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Improving the Performance of Wireless Sensor Networks by Various Energy Efficient Schemes

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Abstract

Thanks to the rapid development of wireless communication and microelectronics, wireless sensor networks emerged and have been used in various fields to sense the characteristics of objects. Considering that the power of each node in a wireless sensor network is provided by a battery, and in most cases the battery is difficult or impossible to be replaced, how to effectively save the energy of the node is very important during the network runtime. To resolve the above issues, various energy-saving schemes have been proposed. In this paper, the classification of energy-saving techniques is illustrated firstly. Then, we present the typical protocols to prolong the lifetime of network in each category.

Keywords

Wireless Sensor Network; Energy Performance; Energy Saving.

1. Introduction

With the development of wireless communication and microelectronics, wireless sensor network (WSN) have emerged. In such network, every node can communicate with other nearby nodes directly, and also, these nodes can sense the characters of objects. Thus, wireless sensor networks have been widely used in various fields [1, 2] to obtatin the status information of objects, and a sample wireless sensor network is illustrated in Figure 1. However, each sensor node in WSNs are are powered by batteries, and it is very difficult to recharge or replace these batteries in most cases. Therefore, how to save the energy of nodes in the WSN so as to enhance the network lifetime is a important question.

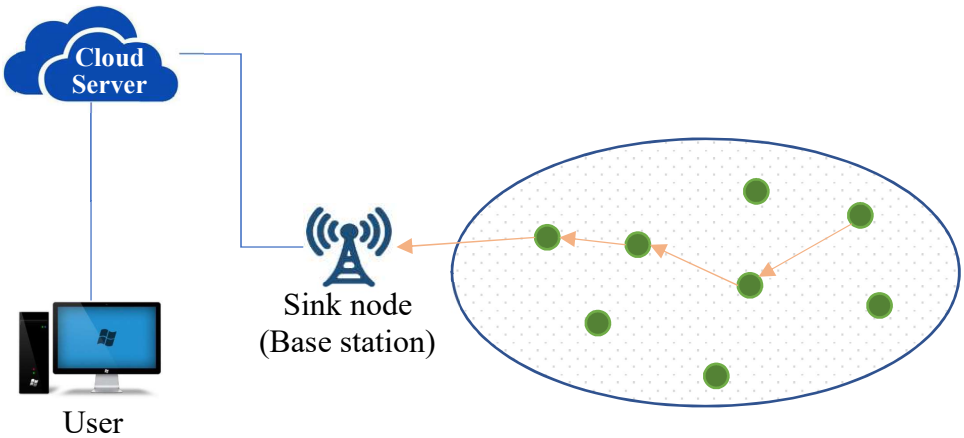

Figure 1. A sample network topology of wireless sensor network

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Various energy-saving techniques have been proposed to extend the network lifetime. According to the different methods to save energy in WSN, the energy-saving techniques can be categorized into data aggregation, MAC-based protocols and cluster-based protocols, which are shown in Figure 2.

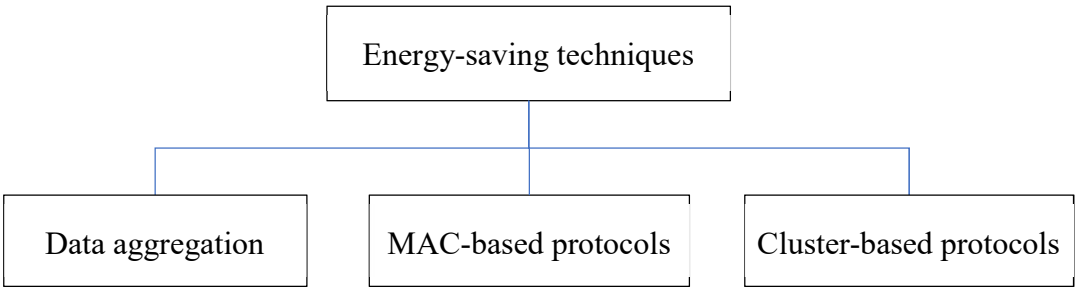

Figure 2. Classification of energy-saving techniques in wireless sensor network

In this paper, we aim to survey the classical schemes to improve the energy performance of networks in WSNs. In section 2, we illustrate the typical data aggregation methods. Then, we present the representative MAC-based protocols to save energy of nodes in section 3. In section 4, we show the classical cluster-based protocols, and we conclude this paper in section 5.

2. Data Aggregation Techniques

Data aggregation is the process of aggregating the sensor data from multiple nodes in order to eliminate the redundant data and provide fused information to the base station, and then, the energy consumption of nodes can be reduced.

