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A Novel Hierarchical Clustering Algorithm for Sensor Networks

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Abstract: ***Energy efficient routing protocol is very necessary in wireless sensor network due to the existence of resource constrained sensors. Clustering is an efficient approach for these problems in large sale networks. Hence, in this paper an energy efficient clustering algorithm is designed for sensor networks by considering the residual energy, cluster size and distance between the cluster head and a sink. NS2 simulator is used to evaluate the performance of the proposed algorithm. Simulation results reveal that the proposed algorithm outperforms the existing leach, leach-m algorithms for sensor networks.***

Keywords: LEACH, LEACH-C, NHCA, Energy, Cluster.

1. Introduction

In twenty first century, Wireless Sensor Networks (WSNs) have been widely used in various real time applications such as environmental monitoring, battle field surveillance, home applications and industry process control [7,8]. This type of networks are enabled by recent advances in Micro Electronic Mechanical Systems (MEMS) and wireless communication technologies, tiny, cheap, and smart sensors deployed in a physical area. WSN consists of battery, process and memory constrained sensors and one or more sinks. Sensor nodes are used to sense the environment such as temperature, humidity, light, dust etc . The sensing information will be forward to sink node in a multi-hop fashion. Fig 1 describes the general architecture for sensor network, where the information from sensors forward to the user via sink. Due to the unique characteristics such as dense node deployment, battery - powered, severe energy, computation, and storage constraints, self - configurable, application specific, unreliable sensor nodes, frequent topology change, and no global identification of the existing ad hoc and wireless networks routing protocols does not suit for WSN networks [9, 10, 11].

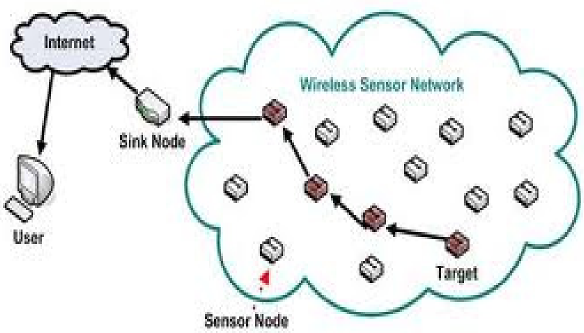

Figure 1: Sensor Network Architecture

A WSN is usually randomly deployed in inaccessible terrains, disaster areas, or polluted environments, where battery replacement or recharge is difficult or even impossible to be performed. For this reason, network lifetime is of crucial importance to a WSN. To prolong network lifetime, there is a need for efficient power control mechanisms to reduce power consumption in sensor nodes and energy - efficient techniques should be employed at all layers of the network [5,6], which should take into account the following unique characteristics and application requirements of WSNs.

Clustering mechanisms have been applied to sensor networks with hierarchical structures to enhance the network performance while reducing the necessary energy consumption [5]. Clustering is a cross - cutting technique that can be used in nearly all layers of the protocol stack. The primary idea is to group node surround a cluster head that is responsible for state maintenance and inter cluster connectivity. In clusters without any cluster head, a proactive strategy is used for intracluster routing while a reactive strategy is used for inter cluster routing. However, as the network size grows, there will be heavy traffic overhead within the network [6]. Therefore, normally one node is selected as the cluster head of a cluster; and it acts as the local coordinator of transmissions within its cluster. A hierarchical routing or network management protocol can be more efficiently implemented with cluster heads. Hence in this paper, an energy efficient clustering algorithm is designed for sensor networks by considering the residual energy, cluster size and distance between the cluster head and a sink.

The rest of the paper is organized as follows. Section 2 describes existing clustering algorithms for sensor networks. Section 3 discusses about proposed clustering algorithm. Section 4 presents experimental setup and analysis. Finally Section 5 concludes the paper.

