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HIERARCHICAL ROUTING PROTOCOL IN WIRELESS SENSOR NETWORK

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ABSTRACT

A wireless network consisting of a large number of small sensors with low-power transceivers can be an effective tool for gathering data in a variety of environments. Wireless distributed micro sensor systems will enable the reliable monitoring of a variety of environments for both civil and military applications. In this paper, we look at communication protocols, which can have significant impact on the overall energy dissipation of these networks. Based on our findings that the conventional protocols of direct transmission, minimum-transmission-energy, multi-hop routing, and static clustering may not be optimal for sensor networks, we propose LEACH (Low-Energy Adaptive Clustering Hierarchy), a clustering-based protocol that utilizes randomized rotation of local cluster based station (cluster-heads) to evenly distribute the energy load 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 to reduce the amount of information that must be transmitted to the base station. Simulations show the LEACH can achieve as much as a factor of 8 reduction in energy dissipation compared with conventional outing protocols. In addition, LEACH is able to distribute energy dissipation evenly throughout the sensors, doubling the useful system lifetime for the networks we simulated. LEACH includes a new, distributed cluster formation technique that enables self-organization of large numbers of nodes, algorithms for adapting clusters and rotating cluster head positions to evenly distribute the energy load among all the nodes, and techniques to enable distributed signal processing to save communication resources. Our results show that LEACH can improve system lifetime by an order of magnitude compared with general-purpose multi hop approaches.

1.0 INTRODUCTION

1.1 Sensor Network

A wireless sensor network is an active research area. A Wireless Sensor Networks (WSN) is a set of hundreds or thousands of micro sensor nodes that have capabilities of sensing, establishing wireless communication between each other and doing computational and processing operations.

Each sensor node comprises sensing, processing, transmission, mobilize, position finding system, and power units (some of these components are optional like the mobilize). The figure 1.1 shows the components of sensor node and communication architecture of a WSN. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed. Sensor nodes coordinate among them- selves to produce high-quality information about the physical environment. Each sensor node bases its decisions on its mission, the information it currently has, and its knowledge of its computing, communication, and energy resources. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station(s).

The typical configuration of such a sensor node in a WSN includes single or multiple sensing elements, a data processor, communicating components and a power source of limited energy capacity. The sensing elements of such a sensor node perform measurements related to the conditions existing at its surrounding environment. These measurements are transformed into corresponding electric signals and are processed by the processing unit. A sensor node makes use of its communication components in order to transmit the data, over a wireless channel, to a designated sink point, referred to as a base station. The base station collects all the data transmitted to it in order to act as a supervisory control processor or an access point for a human interface or even as a gateway to other networks.

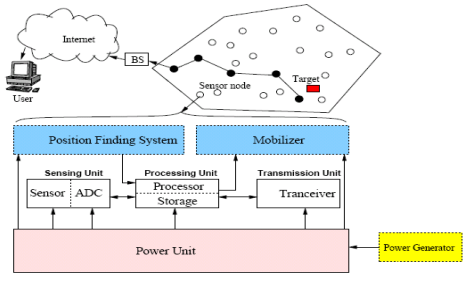

Figure 1.1: The components of a sensor node and communication architecture [1]

1.2 Routing protocol Classification

There are different routing protocols already reported for WSN applications but mostly they are for static networks. All major protocols may be categorized into following four categories:

Data Centric Protocols, Hierarchical Protocols, Location Based Protocols and Network Flow and QoS Aware Protocols. Few representative works of these categories are given below.

No.	Category	Representative Protocols
1	Data Centric Protocols	Flooding and Gossiping, SPIN, Directed Diffusion, Rumor Routing, Gradient Based Routing, Energy-Aware Routing, CADR, COUGAR ACQUIRE.
2	Hierarchical Protocols	LEACH, PEGASIS, HPEGASIS, TEEN and APTEEN
3	Location Based Protocols	MECN, SMECN, GAF, GEAR
4	Network Flow and QoS Aware Protocol	Maximum Lifetime Energy Rout- ing, Maximum Lifetime, Data Gathering, Minimum Cost For- warding, SAR and SPEED

Table I: Classification of Energy-efficient Routing Protocol

2.0 ARCHITECTURE OF WIRELESS SENSOR NETWORK

Let us look at the architecture of a generic Wireless Sensor Network, and examine how the clustering phenomenon 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

