A Comparative Analysis of Energy-Efficient Routing Protocols in Wireless Sensor Networks

K. Narendra, V. Varun and G. H. Raghunandan

Abstract A wireless sensor network (WSN) consists of spatially distributed autonomous sensors for reliable monitoring of a variety of environments for both civil and military application and to cooperatively pass their data through the network to a main location. Routing protocols have significant impact on the overall energy consumption of sensor networks. Suitable energy-efficient routing algorithms are required to the inherent characteristics of these types of networks. Due to resource limitations in wireless sensor networks, prolonging the network lifetime has been of a great interest. Most of the energy of sensor nodes is utilized for the transmission of data to the base station. Thus, it makes them to deplete their energy much faster. In this paper, we look at and compare the different communication protocols, which can have significant impact on the overall energy dissipation of these networks.

Keywords Clusters · Cluster head · Movable base station · Mobile sink · Nodes · Wireless sensor networks (WSN)

1 Introduction

The WSN is built of nodes from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensor. These sensor nodes have certain limits, such as low power, limited processor, limited memory, and

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communication-restricted, and have a wide range of applications such as military, battlefield, and environment monitoring. Each sensor node is based on its decision on transmission, the information it currently has, knowledge of its computing, communication, and energy resources, and have capability to collect and route data either to other sensors or back to an external base station or stations which may be a fixed or a mobile node capable of connecting the sensor network to the Internet or an existing communication infrastructure or to the Internet where users have access to the reported data. The lifetime of a wireless sensor network is limited to the battery lifetime of the sensor nodes. Many energy-efficient protocols or schemes have been proposed for sensor networks in recent years.

One of the conventional protocols in use was direct communication protocol. Using a direct communication protocol, each sensor sends its data directly to the base station. If the base station is far away from the nodes, direct communication will require a large amount of transmit power from each node. This will quickly drain the battery of the nodes and reduce the system lifetime. However, the only reception in this protocol occurs at the base station, so if either the base station is close to the nodes, or the energy required to receive the data is large, this may be an acceptable (and possibly optimal) method of communication. The second conventional protocol we consider is a "minimum-energy" routing protocol. In these protocols, nodes route data destined ultimately for the base station through intermediate nodes. Thus, nodes act as routers for other nodes' data in addition to sensing the environment. These protocols differ in the way the routes are chosen. Some of these protocols only consider the energy of the transmitter and neglect the energy dissipation of the receivers in determining the routes. Then, there are some other protocols like LEACH, HUMS, Average Energy-based Routing Protocol and the Centrality-based Cluster approach. In this paper, we discuss in brief about these protocols and do extensive comparison between them.

Section 2 gives the classification of routing protocols. Section 3 of the paper deals with brief description of four routing protocols. Section 4 is the comparison between the protocols and briefs the advantage of the Centrality-based Cluster approach. Future research is explained in Sect. 5, and finally, Sect. 6 gives the conclusion of the paper.

2 Classification of Routing Protocols

The design space for routing algorithms for WSNs is quite large, and we can classify the routing algorithms for WSNs in many different ways. In general, routing in WSNs can be classified into flat-based routing, hierarchical-based routing, and location-based routing depending on the network structure.

The first category is the flat-based or the data-centric routing protocols. In WSNs, node-centric communication is not a commonly expected communication type. Therefore, routing protocols designed for WSNs are more data-centric or geocentric. In data-centric routing, the sink sends queries to certain regions and

waits for data from the sensors located in the selected regions. Since data are being requested through queries, attribute-based naming is necessary to specify the properties of data. Here, data are usually transmitted from every sensor node within the deployment region with significant redundancy.

The second type is the hierarchical- or cluster-based routing protocols, proposed in wireless networks. A hierarchical routing protocol is a natural approach to take for heterogeneous networks where some of the nodes are more powerful than the other nodes, that is, the higher-energy nodes can be used to process and send the information, while lower-energy nodes can be used to perform the sensing in the proximity of the target. The hierarchy does not always depend on the power of nodes. In these protocols, different nodes are grouped to form clusters and data from nodes belonging to a single cluster can be combined (aggregated).The clustering protocols have several advantages like scalable, energy efficient in finding routes, and easy to manage.

The third category is the location-based routing protocol. In this method, the nodes know where they are in a geographical region. The incoming signal strengths can estimate the distance between neighboring nodes. Relative coordinates of neighboring nodes can be obtained by exchanging such information between neighbors. An alternate for this is that the location of nodes may be available directly by communicating with a satellite, using global positioning system (GPS), if nodes are equipped with a small low power GPS receiver. Some location-based schemes demand that nodes should go to sleep if there is no activity to save energy. The more the number of sleeping nodes, the more the energy saving obtained in the network. Thus, they are used to improve the performance of routing and to provide new types of services.

3 Hierarchical-Based Routing Protocols

3.1 LEACH: Low-Energy Adaptive Clustering Hierarchy

LEACH [1] is an autonomous adaptive clustering protocol that distributes the energy load evenly among the sensors in the network using randomization. The nodes organize themselves into local clusters, with one node acting as the local base station or cluster head. In order to not drain the battery of a single sensor randomized rotation of the high-energy cluster head position such that it rotates among the various sensors. Once the cluster head has all the data from the nodes in its cluster, the cluster head node aggregates the data and then transmits the compressed data to the base station. Since it compress the amount of data being sent from the clusters to the base station, energy dissipation is reduced and system lifetime is thus enhanced.

