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Maximizing Lifetime of Cluster-based WSN through Energy-Efficient Clustering Method

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ABSTRACT

One of the important issues in wireless sensor network is inherent limited battery power within network sensor nodes. Minimizing energy dissipation and maximizing network lifetime are important issues in the design of sensor networks. There are various routing protocols like flat routing protocols, location-based, QoS based, hierarchical routing etc. in which optimal routing can be achieved. Hierarchical routing (cluster-based routing protocols) have shown to be more scalable and energy-aware. The basic idea of clustering is to use information aggregation mechanism in the cluster head to reduce the amount of data transmission, thereby, reduce the energy dissipation in communication. LEACH (low-energy adaptive clustering hierarchy) is well-known & divides the whole network into several clusters, and the run time of network is broken into many rounds. In each round, the nodes in a cluster contend to be cluster head according to a predefined criterion. Since CHs consume more energy in aggregating and routing data, it is important to have an energy-efficient mechanism for CHs' election and rotation. Our proposed algorithm for cluster head selection is based on residual energy, distance & reliability. The main purpose of this paper is to develop a mechanism to increase the lifetime of sensor nodes controlling long distance communication, node balancing and efficient delivery of information**.**

1. INTRODUCTION

A wireless sensor network system usually includes sensor nodes, sink node and management node. A large number of sensor nodes are deployed in the monitored area, constituting a network through the way of self-organization. The data monitored by sensor nodes is transmitted along other nodes one by one, that will reach the sink node after a multi-hop routing and finally reach the management node through the wired and (or) wireless Internet. The energy, the storage capacity and communication capability of sensor nodes are very limited [1], [2]. Random distribution of the nodes in the sensing field makes battery recharge or exchange an impossible fact. A primary design goal for wireless sensor networks is to use the energy efficiently. Due to their energy constraints, wireless sensors usually have a limited transmission range, making multi hop data routing toward the PN more energy efficient than direct transmission (one hop). Cluster-based routing algorithm has a better energy utilization rate compared with non-cluster routing algorithm.

The basic idea of clustering routing is to use the information aggregation mechanism in the cluster head to reduce the amount of data transmission, thereby, reduce the energy dissipation in communication. In the clustering routing algorithms for wireless networks, LEACH (low-energy adaptive clustering hierarchy) is well-known because it is simple and efficient. LEACH divides the whole network into several clusters, and the run time of network is broken into many rounds. In each round, the nodes in a cluster contend to be cluster head according to a predefined criterion. However, since CHs (Cluster Head) consume more energy in aggregating and routing data, it is important to have an energy-efficient mechanism for CHs' election and rotation. In LEACH protocol, all the sensor nodes have the same probability to be a cluster head, which makes the nodes in the network consume energy in a relatively balanced way so as to prolong network.

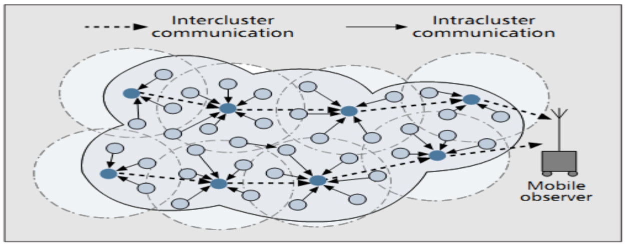


Figure 1 Illustration of data flow in a clustered network

For sensors' states allocation to be optimal, coverage, connectivity of sensors to CHs, and routing has to be taken into account within the same global planning process. Besides achieving energy efficiency, clustering reduces channel contention and packet collisions, resulting in better network throughput under high load. We address the global problem of maximizing network lifetime under the joint clustering, routing, and Coverage constraint.

2. BACKGROUND

We classify the clustering techniques based on two criteria:

•The parameter(s) used for electing CHs (e.g., remaining energy, degree, mobility, and average distance to neighbors).