• 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 organizing 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 (where the required data is gathered from a query sent through the network). This query is generated by the end user. The clustering phenomenon as we can see, plays an important role in not just organization of the network, but can dramatically affect network performance WSN creates a local network hierarchy on one or more levels represented by nodes chosen by certain criteria that are aggregating and sending data to a central base station (BS).Most times it is not necessary to identify the exact location of the node and it's ID. Communication is done mostly from node to BS, the BS sends requests to obtain data from nodes. the answer of a particular node is not important, but the area of origin is. All data has to be aggregated by the cluster-head before reaching the BS. Generally, routing protocols on the basis of network structure are divided in to 3 main groups:-

1.FLAT

2.Hierarchical

3.Location based

Specifically, hierarchical routing protocols have proved to have considerable savings in total energy consumption of the WSN. In hierarchical routing protocols, clusters are created and a head node is assigned to each cluster. The head nodes are the leaders of their groups having responsibilities like collection and aggregation the data from their respective clusters and transmitting the aggregated data to the BS. This data aggregation in the head nodes greatly reduces energy consumption in the network by minimizing the total data messages to be sent to BS.

The less the energy consumption, the more the network life time. The main idea of developing cluster-based routing protocols is to reduce the network traffic toward the sink. This method of clustering may introduce overhead due to the cluster configuration and maintenance, but it has been demonstrated that cluster-based protocols exhibit better energy consumption and per for manse when compared to flat network topologies for large scale WSNs.

3.0 Hierarchical Routing Protocol

3.1 Introduction

There are the following important Hierarchical routing protocols.

- LEACH
- PEGASIS
- TEEN
- APTEEN

The main aim of hierarchical routing is to efficiently maintain the energy con- sumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. Cluster formation is typically based on the energy reserve of sensors and sensors proximity to the cluster head. LEACH is one of the first hierarchical routing approaches for sensors networks.

3.2 LEACH

Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol for sensor networks is proposed by W. R. Heinzelmanetal which minimizes energy dissipation in sensor networks, it is based on a simple clustering mechanism by which energy can be con- served since cluster heads are selected for data transmission instead of other nodes. 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. In order to minimize overhead, the steady-state phase is long compared to the set-up phase.

Set-up phase: During this phase, each node decides whether or not to become a cluster head (CH) for the current round. This decision is based on choosing a random number between 0 and 1.

Once the cluster head is chosen, it will use the CSMA MAC protocol to advertise its status. Remaining nodes will take the decision about their cluster head for current round based on the received signal strength of the advertisement message.

Before steady-state phase starts, certain parameters are considered, such as the net- work topology and the relative costs of computation versus the communication. A Time Division Multiple Access (TDMA) schedule is applied to all the members of the cluster group to send messages to the CH, and then to the cluster head towards the base station. As soon as a cluster head is selected for a region, steady-state phase starts. Figure 1.3 shows the flowchart of the this phase.

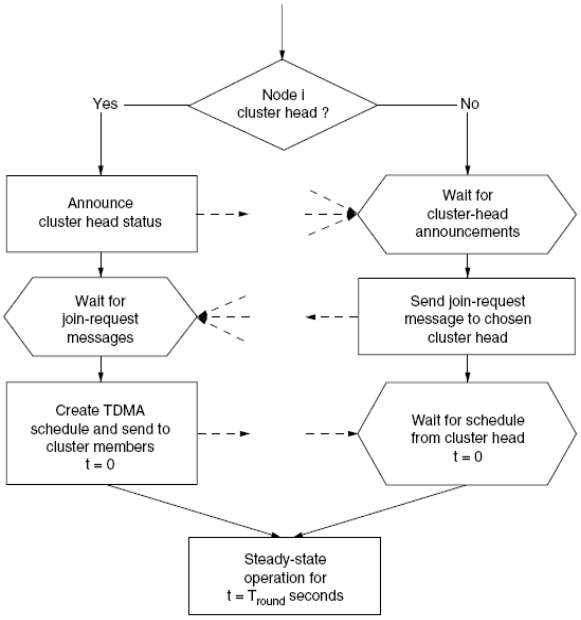

Figure 3.1: Flow chart of the set-up phase of the LEACH protocol

Steady-state phase: 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 (chosen based on the received strength of the cluster- head advertisement). The radio of each non-cluster-head node can be turned off until the nodes 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 generate the composite single signal.

For example, if the data are audio or seismic signals, the cluster-head node can beam form the individual signals to generate a composite signal. This composite signal is sent to the base station. Since the base station is far away, this is a high-energy transmission.