2. Related Work

In this section, various existing clustering and routing protocols are discussed. Heinzelman [1] has proposed a Low Energy Adaptive Clustering hierarchy protocol (LEACH). It was actually designed for reducing the amount of redundant data from flowing in the network, thereby saving energy. This protocol has the following characteristics: random selection of cluster heads from amongst the randomly selfconfigured clusters, localized control and co-ordination amongst the clusters, reduction of the communication overload by compressing the data locally. The main disadvantages of the leach protocol is , the clusters are randomly selected which may give rise to uneven distribution of energy throughout the network, while selecting the cluster head, neither its residual energy nor its distance from the other nodes or base station is considered. It assumes homogenous nodes and uniform energy consumption of the CHs, this algorithm uses single-hop transmission to communicate with the base station, so LEACH can't be used for a large scale network and finally it assumes that the sensor nodes always have some data to send.

Wendi B. Heinzelman [2] has proposed modified LEACH called as LEACH-C. The formation clusters at the beginning of each round, but the nodes randomly self-selecting a CH, a centralized algorithm is run by the sink in LEACH C. The sink first collects the information about the location of all the nodes and then broadcasts its decision about which nodes are to become the CH back to the nodes. However, LEACH-C is depended on the sink location. However once, LEACH-C fails to provide good performance when the energy cost of communicating with the sink becomes higher than the energy cost for cluster formation. In most WSN applications sinks may be located far away from the network. So, the dependency on the sink location is a major disadvantage of LEACH-C. Richard has proposed a method in which the number of clusters will be fixed throughout the network lifetime and the cluster heads rotated within its corresponding clusters. Steady state phase of LEACH-F is identical to that of LEACH. LEACH-F may or may not be provided energy saving and this protocol does not provide the flexibility to sensor nodes mobility or sensor nodes being removed or added from the sensor networks.

Hybrid Energy-Efficient Distributed clustering (HEED) [3] is a distributed clustering scheme in which cluster heads are selected periodically based on the residual energy and intracluster communication cost. In HEED clustering is triggered in every $T_{CP} + T_{NO}$ seconds to select new cluster heads where T_{CP} is time required to create a cluster and T_{NO} is the time interval between the end of a T_{CP} and start of a subsequent T_{CP}. In each iteration before the start of execution each node sets its probability of becoming a cluster head based on its residual energy. The main drawback of the algorithm is decrease of residual energy forces to iterate the algorithm.

Energy Efficient Heterogeneous Clustered Scheme (EEHC) De Freitas [4] has proposed EEHC scheme it also selects the cluster head based on the residual energy. In this algorithm, three types of nodes such as super, advanced and normal nodes. Advanced and super nodes are more powerful, higher battery power than the normal nodes. It elects the cluster head in distributed fashion in hierarchical WSN. The main drawbacks of this algorithm are calculation of weight and finding the spatial density is difficult.

Due to the disadvantages of the existing algorithms, there is a lot of scope to design a new energy efficient algorithm for wireless sensor networks.

3. Proposed Work

In this section, an energy efficient Novel Hierarchical Clustering Algorithm (NHCA) is designed for sensor networks by considering the residual energy, cluster size and distance between the cluster head and a sink.

3.1. System model and assumptions

We assume that a set of mobile static sensors are deployed randomly in the event area to detect and track some events. Sensors are assumed to transmit data either in event based or periodically and the sensors are aware of their locations through GPS or various localization techniques. All the sensors are homogenous and need to transmit the information to its 1-hop neighbors.