•The execution nature of a clustering algorithm (probabilistic or iterative)

LEACH (Low Energy Adaptive Clustering Hierarchy) [9], [10] is a distributed clustering protocol which utilizes randomized rotation of local CHs to evenly distribute energy utilization between the nodes of WSNs. The whole operation of the LEACH protocol is divided into rounds. Each round consists of:

a) Set-up phase (*clusters are organized*)
   Cluster Head Selection.
   Cluster Formation.
b) Steady state Phase (*data transmission*)

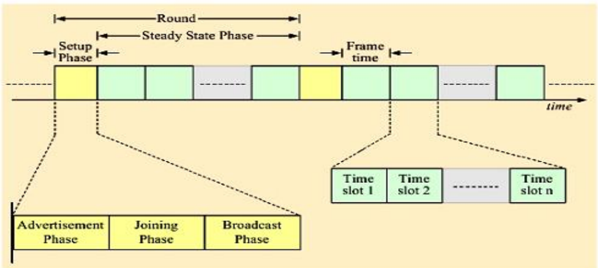


Figure2 Timeline diagram of leach protocol

The number of nodes that remain alive using LEACH is significantly larger (four to eight times larger) than that using static clustering or minimum transmission energy (MTE) routing. But the main problem with LEACH protocol lies in the random selection of cluster heads. There exists a probability that the cluster heads formed are unbalanced and may remain in one part of the network making some part of the network unreachable.

A new adaptive strategy is proposed known as **LEACH-B** to choose cluster-heads and to vary their election frequency according to the dissipated energy. However, the simulation results divulge that there is some degree of improvement using LEACH-B [3].

Moreover, an improved scheme of LEACH was proposed, named **LEACH-C**. In LEACH-C [4], a centralized algorithm at the base station makes cluster formation. However, LEACH-C is not feasible for larger networks because nodes far away from the base station will have problem sending their states to the base station and as the role of cluster heads rotates so every time the far nodes will not reach the base station in quick time increasing the latency and delay.

Further, the clustering protocol known as **LEACH-E** was proposed by Heinzelman et.al.[5] In this protocol it is proposed to elect the cluster-heads according to the energy left in each node. The drawback of LEACH-E is that it requires the assistance of routing protocol, which should allow each node to know the total energy of network.

Distributed Efficient Clustering **(DEEC)** which is dedicatedly designed for energy heterogeneous scenarios, where nodes are initialized at various energy levels [6]. However neither of them assures the selection of energy-rich cluster heads, or the evenness of cluster head dispersion. Decentralized Energy Efficient clustering Propagation **(DEEP)** [7] prevents cluster heads from being too close to each other, but ignores cluster head's energy qualifications.

Lindsey et al. proposed Power-Efficient Gathering in Sensor Information Systems **(PEGASIS)** [8]. PEGASIS makes a communication chain using a Traveling Sales Person heuristic. Each node only communicates with two close neighbors along the communication chain. Only a single designated node gathers data from other nodes and transmits the aggregated data to the sink node.

3. PROBLEM FORMULATION

The lifetime of a WSN can be defined as the time elapsed until the first node dies, the last node dies, or a fraction of nodes die. To maximize network lifetime, we should consider a trade-off between total energy consumption and energy balancing among sensors.

In cluster-based WSN, there is one sensor called as CH which acts as router. All non-CH nodes transmit their data to their CH, which routes it to the remote PN. However, since CHs consume more energy in aggregating and routing data. We present an optimal allocation of states to sensors which maximizes the efficiency of sensors' energy.

PROBLEM: NETWORK LIFE TIME:

Assume a stationary sensor network deployed to observe events. If dense, lots of overlap in network- redundant sensors will report events occurring at the same location.

Two issues at hand:

1. Extra overhead of the routing redundant messages
2. Extra overhead of running redundant sensors.

Many papers address separately energy-efficient routing, clustering, and area coverage and connectivity. Many others address integrated problem of area coverage and network connectivity, but do so in flat networks and don't reap the benefits the energy savings and ease of manageability of cluster-based networks.

"When coverage and connectivity are dealt with separately, the obtained configuration may not be optimal".

Solutions:

1. Using clustering or routing-based compression duplicate observations are eliminated as they are routed towards the sink.
2. Deactivating redundant sensors minimizes coverage overlap and waste.
3. Reduce unnecessary cost by disabling or turning off redundant sensor.
4. Reduction from 12 to 7 active nodes.

ALGORITHM:

Parameters:

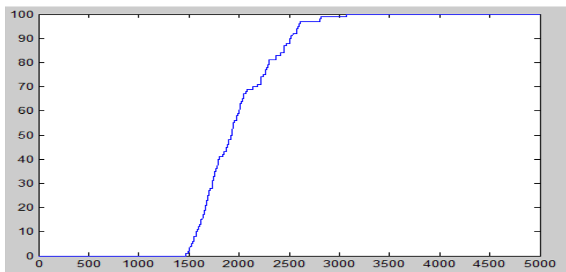
E-initial = initial energy of nodes
E-Transmission = energy consumed during transmission
E-remaining = E-initial - E-transmission
T-life = life time of node.
Remaining life time of node = (E-remaining/E-initial) *T-Life
T-s =sending time-stamp of last data packet
T-R = receiving time stamp of last data packet at base station

LEACH has two phases: the set-up and steady-state. In the set-up phase, the cluster-heads are chosen "stochastically", which is randomly based on an algorithm. A threshold is determined based on this algorithm.

