However, the cost of the network deployment is more due to the GPS device requirements for each node within the network.

Lin et al.[11] have proposed a hierarchical cluster-based data dissemination protocol. It uses a clustering structure to track the location of the mobile sinks and finds the paths from the source to the sink for data transmission. Each cluster consists of a cluster head, several gateway nodes, and ordinary nodes. The mobile sink registers itself to the nearest cluster head, and a notification is then disseminated to all the cluster heads. In this process, each cluster head makes a reverse link to the sender node for transmitting the data.

III. Proposed Work

The proposed work is based on the geographical knowledge of the network area around it. After employment of nodes, every node forwards its location to the BS. The BS calculates the distance of each node and save all information of the sensor nodes into the node data table. The node data table consists of distinctive node ID, Residual energy of node, and its distance to the BS and gateway node. The same topology is being used in this proposed work.

Setup Phase:

The setup phase is the primitive phase in deploying the network. As, we are simulating the actual network on a virtual software environment, we define the various characteristics which are possible for a network, based on the mathematical and physical modeling of the network. The network field is divided into logical regions on the basis of node's distance from gateway node and BS. The various zones are obtained on the basis of this kind of logical division, which can be described by the following equations:

if	NdtoBS < d0	Sector 1	
if	NdtoGS < d0	Sector 2	
if	NdtoBS >d0 & yn>=yBS	Sector 3	
if	NdtoGS >d0 & yN <= yGS	Sector 4	(1)

Cluster Head Selection Phase:

The nodes in Sector 3 and Sector 4 undergo clustering. The node regions are divided into clusters and data is aggregated and sent to cluster heads (CH's), these cluster heads then forward this data to the base station. The selection of Cluster head is done as described:

The base station transmits a starting message packet to all the nodes. This message and all the nodes respond to it. The sensor nodes are required to forward their location, id and energy information to base station over the network. This is followed by base station sending another packet to inquire about the node as to which logical zone, they currently belong to. This packet valuable message for the nodes as their logical positioning depends on this message packet. Nodes near BS connect themselves with BS, similarly nodes near gateway connect themselves with gateway. Other nodes are divided in two regions and use clustering topology. CHs are elected in each region separately. Let 'r' represent the number of rounds to be a CH for the node Si, we call it epoch. each node elect itself as a CH once every r = 1/p rounds. At the start of first round all node in both regions has equal energy level and has equal chance to become CH. After that CH is selected on the basis of the remaining energy of sensor node and with a probability p alike LEACH, in each round, it is required to have n x p CHs. A node can become CH only once in a epoch and the nodes not elected as CH in the current round feel right to the set C. The probability of a node to (belongs to set C) elect as CH increases in each round. It is required to uphold balanced number of CHs. At the start of each round, a node Si belongs to set C autonomously choose a random number between 0 to 1. If the generated random number for node Si is less than a predefined threshold T(s) value then the node is becomes CH in the current round.

The threshold value can be found as:

$$T(n) = \begin{cases} \frac{p}{(1-p\left(r-\mathrm{mod}\left(\frac{1}{p}\right)\right))} & ,if \ \ n \ \varepsilon \ G \\ 0 & ,otherwise \end{cases} \quad (2)$$

where P = the desired percentage of CHs and r = the current round, C = set of nodes not elected as CH in current round. After electing CHs in each region, CHs inform their role to neighbor nodes. CHs broadcast a control packet using a CSMA MAC protocol. Upon received control packet from CH each node transmit acknowledge packet. Nodes finds near CH, becomes member of that CH.

Scheduling

Scheduling is an important concept in clustering. When some nodes are elected as cluster heads and other nodes become member of their corresponding cluster head, member node starts communication with cluster heads. So, it can become fairly impossible for the cluster heads to respond to each and every node in the cluster. Thus a time division is assigned by the cluster heads to all the nodes. All the associated nodes transfer data to cluster heads in its own scheduled time slot. While a particular node is transmitting, all other nodes stay idle. Nodes thus can know their own transmission schedule and need to be turned on only at times its transmission time. This method thus saves lot of energy for the individual nodes and for the network as a whole.

Steady-State Phase:

The steady state phase refers to the actual operational phase of the network. The nodes in sector 1 transmit their data directly to the base station, the nodes in sector 2 send their data to the gateway node which aggregates it and forwards it to the base station. Nodes in sector 3 and sector 4, transmit their data to their respective cluster heads, during their respective schedule. The cluster heads aggregate this data and send to the gateway node which then finally forward it to the base station. This process keeps continued for the complete lifetime of the network

IV. Simulation Results and Analysis

The proposed work was implemented using the MATLAB R2010a software tool, using standard network parameters, as shown in Table 1.