3.2 HUMS: Half-qUadrant–Based Moving Strategy

In this method, it uses a moving strategy where a sink visits each sensor node to collect sensed data [2]. A mobile sink makes moving decision based on HUMS. The sink moves toward the nodes, which has the highest residual energy and starts collecting the data. The node and sink communication include three phases. In the first phase, sink sends position notification to the nodes and then the nodes send their respective data to the sink. In the second phase, it sends by multi-hop, and in the final phase, the sink moves to a new position based on an algorithm and the new reporting commences. By using HUMS, the sink can move on its own by adapting to the diverse node deployments. Thus, energy dissipation is checked and system lifetime is enhanced considerably. But this protocol can be applied only for an event-driven application.

3.3 An Average Energy-Based Routing Protocol for Mobile Sink

This protocol [3] is an energy-efficient cluster-based mechanism. It has been designed to improve the energy efficiency with decreasing communication. It adopts a Sink Routing Schedule Scheme where it randomly selects a cluster head whose remaining energy is above the threshold value. This protocol uses Hello Packet as an indication to the visited cluster by the mobile sink and Information Packet where the cluster head collects the information and transmits it to the sink. Since it follows a queuing procedure, the mobile sink will not be able to move to the cluster head region immediately where there is a requirement if nodes are about to die.

3.4 Centrality-Based Cluster Approach

Here, the Centrality-based Cluster Approach [4] is taken into consideration where a movable base station is used to reduce the energy consumption of the cluster heads. In this approach, a node which is at equal distances from all other nodes in the cluster is elected as the cluster head. According to the algorithm proposed, the base station is moved to a specific cluster head and reduces the CH's energy consumption in each of the rounds. Decision to which critical CH it should move is made by the fuzzy system at the base station. The fuzzy logic decision is based on three parameters:

Table 1 Comparison of Routing Protocols in WSN

Routing protocols	LEACH	HUMS	AERP	CBCA
Classification	Hierarchical	Hierarchical	Hierarchical	Hierarchical
Movable base station	No	Yes	Yes	Yes
Cluster heads	Yes	Yes	Yes	Yes
Energy consumption	Highest	Lesser than AERP	Lesser than LEACH	Lowest
Lifetime of nodes	Low	Moderate	Moderate	High
Data aggregation	Yes	Yes	Yes	Yes
Energy dissipation	High	Moderate	Moderate	Low
Variance of energy	High	Moderate	Moderate	Low

- CH residual energy.
- Number of nodes in the cluster.
- Distance from the base station to CH.

4 Comparison of Routing Protocols

In this paper, we have compared the following routing protocols according to their design characteristics:

- LEACH [1]: Low-Energy Adaptive Clustering Hierarchy.
- HUMS [2]: Half-qUadrant-based Moving Strategy (HUMS).
- AERP [3]: Average Energy Routing Protocol.
- CBCA [4]: Centrality-based Cluster Approach (Table 1).

5 Future Research

Future works in routing techniques focus on different directions. In comparison with the above-mentioned routing protocols, the variance of energy is high in the LEACH, moderate in HUMS and AERP, whereas in CBCA, it is low. Although CBCA is relatively better when compared to other routing protocols, there is a need to make the variance of energy more stable. Also, prolonging the network lifetime has been of a great interest due to resource limitations in wireless sensor networks.

There needs to be a significant research done to improve the lifetime of the wireless sensors. Works on reducing the energy consumption by the nodes need to be done in a more efficient manner.

6 Conclusion

Prolonging the network lifetime has been of a great interest due to resource limitations in wireless sensor networks. Here, we have done a comparative analysis of energy efficient routing protocols, namely LEACH, HUMS, AERP, and CBCA. By comparing, we can observe that the energy dissipation and energy consumption of the sensors are lesser in CBCA than the other routing techniques. When we take into consideration the energy variation, it is highest in LEACH, moderate in AERP and HUMS, but better stable in CBCA. As found in the comparative study based on the above parameters, lifetime of the nodes is more in CBCA. Although the CBCA routing protocol looks promising, there is a need to explore the practicality of the technique employed. We have highlighted some of the future challenges and issues in improving the energy efficiency of sensors.

References

1. Heinzelman WR, Chandrakasan A, Balakrishnan H (2000) Energy-efficient communication protocol for wireless microsensor networks. In: Proceeding of 33rd Hawaii international conference on system sciences 2000, vol 8. pp 8020
2. Sun L, Bi Y (2009) A moving strategy for mobile sinks in wireless sensor networks. IJSNet 5(3):173–184
3. Wang YH, Yu CY, Chen WT, Wang CX (2008) An average energy based routing protocol for mobile sink in wireless sensor networks. In: First IEEE international conference on Ubi-media computing. pp 44–49
4. Raghunandan GH, Metri S (2012) A novel approach to increase overall efficiency in wireless sensor networks. In: IEEE international conference on computing, electronics and electrical technologies 2012. pp 699–703

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