F Code Division Multiple Access (CDMA) is utilized between clusters to eliminate the interference from neighboring clusters.

LEACH achieves over a factor of 7 reduction in energy dissipation compared to direct communication and a factor of 4-8 compared to the minimum transmission energy outing protocol. The nodes die randomly and dynamic clustering increases life time of the system. LEACH is completely distributed and requires no global knowledge of network.

3.3 PEGASIS

PEGASIS which stands for Power-Efficient Gathering in Sensor Information Systems [8] is a data-gathering and near-optimal chain-based algorithm that establishes the concept that energy conservation can result from no des not directly forming clusters. This algorithm decreases the energy consumption by creation of a chain structure comprised of all nodes and continually data aggregation across the chain. The algorithm presents the idea that if nodes form a chain from source to sink, only one node in any given transmission time-frame will be transmitting to the base station. Data-fusion occurs at every node in the sensor network allowing for all relevant information to permeate across the network.

PEGASIS avoids cluster formation and uses only one node in a chain to transmit to the BS instead of using multiple nodes. In order to increase network life time, nodes need only to communicate with their closest neighbors and they take turns in communicating with the BS. When the round of all nodes communicating with the base-station ends, a new round will start and so on.

3.4 TEEN

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) [4], is a hybrid of hierarchical clustering and data-centric protocols designed for time-critical applications. It is a responsive protocol to sudden changes of so me of the attributes observed in the WSN (e.g., temperature). The algorithm first goes through cluster formation. The CHs then broadcast two thresholds to the nodes in their clusters. Those are hard and soft thresholds for the sensed attribute: Hard Threshold (HT): This is a threshold value for the sensed attribute. It is the absolute value of the attribute beyond which, the node sensing this value must switch on its transmitter and report to its cluster head. Soft Threshold (ST): This is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit. It stimulates the node to switch on its transmitter and report the sensed data. A node will report data only when the sensed value is beyond the HT or the change in the value is greater than the ST. However , TEEN cannot be applied for sensor networks where periodic sensor readings should be delivered to the Sink, since the values of the attributes may not reach the threshold at all. Moreover, we have some wasted time-slots in TEEN protocol and there is always a possibility that the sink may not be able to distinguish dead nodes from alive ones. Another limitation of the protocol is that the message propagation is accomplished by CHs only. If CHs are not in each other's transmission radius, the messages will be lost.

3.5 APTEEN

The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) [5] is an extension to TEEN and aims at both capturing periodic data collections and reacting to time critical events. The architecture is same as in TEEN. When the base station forms the cluster s, the cluster heads broadcast he attributes, the threshold values, and the transmission schedule to all nodes. luster heads also perform data aggregation in order to save energy. APTEEN supports three different query types: historical, to analyze past data values; one-time, to take a snapshot view of the network; and persistent to monitor an event for a period of time.

4.0 COMPARISON BEASED ON NETWORK LIFETIME

In LEACH the first node death occurs 8 times later than conventional methods. So we can see that this gives a greater network lifetime. TL-LEACH which was the improvement of LEACH gives a 30% in network lifetime than the form er one. EECS which was proposed later as an improvement to standard LEACH gives a 35% improvement in network lifetime. Simulations have shown that PEGASIS will give a 100% to 300% improvement in network lifetime compared to standard LEACH

5.0 CONCLUSION

In this paper we have examined the current state of proposed hierarchical routing protocols, specifically with respect to their power and reliability requirements. In wireless sensor networks, the energy limitations of nodes play a crucial role in designing any protocol for implementation. In addition, Quality of Service metrics such as delay, data loss tolerance, and network lifetime expose reliability issues when designing recovery mechanisms for clustering schemes. However there is still much work to be done. Many energy improvements thus far have focused with minimization of energy associated in the cluster head selection process or with generating a desirable distribution of cluster heads.

Optimal clustering in terms of energy efficiency should eliminate all overhead associated not only with the cluster head selection process, but also with node association to their respective cluster heads. Sensor network reliability is currently addressed in various algorithms by utilizing re-clustering that occurs at various time intervals ; however the result is often energy inefficient and limits the time available within a network for data transmission and sensing tasks. Further improvements in reliability should examine possible modifications to the reencountering mechanisms following the initial cluster head selection. These modifications should be able to adapt the network clusters to maintain network connectivity while reducing the wasteful resources associated with periodic re-clustering. In addition, other mechanisms such as the ability of nodes to maintain Membership in auxiliary clusters can reinforce the current state of sensor network reliability.

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