Indian Journal of Science and Technology

Supplementary Article

Improving Network Life Time using Static Cluster Routing for Wireless Sensor Networks

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Abstract

Wireless Sensor Networks (WSN) with a large number of tiny sensor nodes can be used as an effective tool for gathering data in various situations. Hierarchical cluster based routing protocol were proposed for increasing network lifetime in the WSN. Major issues of cluster based routing protocol are power consumption and over heading which reduces the overall lifetime of the sensor network. In this project we propose a new static clustering protocol technique which partitions the network into static clusters with static cluster heads, eliminating the dynamic over heading and reduces the power consumption thereby improving the performance of the network. The performance of the proposed algorithm will be evaluated with the help of network simulation tool.

Keywords: WSN, LEACH, ADV-advertisement, Cluster Head, TDMA, CDMA.

1. Introduction

A Wireless Sensor Network is an infrastructure comprised of sensing (measuring), computing, and communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment. There are four basic components in a sensor network:

- An assembly of distributed or localized sensors,
- An interconnecting network (usually, but not always, wireless-based),
- A central point of information clustering, and
- A set of computing resources at the central point (or beyond) to handle data correlation, event trending, status querying, and data mining.

Due to advances in wireless communications and electronics over the last few years, the development of networks of low-cost, low-power, multifunctional sensors has received increasing attention. These sensors are small in size and able to sense, process data, and communicate with each other, typically over an RF (radio frequency) channel.

These are the different issues in wireless sensor networks

1. **Energy Efficiency:** In sensor networks, it is of crucial importance to consume nodes' energy wisely and efficiently. As sensor nodes are normally equipped with non-chargeable batteries with limited energy supply, a sensor network cannot function well after a fraction of nodes run out of energy.
2. **Network Autonomy:** Sensor nodes can be either deterministic placed or randomly scattered into a field of interests. In a remote or dangerous field, randomly scattering nodes might be the only way to deploy a sensor network. In such cases, the untended nodes should self-organize into an autonomous network to decide the structure and topology of the network. Such an autonomous network should be able to schedule sensing tasks and to arrange delivery routes all by itself.

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3. **Network Scalability:** In many envisioned applications, the number of sensor nodes in a sensor network may be in the order of thousands, tens of thousands, or even millions. In such large-scale networks, scalability is a critical factor, guaranteeing that the network performance does not significantly degrade as the network size increases.
4. **Fault Tolerance:** Sensor nodes are cheap devices and prone to failures. Node failure rate may be very high if they are deployed in hostile or harsh environments. Fault tolerance, or robustness, should be included in the design and implementation of algorithms for sensor networks such that the network Performance is not sensitive to individual node failures.
5. **Data Accuracy:** Obtaining accurate information is the main task of sensor networks. Accuracy can be improved through joint signal processing by cooperative sensors.
6. **Information Security:** Information security, which is a basic yet common requirement in almost all types of networks, requires that sensing data should be accessed, transmitted, and processed securely and privately.

The remainder of this paper is structured as follows. We begin a discussion of related work in Section II, and then present the Basic LEACH Protocol in Section III as shown in Figure 1. We describe our Static Cluster Routing in Section IV, we give Simulation Results in Section V and we give Conclusion in Section VI.

2. Related Works

In [1] proposes EEPSC (Energy-Efficient Protocol with Static Clustering), a hierarchical static clustering based protocol, which eliminates the overhead of dynamic clustering and engages high power sensor nodes for power consuming tasks and as a result prolongs the network lifetime. In each cluster, EEPSC chooses the sensor node with maximum energy as the cluster-head (CH); thus, not only there is always one CH for each cluster, but also the overhead of dynamic clustering is removed. EEPSC is a self-organizing, static clustering method that forms clusters only once during the network action. The operation of EEPSC is broken up into rounds.

2.1 Setup Phase

EEPSC uses the static clustering scheme, only once at the beginning of network operation cluster formation performed. The base station broadcasts has different messages with different transmission powers for the desired number of clusters. The base station selects randomly one temporary-CH for each cluster and advertises these rules to the whole network. In addition, base station (based on the number of each cluster) sets up a TDMA (time-division multiple-access) schedule and transmits this schedule to the nodes in each cluster.

