Gateway based Design of Network Model for WSN

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Abstract: In this research work, we advise gateway based energy efficient routing protocol for Wireless Sensor Networks (WSNs). We introduced number of gateway nodes which are rechargeable and place them at the edge of sensing field and base station is located out of the sensing field. Gateway Nodes are introduced to reduce traffic and to reduce distance for reliable data communication. We analyse our proposed network model design is better in terms of energy consumption and network lifetime as compared to other models.

Keywords: Wireless Sensor Network, SEP, clustering, gateway, lifetime.

Introduction

Wireless sensor networks (WSNs) are designed to sense and transmit data information from interested areas to end-users. Its potential applications mainly include military tracking and surveillance, hazardous environment exploration, and health monitoring. The main concern in WSN [11] technology is to enhance the network lifetime and to reduce the energy consumption of the sensor network because replacement of the embedded batteries is a very [8] difficult process. Classical approaches like Direct Transmission and Minimum Transmission Energy do not guarantee well data transmission among nodes of the sensor network. In Direct Transmission (DT), sensor nodes transmit directly to the sink, as a result nodes that are far away from the sink would die first [6]. On the other hand, Minimum Transmission Energy (MTE), data is routed over minimum cost routes, where cost reflects the transmission power expended. Under MTE, nodes that are near to sink act as relays with higher probability than nodes that are far from the sink. Under DT and MTE, a part of the field will not be monitored for an important part of the lifetime of the network, and as a result the sensing process of the field will be biased.
Most of the time, study on Wireless Sensor Networks has assumed homogeneous nodes [6]. But in reality, homogeneous nodes have different levels of initial energy and depletion rate. This leads to the research on heterogeneous networks where two or more types of nodes are considered and the more powerful sensor nodes act as cluster heads.

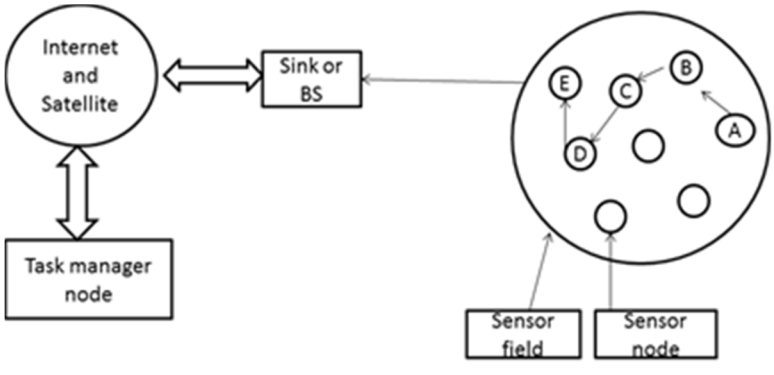

Fig 1: A typical Wireless Sensor Network

In recent years, researchers have done numbers of study on clustering protocols. [9] Clustering has characteristics such as scalable, energy-efficient, low latency, increased lifetime which make it a very popular technique for WSNs. Its essential operation is to select a set of CHs from the set of nodes in the network, and then cluster the remaining nodes with these heads [10]. The data gathered are transmitted through cluster heads to base station or sink node. Consequently, transmission energy of sensors reduces to significant amount. In our research work, we design a gateway based energy-aware multi-hop routing protocol.

The impulse behind this research work is to trim the energy consumption of the sensor nodes by introducing gateway nodes which are rechargeable. These nodes are located at the edge of the sensing area and the base station is located out of the sensing area. Now, Nodes will send data to selected Cluster Head then CH gathered data and transfer that data to the nearest placed gateway by calculating minimum distance, and finally data reaches base station. The main advantage of this research is to increase lifetime of the sensor network.

Experimental Work

In [1] Low Energy Adaptive Clustering Hierarchy (LEACH) is the first dynamic clustering protocol which addressed specifically the WSNs needs, using homogeneous stationary sensor nodes which are randomly deployed. LEACH reduces communication energy by using single-hop routing compared with direct transmission and minimum-transmission energy routing where each node can transmit directly to the cluster-head and the sink. But, it is not recommended for networks that are deployed in large regions.

In [2] M (Multihop) – LEACH Protocol: This protocol selects optimal path between the CH and the BS through other CHs and use these CHs as a relay station to transmit data over through them. First, multi-hop communication is adopted among CHs. Then, according to the selected optimal path, these CHs transmit data to the corresponding CH which is nearest to BS. Finally, this CH sends data to BS. It shows an improvement over LEACH.