Table I: Network parameters

Parameters	Values
Network Area	200m
Threshold distance, d0	sqrt(E_{fs}/E_{mp})
Energy consumed in the electronics circuit to transmt in or receive the signal, E_{elec}	50 nJ/bit
Energy consumed by the amplifier to transmit at a short distance, E_{fs}	10 pJ/bit/m_2
Energy consumed by the amplifier to transmit at a longer distance, Emp	0.0013 pJ/bit/m_4
Data Aggregation Energy, EDA	5 nJ/bit/signal
Message Size	4000 bits
Initial Energy, E0	0.5 J

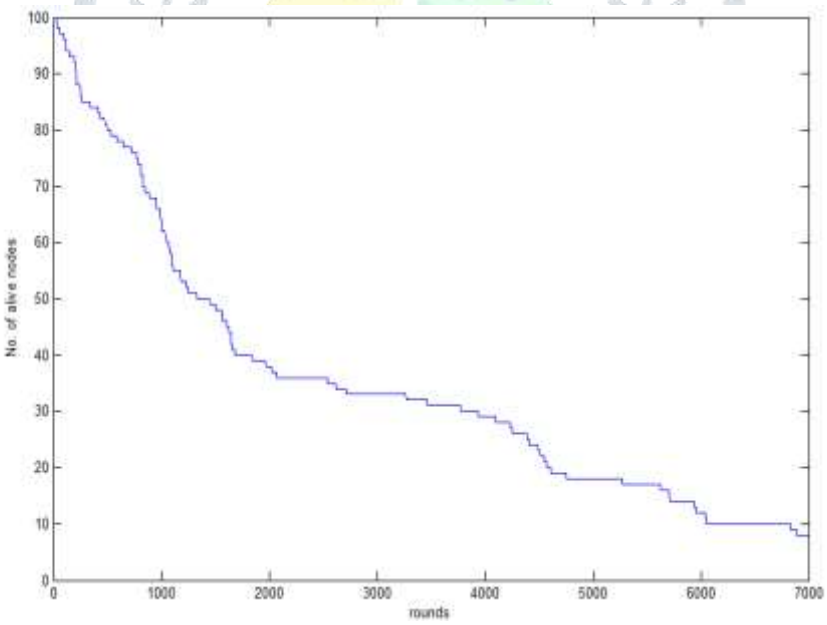

Figure 1: Number of Alive nodes

The above figure shows the various simulation results for 7000 rounds. As shown from the figure 1 and figure 2 the method shows a considerable improvement in the network lifetime.

