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Maximize Network Lifetime Through Cluster Formation In Wireless Sensor Networks

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Abstract

In designing Wireless Sensor Networks, energy is the most important consideration because of lifetime of the sensor node's limited by the battery of it. To overcome this many research have been done, In which Clustering is the one of the representative approaches. In clustering, the cluster heads gather data from nodes, aggregate it and send the information to base station. In this way, the sensor node can reduce communication overheads that may be generated by each sensor node that reports sensed data to the base station independently. In this paper we taken LEACH which is one of the most famous clustering mechanisms. It elects a cluster head based on probability model.. We verify our proposed method by simulations that the analytical optimal cluster number can still effectively function, regardless of the different densities of sensors in various OA's. .

Key words: Low-Energy Adaptive Clustering Hierarchy (LEACH), Observation area (OA)

1. Introduction

A wireless sensor network typically consists of a potentially large number of resource constrained sensor nodes [1]. Each sensor node is usually battery powered, low-end processor, a limited amount of memory, and a low power communication module capable of short-range wireless communication. Wireless sensor networks are ideal candidates for a wide range of applications, such as target tracking and monitoring of critical infrastructures.

In large sensor networks, the sensor nodes can be grouped into small *c*lusters by their physical proximity to achieve better efficiency. Cluster based sensor networks have many advantages. For example, with clustering, energy consumption can be improved, because only one representative node per cluster is required to be active, and the other nodes can enter the dormant mode [2][3]. Clustering architecture has important applications of high-density sensor networks, because it is much easier to manage a set of cluster representatives from each cluster than to manage whole sensor nodes, and each cluster may elect a cluster-head to coordinate the nodes in the cluster. Many efficient cluster based protocols have been developed for sensor networks to achieve scalability, power saving, channel access, routing, etc. For example, the cluster structure can prolong the lifetime of the sensor network by making the cluster-head aggregate data from the nodes in the cluster and reduce the data sent to the base station.

2. Sensor Network Architecture

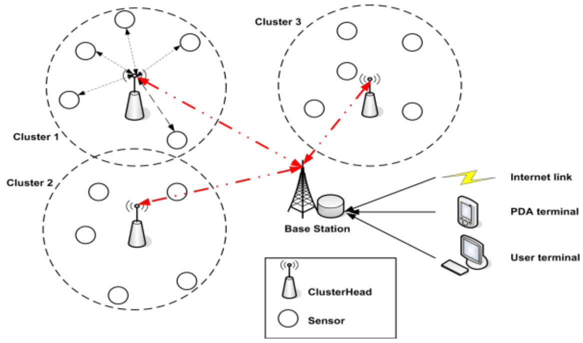

Fig.1 General Cluster based Wireless Sensor Network Architecture

The architecture of a generic Wireless Sensor Network [4] is given figure 1, and examine the clustering phenomenon that is an essential part of the organizational structure.

Sensor Node: A sensor node is the core component of a WSN. Sensor nodes can take on multiple roles in a network, such as simple sensing, data storage, routing, and data processing.

Clusters: Clusters are the organizational unit for WSNs. The dense nature of these networks requires the need for them to be broken down into clusters to simplify tasks such a communication.

Cluster heads: Cluster heads are the organization leader of a cluster. They often are required to organize activities in the cluster. These tasks include but are not limited to data-aggregation and organization the communication schedule of a cluster.

Base Station: The base station is at the upper level of the hierarchical WSN. It provides the communication link between the sensor network and the end-user.

End User: The data in a sensor network can be used for a wide-range of applications. Therefore, a particular application may make use of the network data over the internet, using a PDA, or even a desktop computer. In a queried sensor network

The clustering phenomenon as we can see, plays an important role in not just organization of the network, but can dramatically affect network performance. There are several key limitations in WSNs, that clustering schemes must consider

2.1 Limitations in Clustering schemes of WSN's
Limited Energy: Unlike wired designs, wireless sensor nodes are "off-grid", meaning that they have limited energy storage and the efficient use of this energy will be vital in determining the range of suitable applications for these networks. The limited energy in sensor nodes must be considered as proper clustering can reduce the overall energy usage in a network.

Network Lifetime: The energy limitation on nodes results in a limited network lifetime for nodes in a network. Proper clustering should attempt to reduce the energy usage, and hereby increase network lifetime.

Limited Abilities: The small physical size and small amount of stored energy in a sensor node limits many of the abilities of nodes in terms of processing and communication abilities. A good clustering algorithm should make use of shared resources within an organizational structure, while taking into account the limitation on individual node abilities.