2.2 Responsible Node Selection Phase

When the clusters established, network starts its normal operation and responsible nodes (temporary-CH and CH) selection phase begins. At the beginning of each round, every node sends its energy level to the temporary-CH in its time slot [1]. Afterward, temporary-CH choose the sensor node with utmost energy level as CH for current round to collect the data of sensor nodes of that cluster, do local data aggregation, and communicate with the base station; and the node with lowest energy level as temporary-CH for next round and sends a round-start packet including the new responsible sensor IDs for the current round. This packet also indicates the beginning of round to other sensor nodes. Since every sensor node has a pre-specified time slot, changing the CHs has no effect on the schedule of the cluster operation.

2.3 Steady-State Phase

The steady-state phase has broken into frames where nodes send their results to the CH during pre- allocated time slots. These data contain node ID and the measure of sensed value. By using direct transmission approach the sensed data is send from CH to base station.

In [2] The Stable Cluster Head Election (SCHE) was designed with specific criteria such as random network, fixed location of sensor node and base station so that the protocol becomes computational simple as the static route could be used. SCHE is source initiates protocol with time driven reporting, so the sensor node would always have data to send to the base station. SCHE would also apply data aggregation to avoid information overload or access of data.

A new clustering method to decrease probability of failure nodes and increasing the lifetime in Wins was discussed in [3]. Here To avoid this extra load and unstable consumption of energy some of the nodes have been expanded with a high- energy called Gateway sensors are used as head clusters due to decrease the failure probability of head clusters. After establishing the network, the sensors have the role of a gateway between central stations and head clusters. To be attentive that head clusters to transmit to central stations and data assembling and calculating in protocol consume a great deal of energy. All the responsibility of head cluster is given over to joint cluster sensors or Gateway. Then after receiving data from its joint nodes without any calculating delivers them to gateway. And its gateway that transmits them to base station after doing necessary works and calculations.

[4] Discusses *RCFT (Re-Clustering Formation Technique)* which selects randomly cluster heads at first, then re-selects cluster heads considering the numbers of hops between each cluster heads, and the numbers of hops of cluster nodes farthest away from the cluster heads. After selecting cluster heads, RCFT re-organizes cluster which is to be fixed till the termination of network's life-span. After broadcasting the broadcast message, the sensor-nodes selected as the first cluster heads wait for response for a while, and when received response, they inspect whether the responses are identical with ones from the same sensor-nodes, which responded before. If the response is the first time, they record the response of head with most small numbers of hops, and also record the information of the sensor-node with the most counting values among the responses on sensor-nodes. If there are over two of sensor-nodes having the most counting values, the information of sensor-node, which responded at the last, is to be recorded as it means that the sensor-node, which responded at the last, is the farthest away.

A Cell Based Clustering Algorithm in Large Wireless Sensor Networks was proposed in [5]. The target field is divided into small non-overlapping cells. Sensor node set in each cell is a cluster. The size of cell is well selected so that any node in adjacent cell can communicate with each other.

In [6] an improved leach protocol was proposed where the cluster contains; CH (responsible only for sending data that is received from the cluster members to the BS), sub-CH (the node that will become a CH of the cluster in case of CH dies), cluster nodes (gathering data from environment and send it to the CH). Besides having a CH in the cluster, there is a sub-CH that takes the role of the CH when the CH dies earlier than the other nodes in the cluster because of its operation of receiving, sending and overhearing. It will become useless because the data gathered by cluster nodes will never reach the base station [8].

3. Basic Leach Protocol

A Hierarchical clustering algorithm for sensor networks called low energy adaptive clustering hierarchy (LEACH). LEACH is a cluster-based protocol that includes distributed cluster formation shown in Figure 2. The authors allowed for a randomized rotation of the cluster head's role in the objective of reducing energy consumption (i.e., extending network lifetime) and to distribute the energy load evenly among the sensors in the network.

LEACH uses localized coordination to enable scalability and robustness for dynamic networks and incorporates data fusion into the routing protocol in order to reduce the amount of information that must be transmitted to the base station. It use of a TDMA/CDMA (Time Division Multiple Access/Code Division Multiple Access) MAC (Medium Access Control) to reduce inter- and intracluster collisions. Because data collection is centralized and performed periodically, this protocol is most appropriate when constant monitoring by the sensor network is needed [7]. A user may not need all the data immediately. Thus, periodic data transmissions, which may drain the limited energy of the sensor nodes, are unnecessary.