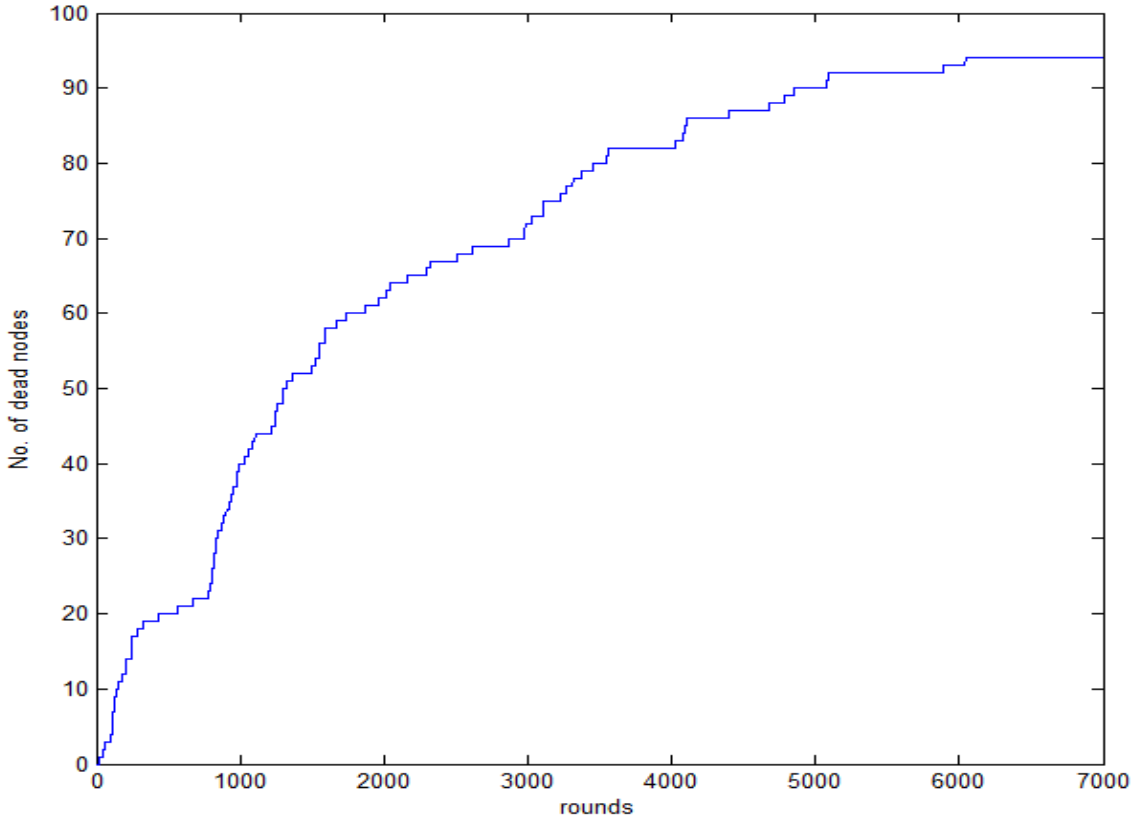

Figure 2: Number of Dead nodes

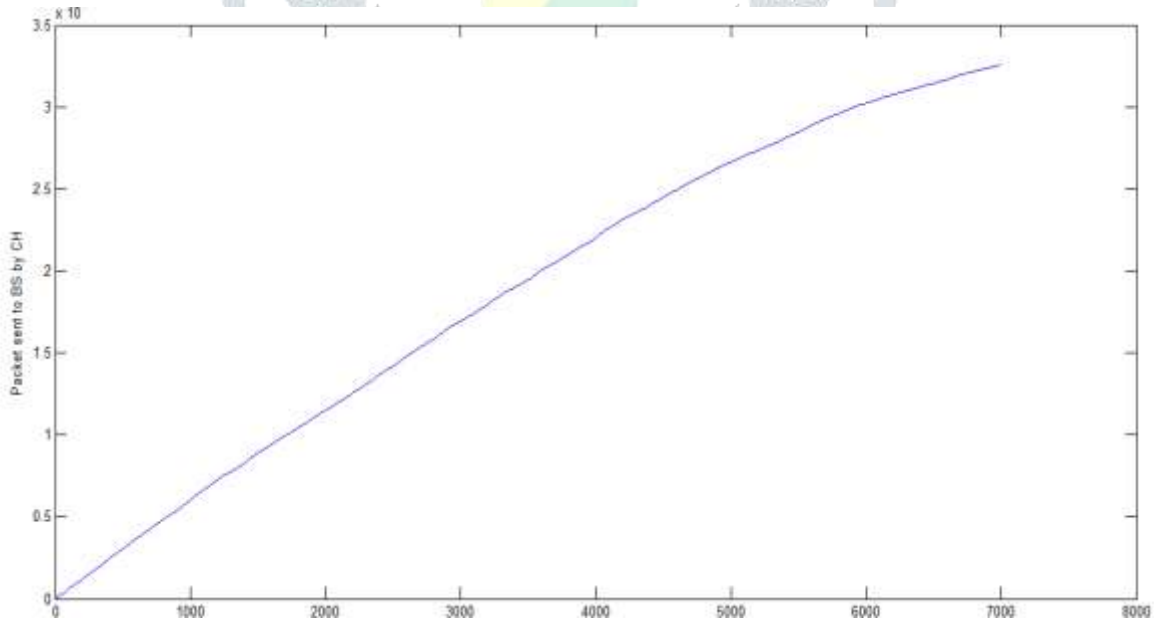

Figure 3: Throughput

In order to investigate the performance of the network, the throughput or the number of packets transferred by cluster head per round to the base station is the parameter which has been used. The graph shown in figure 3 shows the throughput value with rounds.

V. Conclusion

A novel approach for multi hop routing has been proposed where the network area is divided into several different logical areas or sectors. Different routing mechanisms are used by different nodes depending on the type of sector they belong to. The proposed protocol gives good result with increasing round number in terms of number of alive nodes with around 10% nodes still functional even after 7000 rounds.

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