3. Study Area and Data Collection

3.1 One Hop Model
This is the simplest model and represent direct communication as shown in Figure.2. Every node in the network transmits to the base station[5]. This is not only expensive in terms of energy consumption it is also infeasible because nodes have limited transmission range. Their transmission cannot always reach the base station. Direct communication is not a feasible model for routing in WSN.

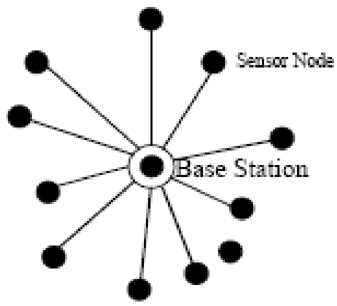

Figure.2. One hop Model

3.2 Multi-Hop Planar Model
In this model, a node transmits to the base station by forwarding its data to one of its neighbors which is closer to the base station which in turns sends it to a neighbor that is yet closer to the base station as shown in Figure.3. Thus the information travels from source to destination by hop from one node to another until it arrives at the

destination. A number of protocol employ this approach. Some use other optimization technique to enhance the efficiency of this model. One such technique is data aggregation used in all cluster based routing protocol. Although there optimization technique improve the performance of this model, it is still planner model. This network is comprised of thousands of sensor, where sensor will exhibit high data dissemination latency.

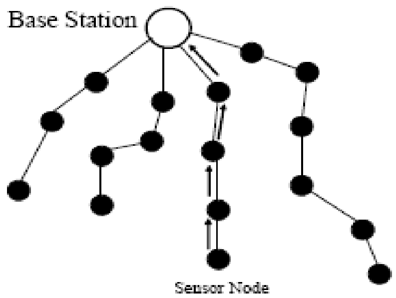

Figure.3. Multi hop Model

3.2 Cluster-based Hierarchical Model

A hierarchical approach breaks the network into cluster layer as shown in Figure 4. Nodes are grouped into cluster with a cluster head which has the responsibility of routing from the cluster to other cluster head or base station. Data travel from a low clustered layer to a higher one. Although it hops from one node to another but as it hops from one layer to another it cover large distance. This moves the data transfer to the base station. Clustering provides inherent optimization capabilities at the cluster head. This Model is better than one hop or Multi-hop model.

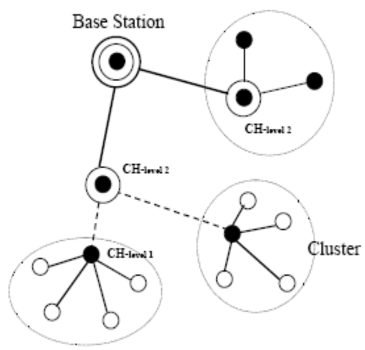

Figure.4. Cluster based Hierarchical Model

Current methods for determining the optimal number of clusters are based on each individual protocol layer aspect. But in this proposed work we used, PHY/MAC/NET cross-layer analytical approach for determining the optimal number of clusters. The objective of this work is to develop a PHY/MAC/NET cross-layer analytical method for calculating the optimal number of clusters in each basic OA for a high-density sensor network [6].

- First, we propose a cross-layer analytical approach to determine the optimal number of clusters. In cluster number design problem, it is a concept of average sense. Hence, we first suggest adopting the criterion of the minimal total average energy to calculate the optimal number of clusters per OA. The PHY/MAC/NET cross-layer analytical design approach for the optimal number of clusters in high-density sensor networks has not been seen in the literature.
- Second, we show the existence of the optimal cluster number, regardless of the different densities of sensors invariousOAs by simulations and analyses. We also take account of other randomness factors in our simulation platform, including lognormal shadowing and a more realistic two-slope path loss model. The simulation results are shown to match the proposed analytical results quite well. To the best of our knowledge, this interesting finding of the optimal cluster number, regardless of the different densities of sensors in various OAs.

3.1.1 LEACH: Low-Energy Adaptive Clustering Hierarchy

LEACH is a self-organizing, adaptive clustering [7][8] protocol that uses randomization to distribute the energy load evenly among the sensors in the network. In LEACH, the nodes organize themselves into local clusters, with one node acting as the local base station or cluster-head. LEACH includes randomized rotation of the high-energy cluster-head position such that it rotates among the various sensors in order to not drain the battery of a single sensor. In addition, LEACH performs local data fusion to ”compress” the amount of data being sent from the clusters to the base station, further reducing energy dissipation and enhancing system lifetime.