The operation of LEACH is separated into two phases: the setup phase and the steady state phase. In the setup phase, the clusters are organized and cluster heads are selected. In the steady state phase, the actual data transfer to the base station takes place. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead [9]. During the setup phase, a redetermined fraction of nodes, *p*, elect themselves as

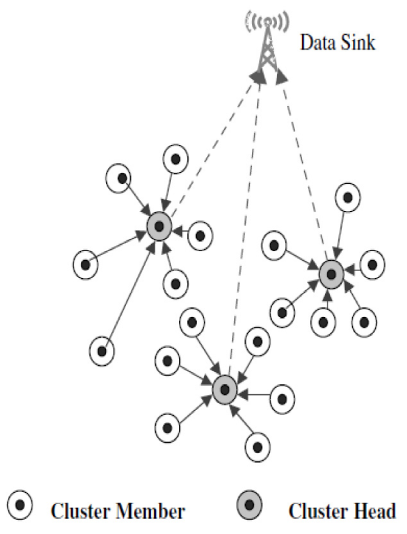

Figure 1. Network model for leach protocol.

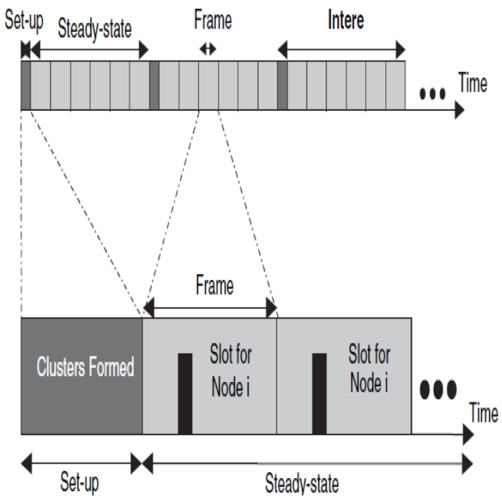

Figure 2. TDMA/CDMA schedule for leach protocol.

cluster heads as follows. A sensor node chooses a random number, r , between 0 and 1. If this random number is less than a threshold value, $T(n)$, the node becomes a cluster head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster head, the current round, and the set of nodes not selected as a cluster head in the last $(1/P)$ rounds, denoted by G . This is given by:

$$T(n) = \frac{P}{1 - P \times (r \bmod P^{-1})} \qquad \forall n \in G$$

$$T(n) = 0 \qquad \forall n \notin G$$

Where n is a random number between 0 and 1
P is the cluster-head probability and
G is the set of nodes that weren't cluster-heads the previous rounds

After the cluster heads have been elected, they broadcast an advertisement message to the rest of the nodes in the network that they are the new cluster heads [10]. Upon receiving this advertisement, all the noncluster head nodes decide on the cluster to which they want to belong, based on the signal strength of the advertisement. The noncluster head nodes inform the appropriate cluster heads that they will be members of the cluster. In Figure 3 flowchart shows the cluster head election procedure. After receiving all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the cluster head node creates a TDMA schedule and assigns each node a time slot when it can transmit. This schedule is broadcast to all the nodes in the cluster. During the steady state phase, the sensor nodes can begin sensing and transmitting data to the cluster heads. The cluster head node, after receiving all the data, aggregates them before sending them to the base station.

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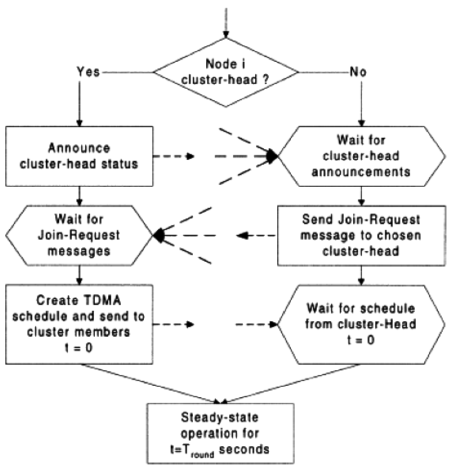

Figure 3. Flow chart for selection for cluster head.