In PEGASIS [3] nodes form a chain to transfer data from source to sink. In chain formation process each node connects with next node. The chain formation process require global knowledge of sensor nodes, hence, it is very difficult to implement this topology.

In [5] Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN): It is hybrid combination of LEACH and TEEN. It is a hybrid clustering-based routing protocol that allows the sensor to send their sensed data periodically and react to any sudden change in the value of the sensed attribute. When the base station forms the clusters, the CHs broadcast the attributes, the hard and soft threshold values, and TDMA transmission schedule to all nodes, and a maximum time interval between two successive reports sent to a sensor, called count time (TC). CHs also perform data aggregation in order to save energy.

In [6] Energy Efficient Heterogeneous Clustering Protocol (EEHC): The main objective of this algorithm was to address the shortcomings of one-hop random selection algorithms such as LEACH by extending the cluster architecture to multiple hops. It is based on weighted election probabilities of each node to become cluster head. The election probabilities of cluster heads are weighted by the initial energy of a node relative to that of other nodes in the network.

In [7] Hybrid Energy-Efficient Distributed Clustering (HEED) every node can act as both a source and a server (cluster head), which motivates the need for efficient energy consumption. It is possible that the nodes with minimum residual energy acquire larger probability to become CH.

In [8] SEP uses the impact of energy heterogeneity of nodes in WSNs that are hierarchically clustered. There are two types of nodes with different energy levels, called normal nodes and advanced nodes Nodes are not mobile and are uniformly distributed over the sensing area. Performance of SEP in multi level Heterogeneous networks is not good.

In [10] propose a Mobile sink based improved Stable Election (MSE) algorithm with non uniform node distribution. They define mobile sink's trajectory as the centre line of the sensing field. Sink node can move back and forth along the fixed trajectory which is predictable. Each cluster head collects data and sends it to the mobile sink. This research does not perform well because an external source is needed to move base station and therefore data can be dropped.

In [11] design a gateway based energy-aware multi-hop routing protocol. A single Gateway node is located at the center of sensing area and base station is out of the sensing area. In this research, energy consumption of sensor nodes is reduced by logically dividing the network into four regions. Nodes in one region communicate directly to BS while nodes in region 2 communicate directly to gateway node. Nodes in other two regions use clustering hierarchy and sensor nodes transmit their data to gateway node through their CHs. Gateway node assists in defining clusters and issue a TDMA schedule for CHs.

System Model

Basic Assumptions

- We deploy the BS far away from the sensing field. Sensor nodes and the BS are stationary after deployment.
- A gateway node is deployed in the same network field at the edge of the network.
- Gateway nodes are stationary after deployment and rechargeable.
- Each sensor node is assigned with a distinctive identifier (ID).
- The links in the network are symmetric.

First Order Radio Model

Here, a simple model where the radio dissipates E_{elec} = 50 nJ/bit to run the transmitter or receiver circuitry and ε_{mp} = 100 pJ/bit/m^2 for the transmitter amplifier to achieve an acceptable E_b/ N_o. These parameters are slightly better than the current state-of-the-art in radio design.

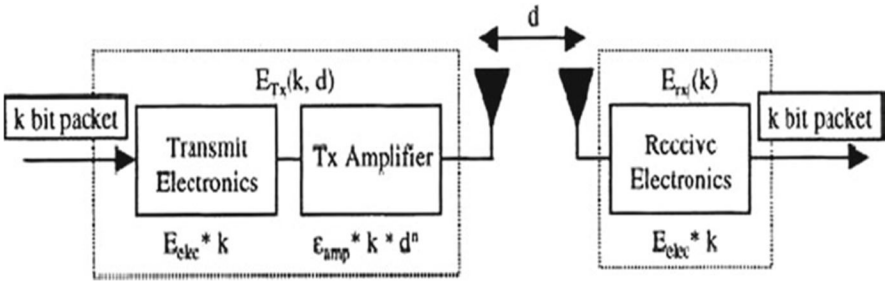

Fig 2: Radio Energy Dissipation Model

The optimal probability of a node being elected as a cluster head as a function of spatial density when nodes are uniformly distributed over the sensor field whose area is defined to be 100*100m. This clustering is optimal in the sense that energy consumption is well distributed over all sensors and the total energy consumption is minimum in order to increase lifetime of the network. Such optimal clustering highly depends on the energy model [6]