3.2. Radio Model

In the proposed work, a simple radio model is assumed, it dissipates E_{elec}= 50nJ/bit to run the transmi9tter or receiver circuitry and E_{amp}= 100 pJ/bit/m^{2}for the amplifier. The radio model is described in figure 2. The energy loss due to channel transmission for m-bit message a distance d is

$$E_{TX}(m,d)= E_{elec}*m+E_{amp}*m*d^2 \quad (1)$$

and to receive the message

$$E_{RX}(m) = E_{elec} *m \quad (2)$$

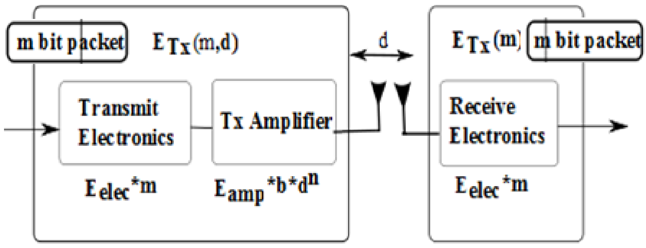

Figure 2: Radio model

3.3 Clustering algorithm

The proposed algorithm is a self-organizing, weight based clustering protocol. It consists of two phases: Setup phase and Steady state phase. In the Setup phase, sensors organize themselves into clusters, where one sensor acts as a cluster head. The cluster head is selected based on the residual energy, the average distance to the sink. To calculate the average residual energy of each sensor in the network.

$$F_e = \sum_{j \in N_i} \frac{E_{j\ current}}{|N_i|.E_{i\ current}} \quad (3)$$

where, N_i is the set of neighbors, which are in radio range of node i , $E_{j\ current}$, $E_{i\ current}$ is the residual energy of the node j and i respectively. The average distance of the node i to its 1-hop neighbors are calculated as

$$F_d = \sum_{j \in N_i} \frac{d_{i,j}^2}{|N_i|} \quad (4)$$

where $d^2_{i,j}$is the distance between node i to j.

To calculate the threshold value

$$T_{thr} = \alpha_1 F_e + \alpha_2 F_d \quad (5)$$

Where, α_1 and α_2 are the weights of the factors and $\alpha_1<\alpha_2$ ($\alpha_1+\alpha_{2=1}$). i.e. in our proposed algorithm more importance given to average residual energy of a node than the distance. For each round of cluster formation, sensors forward their probability of becoming a cluster head based on its threshold value. Each sensor that has elected as a cluster head for the current round broadcasts an advertisement message to the rest of the sensors. To send the message, the cluster heads use a CSMA MAC protocol, and with same energy. Each non cluster sensor decides to join the cluster based on the received signal strength of the advertisement. The non-cluster sensors join the cluster by forwarding *Join* message to the corresponding cluster using CSMA MAC protocol. Based on the number of nodes in the cluster, the cluster head creates a TDMA scheduling and forward to its cluster members. The cluster members forward their sensing data to the head in its corresponding time schedule.

3.4. Cluster size

The size of the cluster is also very parameter in sensor networks. If the cluster size is more, then High energy loss and collisions are more, while forwarding the data. If the size of the cluster is less, due to high number of clusters they loss of energy is more. Calculation of optimal cluster size is very important to increase the life time of the network. The optimal number of clusters is calculated based on number of sensors, network area and distance between cluster head and sink. The calculation of optimal number of clusters is described below.

$$K = \sqrt{\frac{N}{2\pi}} \frac{D\sqrt{\varepsilon_{fs}}}{\sqrt{E_{elec}(N+1)+\varepsilon_{mp} l^4}} \quad (6)$$

Where N is number of sensors, *D* is the length of the side of network area., *l* is the distance from cluster head to sink node, E_{fs}, E_{mp}, E_{elec} are the amplifier energy of the free space, multi path models and electronics energy respectively.

3.5 Round Time

In the existing algorithms the cluster formation restarts for every predefined time, which reduces the life time of the network. To overcome this problem, in our proposed algorithm the round time $T_{current}$ is defined at the beginning of the round $R_{current}$. It depends on the optimal cluster size, rather than using a constant round time T for every round. The current round time $T_{current}$ is defined as

$$T_{current}=NF_{avg} .(M_{min}*\sigma + \lambda) \quad (7)$$

where, NF_{avg} is the average number of frames for a cluster with size 1/k. ($M_{min}*\sigma+\lambda$) is the frame time of a cluster which has the minimum size (the minimum number of nodes M_{min}).After defining the round time $T_{current}$ for the current round, the sink sends the cluster information and the modified $T_{current}$ to all nodes in the network.