3.1.2 LEACH Algorithm

The operation of LEACH is broken up into rounds, where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur.

3.1.3 Advertisement Phase

Initially, when clusters are being created, each node decides whether or not to become a cluster-head for the current round. This decision is based on the suggested percentage of cluster heads for the network and the number of times the node has been a cluster-head so far. This decision is made by the node n choosing a random number between 0 and 1. If the number is less than a threshold T(n), the node becomes a cluster-head for the current round. The threshold is set as:

$$T(n) = \begin{cases} \dfrac{P}{1-P(r \bmod {}^{1}/_{P})} & \text{If } n \in G \\ 0 & \text{otherwise} \end{cases}$$

where
P = the desired percentage of cluster heads,
r = the current round, G is the set of nodes.

3.1.4 Cluster Setup Phase

After each node has decided to which cluster it belongs, it must inform the cluster-head node that it will be a member of the cluster. Each node transmits this information back to the cluster-head again using a CSMA MAC protocol. During this phase, all cluster-head nodes must keep their receivers on.

3.1.5 Schedule Creation

The cluster-head node receives all the messages for nodes that would like to be included in the cluster. Based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule telling each node when it can transmit. This schedule is broadcast back to the nodes in the cluster.

3.1.6 Data Transmission

Once the clusters are created and the TDMA schedule is fixed, data transmission can begin. Assuming nodes always have data to send, they send it during their allocated transmission time to the cluster head. This transmission uses a minimal amount of energy. The radio of each non-cluster-head node can be turned off until the node's allocated transmission time, thus minimizing energy dissipation in these nodes. The cluster-head node must keep its receiver on to receive all the data from the nodes in the cluster. When all the data has been received, the cluster head node performs signal processing functions to compress the data into a single signal.

3.1.7 Multiple Clusters

Transmission in one cluster will affect communication in a nearby cluster. To reduce this type of interference, each cluster communicates using different CDMA codes. Efficient channel assignment is a difficult problem, even when there is a central control center that can perform the necessary algorithms. Using CDMA codes, while not necessarily the most bandwidth efficient solution, does solves the problem of multiple-access in a distributed manner.

4. Simulation Setup

4.1 Simulation Parameters

We evaluated our LEACH scheme through NS2 simulation. We considered 200 node random network deployed in an area of 100 X 100 m. Initially the nodes are placed randomly in the specified area. The base station is assumed to be situated 100 meters away from the above specified area. We also assume that 5% of nodes are considered as cluster heads for the entire cycles. Obviously, the first set of cluster heads are taken randomly. The initial energy of all the nodes assumed as 0.5 joules. The cluster heads which are closer to every node will act as a cluster head for those nodes for the first cycle. The nodes and the cluster head nearer to those nodes will form a group. Thus we formed 5 groups since we have five cluster heads.

In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. The simulated traffic is FTP with TCP source and sink. All experimental results presented in this section are averages of five runs on different randomly chosen scenarios. The following table2 summarizes the simulation parameters used.

Number of Nodes	204
Area size	100*100
MAC	802.11
Simulation Time	50 sec
Traffic Source	TCP
Packet Size	512
Transmit Power	0.360 w
Receiving Power	0.395 w
Idle Power	0.335 w
Initial Energy	0.5 J
Transmission range	75 m

Table.1. Simulation Parameters

4.2 Simulation Result analysis

The following screenshots represents the output of this work. Fig 5. Shows the node and its physical position. Fig 6 shows one cluster head and 3 member of head node, blue circles represents head node and red colored nodes are member nodes. Fig 7 shows the node movements towards cluster head. Fig 8 shows acceptance of the member node when node crosses over to new region. Fig 9 It act as a normal node when it cross over out of region.