According to the radio energy dissipation model as illustrated in Figure2, in order to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting an L−bit message over a distance d, the energy expended by the radio is given by:

$$E_{Tx}(l, d) = L.\ E_{elec} + L.\varepsilon_{fs}.\ d^2 \quad \text{if } d < d_0$$
$$L.\ E_{elec} + L.\varepsilon_{mp}.\ d^4 \quad \text{if } d \geq d_0$$

Where, E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, ε_{fs} and ε_{mp} depends on the transmitter amplifier model, and d is the distance between the sender and the receiver.

$$\text{At } d=d_0,\ do = (\varepsilon_{fs} / \varepsilon_{mp})^{1/2}$$

Table 1: Radio Characteristics

Operation	Energy Dissipated
Transmitter Electronics (E_{Tx-} E_{elec}) Receiver Electronics (E_{Rx-} E_{elec}) E_{Tx-} E_{elec} = E_{Rx-} E_{elec} = E_{elec}	50 nJ/bit
Transmit Amplifier	100 pJ/bit/m^2

For these radio parameters, receiving a message is not a low cost operation. The protocols should try to minimize not only the transmit distances but also the number of transmit and receive operations for each iteration. The radio channel is symmetric so that the energy required for transmitting data from node A to node B is the same as the energy required transmitting data from node B to node A for a given SNR.

Design of Network Model

In this article, we assume S1 sensors which are deployed randomly in a field to monitor environment. We represent the i-th sensor by $S1_i$ and consequent sensor node set S1= $S1_1$, $S1_2$ ….. $S1_n$.

We design our gateway based network model using MATLAB. Consider a wireless sensor network with 100 nodes distributed randomly in 100m * 100m field.

The sensor nodes are categorized into two types on the basis of their energy level: Normal Nodes, Advanced Nodes. The advanced nodes have more energy factor than the normal nodes.

E_0 is the initial energy of each normal sensor node. The energy of each advanced node is $E_0 (1+\alpha)$.

$$P_{nrm} = P_{opt} / (1 + m\alpha)$$
$$P_{adv} = P_{opt} (1+\alpha) / (1 + m\alpha)$$

Where, P_{nrm} is the weighted probability for the normal nodes,

P_{adv} is the weighted probability for the advanced nodes, and

$1/P_{opt}$ is epoch= number of rounds.

Number of gateway nodes is deployed at the edge of the sensing field. The number of gateway node is chosen approximately according to sensor field area. The advantage of gateway nodes is they are rechargeable. Another advantage is in case if one of gateway node is damaged then it can be overcome by another gateway node. Gateway nodes also reduce traffic problems having multiple numbers of gateway nodes. The sink or base station is located far away from the sensing field.

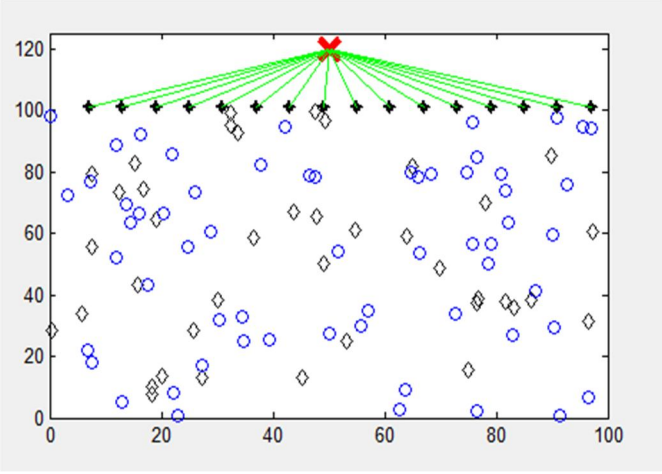

Fig 3: Network Model

◊ Advanced nodes
○ Normal nodes
× Base Station
* Gateway nodes

Conclusion and Future Scope

We design a gateway based network model in order to minimize energy consumption of sensor network. In this work, we categorized sensor nodes into normal nodes and advanced nodes. A number of gateway nodes are located at the edge of sensing field area. The base station is located away from the sensing field. This technique encourages better transmission of data which further increases lifetime of the network. The main advantage of using gateway nodes is that it reduces distance for transmitting data to base station. This network model can be implemented on heterogeneous protocols in WSNs and performance of different parameters can be analyzed.

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