4. Experimental setup and analysis

To evaluate the performance of the proposed algorithm. The proposed algorithm is simulated in NS2 using various parameters described in Table 1 and compared with existing algorithms. Ns2 is a discrete event simulator to implement algorithms for wired, wireless and ad hoc networks. We simulated the proposed algorithm for 200 sec; with 100-1000 sensors each contains 2J initial energy.

Table 1: Simulation parameters

Parameter	*value*
Network area	500*500 m^2
Simulation duration	200 sec
MAC layer	802.15.4
Traffic flow	CBR
Antenna model	Omni directional
Number of sensors	100 – 1000
Packet size	500 b
Transmission range	100 m

Energy dissipation: The energy dissipation is defined as how much energy is lost while forwarding the data, control packets to its 1-hop neighbors, overhearing of others data and collisions. Fig 3 describes how the energy is related to the diameter of the networks and compared the proposed novel hierarchical clustering algorithm with leach and leach-c algorithm. The proposed algorithm is performing well when compared to the existing algorithms.

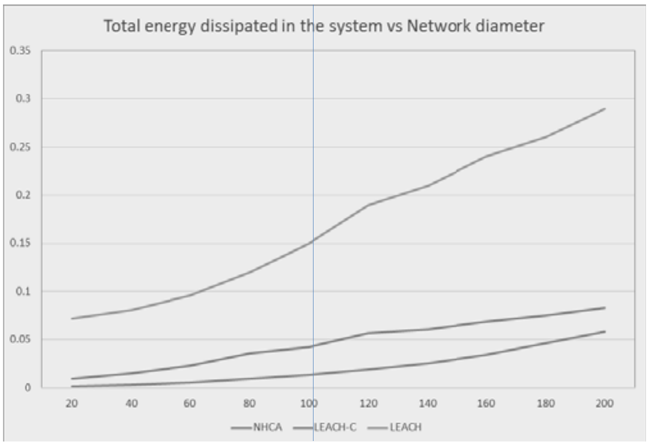

Figure 3: Total energy dissipated in the system in joules

Network lifetime: Due to the existence of battery constrained sensors, designing an energy efficient algorithm in sensors networks is very important. Hence, aim of the proposed algorithm to improve the network lifetime by reducing the energy usage in the network. Fig 4 presents the proposed algorithm performs well than existing algorithms in for 1000 sensors simulated during 200 sec.

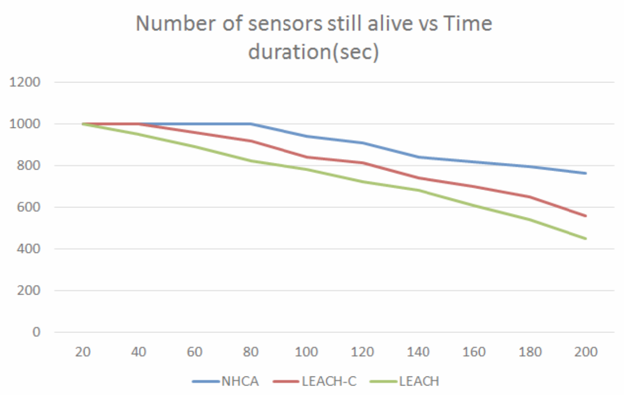

Figure 4: System lifetime with 2J/node

5. Conclusions

Clustering is an efficient method to design an energy efficient routing protocol for wireless sensor networks. In this proposed an energy efficient clustering algorithm is designed for sensor networks by considering the residual energy, cluster size and distance between the cluster head and a sink. NS2 simulator is used to evaluate the performance of the proposed algorithm. The proposed algorithm performs well then existing Simulation results reveal that the proposed algorithm outperforms the existing leach, leach-c algorithms in energy parameters and increased the lifetime of the network.

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