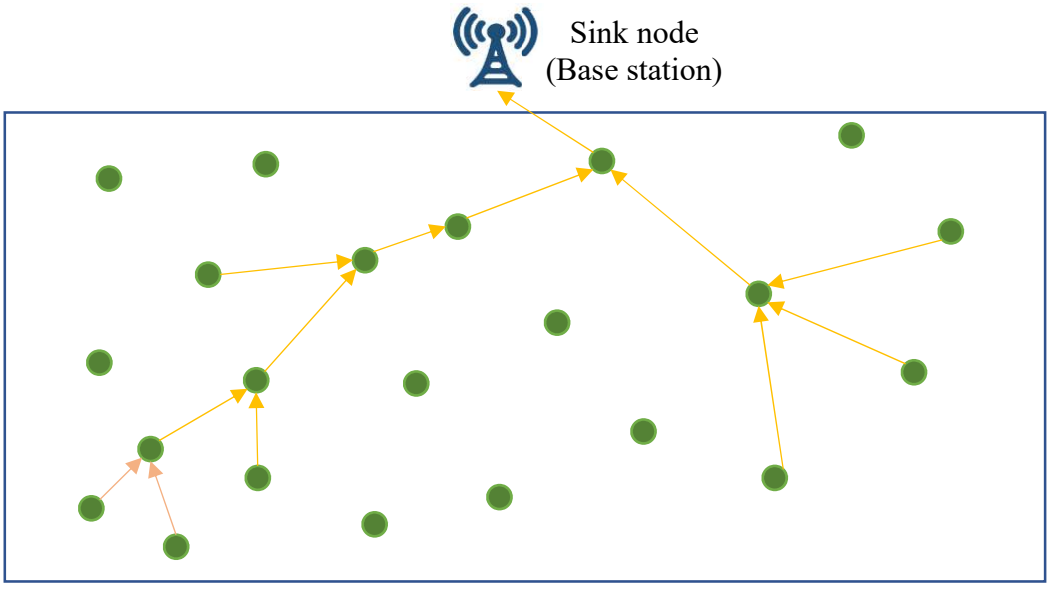

Figure 3. Data aggregation among nodes

Authors in [3] proposed an efficient tree-based energy-svaing scheme for WSNs with mobile sink. In the above protocol, researchers take advantage of a dynamic sorting algorithm to construct a tree-cluster routing structure for the nodes. This scheme aims to reduce the data transmission distances of the nodes by utilizing the tree structure and multi-hop concepts. Based on the mobile sink's position, the distances between the nodes, and the residual energy of each node, the suggested method makes

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an efficient decision for creating the routing structure. The energy consumption is reduced and the lifetime of the network is prolonged by balancing the energy load.

In [4], researchers try to study the creation of a data-gathering tree when there is a single base station in the WSN, and the aim is to extend the lifetime of the network. The authors first design a mechanism that starts from an arbitrary tree and iteratively reduces the work load on bottleneck nodes, which has the lower residual energy compared with other nodes. Then, they extend the above work to the case when there are several base stations and research the creation of a maximum-lifetime data-gathering forest. Analysis results indicate that both the above algorithms terminate in polynomial time and are provably near optimal.

The goal of research in [5] is to creat optimal aggregation tree in deadline-constraints WSNs, and a combinatorial optimization problem is cast to resolve the optimal tree construction, which has been proved to be NP-hard problem. The researchers use the Markov approximation framework to search close-to-optimal solution with bounded approximation gap. Moreover, to further improve the convergence of the Markov-based scheme, another initial tree construction algorithm with low-computational complexity is suggested.

3. MAC-based Protocols

The disadvantage of traditional SCMA/CA protocol is asking every node to sense the channel continuously, which is energy excessive. So as to reduce the energy consumption of nodes in the network, S-MAC protocol [6] suggests duty cycle operation. Based on the above scheme, the operation of nodes is divided into several round, which is called a frame. During the above frame, every node keeps in sleep state for a specific amount of time and then listens to the wireless channel for the rest of the frame. When node steps into sleep state, most components of nodes is power-off, and thus, the energy of nodes can be saved.

In [7], an energy-efficient and low-latency MAC protocol is introduced. In the above protocol, the state of nodes can be one of the following three modes: sleeping, receiving and sending. If a node has no data to transmit, it can go to sleep state to save energy. When a node begins to go to sending state, the lower-hop node will be in receiving state. After having been received data from the upper-hop node, each node can transmit it to lower-hop node in the sequent sending period. The above process is repeated until the data arrives at the desired node. Therefore, the multi-hop end-to-end delay is reduced greatly due to periodical sleeping. Furthermore, an adaptive sleeping scheme which makes the nodes with lower traffic have longer time to sleep is adopted to reduce more energy.