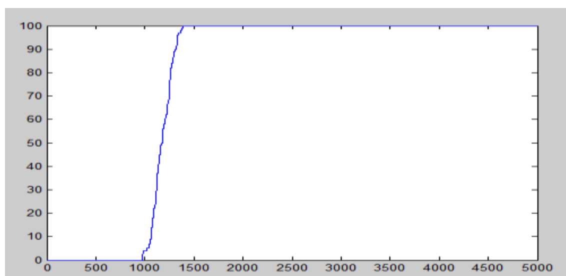
1) The first round will be same as normal leach round.
2) In the 2nd round, each node would send residual energy along with the sending time stamp T-S and the remaining lifetime of battery.
3) When the base station receives the packet, it will calculate T-R - T-S (the difference between receiving timestamp and current time stamp)
4) If difference > = remaining lifetime of node the node will become=non-cluster head
else If remaining lifetime = max among all nodes of the cluster choose the node as cluster head.

4. RESULTS

Figure 3 illustrates the graph that indicates the statistics of dead nodes in different number of rounds in our proposed algorithm as well as in LEACH. In LEACH sensor nodes start dying after 1000 rounds. But in our proposed scheme nodes work satisfactorily uptil 1500 rounds and then start dying after 1500 rounds. Hence network lifetime is increased.



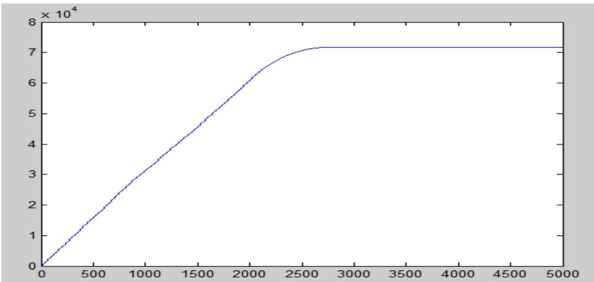
(a)



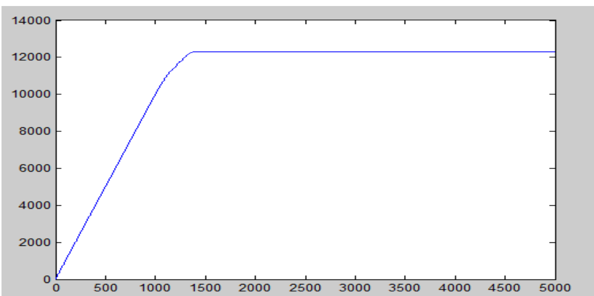
(b)

Figure 3 Total number of dead nodes in different number of rounds (a) In our proposed scheme (b) In LEACH

Figure 4 illustrates that graph indicates total number of packets arrived at Base Station or Sink in different rounds. In fig (a), i.e. In our proposed scheme total number of packets transmitted to BS in 2500 to 5000 rounds are approximately 70,000. While in LEACH this number is only around 12,000 in 1500 to 5000 rounds. Hence we conclude that throughput (number of packets transmitted to BS) is also increased in our scheme.



(a)



(b)

Figure 4 Total number of packets transmitted to BS in different number of rounds (a) In our proposed scheme (b) In LEACH

5. CONCLUSIONS AND FUTURE WORK

The cluster head generation algorithm with the original LEACH clustering protocol can cause unbalanced distribution of cluster heads, which often leads to redundant cluster heads in a small region and thus cause the significant loss of energy. To solve this problem, we proposed a progressive algorithm for the cluster head selection. Simulation results show that our algorithm is much more efficient and indicate that this algorithm can balance nodes' energy consumption and prolong the network's life span. It also has good stability and extensibility. Such results are obtained under additional conditions, i.e., known location information and ability to adjust data transmission power based on distance. The algorithm can be easily implemented.

The factors affecting cluster formation and CH communication are open issues for future research. Moreover, the process of data aggregation and fusion among clusters is also an interesting problem to explore.

Though the performance of the protocols discussed in this paper is promising in terms of energy efficiency, further research would be needed to address issues related to Quality of Service (QoS) posed by video and imaging sensors and real-time applications.

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