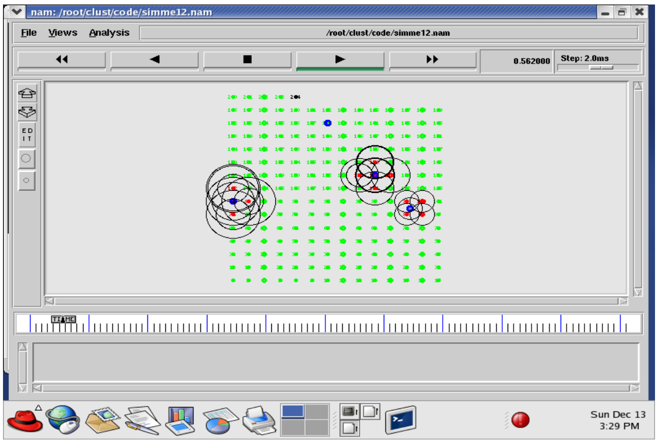

Figure.5. Nodes are Created with Cluster head and member Nodes using NS2

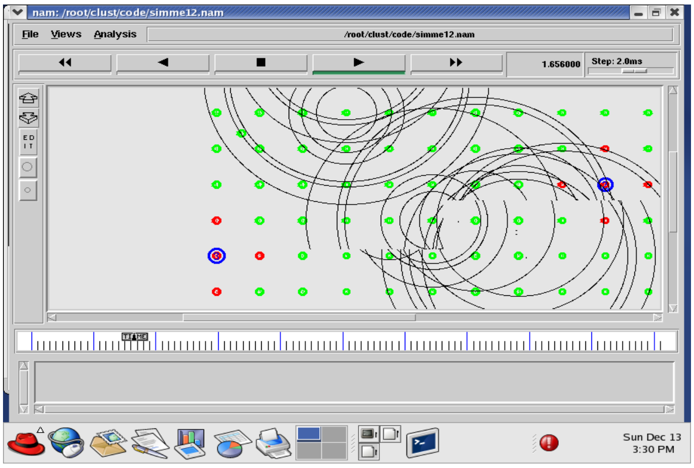

Fig.6 One node moving towards Cluster head.

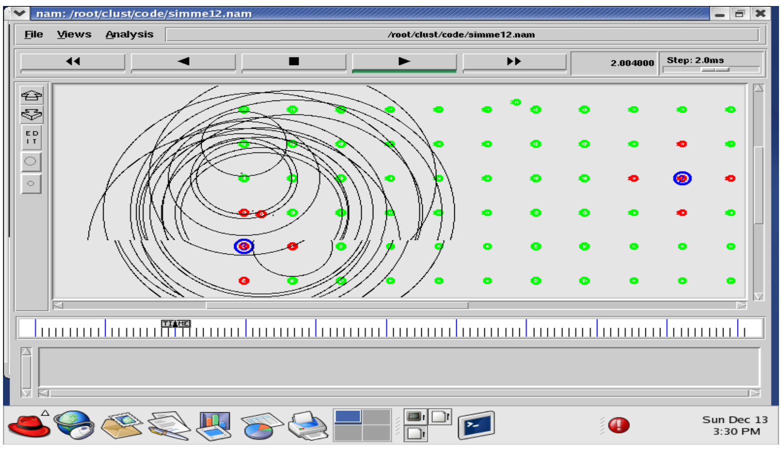

Figure.7. Accepting the member node .

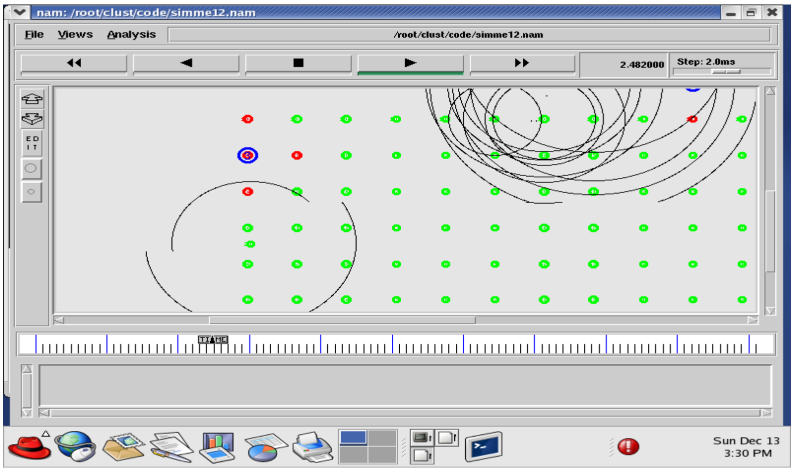

Figure.8. Member node acting as normal node when it is move out region.

5. Conclusion

Our proposed method provides an analytical approach to determine the optimal number of clusters in a basic OA from the PHY/MAC/NET cross-layer perspectives. This cross-layer analytical model integrates the effects of the transmission distance, power, and shadowing in the PHY layer, and the retransmission times in the MAC layer, as well as the number of hops in the NET layer. Our research proves that the optimal number of clusters per OA can significantly improve the energy consumption. Our simulation results show the existence of the optimal cluster number, regardless of the different densities of sensors in various OAs. This solution could be extended to determine the optimal number of cluster based on other MAC and routing strategies with different values of *r* and *h*.

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