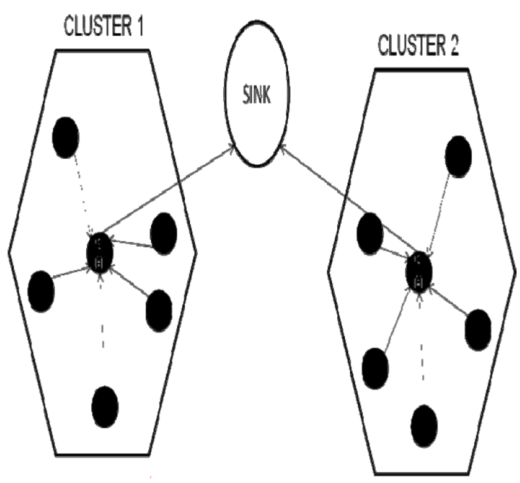

Figure 4. System model for static cluster routing

schedule is broadcast to all the nodes in the cluster. During the steady state phase, the sensor nodes can begin sensing and transmitting data to the cluster heads. The cluster head node, after receiving all the data, aggregates them before sending them to the base station.

4. Static Cluster Routing

Static cluster routing protocol has a two phase - setup phase and steady state phase shown in Figure 4.

Setup phase - The sink which is a base station selects the static cluster head which is a high energy node present in the cluster. This selected high energy node will serve as Cluster Head for that particular Cluster for a period till the node energy reaches a minimum threshold value. Once the minimum value is reached, selection of Cluster Head is performed in the same cluster. Now the selection of Cluster is based on residual energy of the node. That is node having high residual energy is elected as Cluster Head and the process continue. The formation of the clusters is done by the base station in a form of regular hexagon shape which avoids the randomized formation cluster at every iteration in the network. After selection of cluster head the CH will send an ADV- advertisement message to it cluster members in the cluster along with the cluster head node ID. All the remaining nodes in the cluster will send a RLP-reply message to the cluster head along with their nod id and cluster head node id for membership into the cluster. Then the cluster head will create the TDMA schedule for the intra cluster communication and CDMA schedule for inter cluster communication and from cluster head to the sink node.

Steady state phase – which is a data transmission phase in which the sensed data for a particular area for cluster will be sensed by the sensor node and sends the data to it cluster head in the schedule allotted. The CH collects the data from all the leaf node in the cluster and does all the operations such as Data aggregation, data compression and sends to the sink node.

5. Simulation Results

A Network Scenario was created and the LEACH protocol and Static Cluster Routing for Wireless Sensor Networks was simulated with the help of Network Simulator NS 2. The Network parameters are given in Table 1. The simulation results are shown in Energy vs. Time (Figure 5), and Data Received at BS vs. Time (Figure 6).

Table 1. Network Parameters

Layers	Parameters
Physical (Radio Propagation)	Free space, Two-Ray
Data Link (MAC)	CSMA, MACA, TSMA, 802.11
Network (Routing)	Bellman-Ford, FSR, OSPF, DSR, WRP, LAR, AODV
Transport	TCP, UDP
Application	Telnet, FTP and CBR

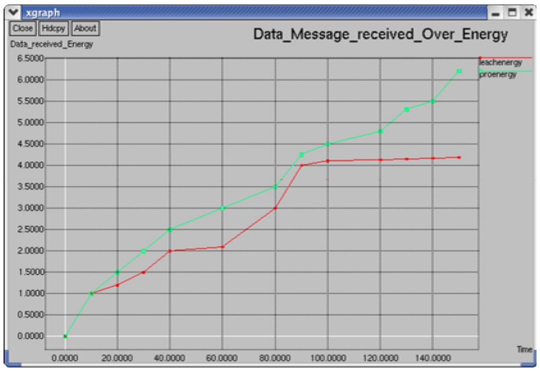

Figure 5. Energy vs. time.

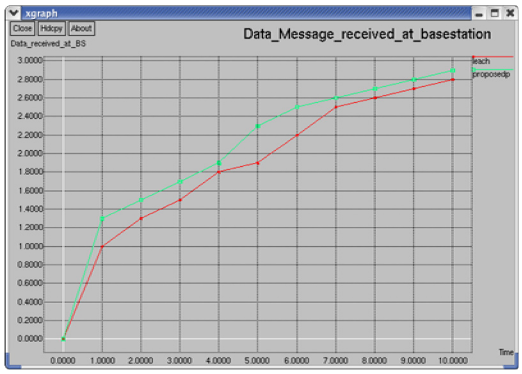

Figure 6. Data received at BS vs. time.

6. Conclusions

In this paper, the average energy is analyzed and compared with the LEACH Protocol and Static Cluster Routing Protocol with the given network parameters. Static Cluster Routing is proposed as better energy efficient than basic protocol.

7. References

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