Recently, few researches have investigated the impact of a dynamic TDMA frame size on the network energy consumption. In [8], researchers proposed Sensor One shot Slot TDMA-based Reservation (S-OSTR) protocol to improve the energy efficiency in WSN. The proposed protocol employs the method of a dynamic active period. Because S-OSTR adopts a dynamic frame size that is built slot-by-slot according to nodes arrival to the network, and this results in a shorter frame size. The short frame size combined with proper spatial reuse scheme reduced an enormous amount of energy.

4. Cluster-based Protocols

In cluster-based protocols, network is partitioned into several clusters according to the distance among nodes, and the nodes in the same cluster has short distances. In each cluster, one node is selected as cluster head, and the other nodes are all clustrer members. In the sensor data retrieval process, cluster members first send its data to the local cluster head, and when cluster head aggregates all the data from the cluster members, it will transmit the data to the base station. Since the cluster-based protocols limite the communication scope of a large number of cluster members in the network and also reduce the redundant transmission of data, a large amount of energy can be saved. A sample of cluster-based protocol is shown in Figure 4.

In order to reduce and balance energy consumption of nodes in the network, researchers in [9] proposed EBDC protocol, which includes two phases: advertisement phase and transmission phase.

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The perdefined number of cluster heads are selected out in the advertisement phase, and every running cluster head makes decision whether to continue its current role or re-cluster the whole network according to the cluster size and the number of rounds that the running nodes operate as cluster heads.

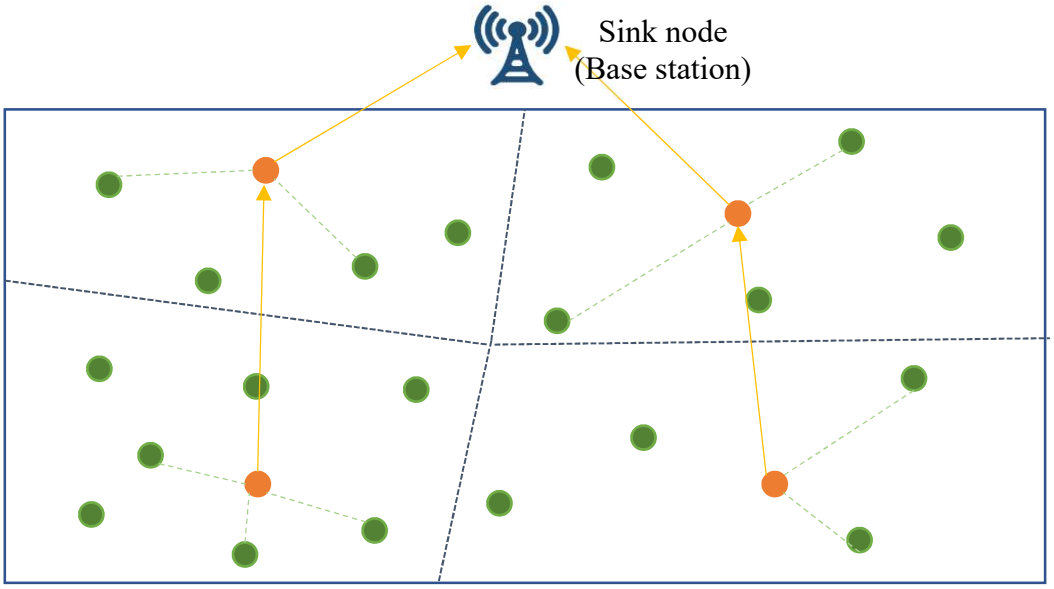

Figure 4. Sensor data retrieval in cluster-based protocols

Classical clustering protocols aim to enhance the network lifetime by improving the node clustering and inter-cluster routing in a distributed way, which are complex and energy-consuming. Researchers in [10] introduce a low-energy clustering protocol, called LEDC, for query-based WSNs. In LEDC protocol, a prediction-based scheme is first suggested to make centralized node status information maintenance scalable. Then, a centralized dynamic cluster formation algorithm is introduced to reduce the cost in the process of node clustering. Moreover, a energy-aware forwarding algorithm is raised to reduce and balance the energy consumption in inter-cluster routing. Simulation results have validated the superiority of LEDC protocol.

5. Conclusion

Nowadays, wireless sensor network has been widely used in various fields to build intelligent city. Nevertheless, the constraint energy resources of nodes in WSNs makes researchers have to consider the energy efficiency when designing a network protocol. In this paper, we first introduce the classical approaches to raise the energy efficiency in WSNs, and then, illustrate several typical protocols for each type.

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