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Energy Efficient Strategies in Wireless Sensor Networks with Mobile Sink

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Abstract. In this paper we present an overview of energy efficient strategies in wireless sensor networks (WSNs) with mobile sink. Firstly, we investigate the existing issues in WSNs. Then we focus on the problem of energy efficient data gathering strategy with mobile sink and present some existing solutions. Finally, we conclude this paper with some potential extensions which need to be further explored. Through the existing works, we can see that sink mobility can enhance the network performance.

Keywords: Wireless sensor networks, sink mobility, energy efficiency, data gathering.

1 Introduction

In wireless sensor networks (WSNs), Sensor nodes, which are powered by batteries, are deployed in un-attended or dangerous environments. This makes sensors die quickly because of the energy depletion of batteries. So the most important issue for WSNs is minimizing the energy consumption of sensor nodes.

In WSNs with static sink, energy of sensor nodes in the vicinity of sink deplete quicker than other nodes because of the concentration of data traffic towards the sink, which give rise to the hotspot problem [1]. Sensor nodes near the sink will die quickly and the sink will be isolated, the data gathered across the network will no longer be transmitted to the sink. Therefore, sink mobility are proposed to tackle this issue [2]. With the sink moves, the hotspot area will change. This can help uniform the energy consumption of sensor nodes and prolong the lifetime of the whole network. However, sink mobility also contributes to issues such as data latency and communication overhead. Thus, the defects of sink mobility should be taken into consideration before using it.

The main contribution of this paper is to provide an overall survey on the energy efficiency routing protocols for WSNs with mobile sink. We address on the strategies these protocols used to transmit data, considering the energy they consume and how

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they achieve this. Moreover, we discuss the benefits and defects of each protocol with some metrics (data latency, stability and power consumption).

2 Movement Patterns based on Mobile Sink

Recently, many researches have been conducted on the issue of prolong the lifetime of a WSN through the management of mobile sink [2]. We can classify sink mobility into three categories: random mobility, predictable mobility and controllable mobility. Table 1 shows the characteristics, issues and examples of each category.

Table 1. Classification of Sink Mobility Approaches

Approaches	Characteristics	Issues	Examples
Random Mobility	Sinks randomly move	data packet drop, data latency	TTDD[3]
Predictable Mobility	Sinks moving along predefined trajectory	data latency	VGDRA[5]
Controllable Mobility	Sinks move to the interest area	Motion control, data latency	BRH-MDC[6]

Also, there are some issues need to be considered before designing energy efficient routing protocols with mobile sink:

- Motion control. For predictable mobility, speed control should be considered. For uncontrolled mobility, both speed control and trajectory design is under consideration. But for random mobility, there is no such issue since the sink is not under control.
- Data latency. A sensor node is far from a sink or the network traffic overload will give rise to latency. Also, the time for sensor nodes locate the position of a sink may cause latency.
- Reliability. Minimizing the data packet loss can increase the reliability of the network. The data buffer overflow of sensor nodes or the sudden increase of traffic load of the network will lead to packets loss.

3 Data Gathering Strategies of WSNs Based on Mobile Sink

In this section, we present a comprehensive review of energy efficient routing protocols of WSNs with mobile sink. We first introduce delay-torrent routing strategy, which is most energy efficiency since it produces less overhead of the network; then we introduce delay-sensitive routing strategy, which produces huge communication overhead for location update and mobility-aware data routing.

3.1. Delay-torrent Routing

In delay-torrent routing strategy, data packages are not necessarily needed to be disseminated to the sink in real time. The data packets are stored in buffer or sent to rendezvous point (RP). Below we will introduce some existing delay-torrent routing algorithms in details.

1) Data Mules: Shah et al. present three-tier mule architecture do decrease energy consumption of nodes and reduce infrastructure cost [7]. MULEs communicate with sensors or an access point (AP) via single hop routing when a MULE moves among the communication range.

Advantages and disadvantages: Data MULEs can decrease the energy consumption of sensor nodes and relief communication overhead of the network; however, data latency of this approach is extremely high.

2) TTDD: Luo et al. present a Two-Tier Data Dissemination approach [3] to address the multiple mobile sink problems. The whole network will be divided into grids with a predefined size. It updates forward information of the sensor to the closest grid point.

Advantages and drawbacks: This approach divides the network into girds, and thus avoids flooding the whole network for sink location; however, Data routing of this protocol can be optimized due to its flood-based feature.

3) DQM: Data Quality Maximization (DQM) [8] is a backbone-based routing protocol. It consists of three tiers: common sensors at bottom tier; gateways at middle tier; mobile sink at upper tier. Besides, gateways aggregate incoming data and transmit data with sink in single-hop routing.

Advantages and drawbacks: This approach eliminates energy consumption through single-hop routing between gateways and mobile sink; However, DQM reduces energy consumption at the cost of long data latency.

4) Subflow-based and Queue-based models: In [9], Yun and Xia proposed a framework to improve the network lifetime. It reduces energy consumption at the cost of data latency. This framework is divided into two models through the data buffer strategy: subflow-based model and queue-based model.

Advantages and drawbacks: This framework effectively prolong the lifetime of sensor nodes. It provides two different models that can be conducted on different scenarios; however, it neglects the traveling time of mobile sink between each stop.

3.2. Delay-sensitive Routing

In delay-sensitive routing strategy, data packages should be transmitted to mobile sink in time via multi-hop routing. Frequent routing update is needed to transmit data packets to mobile sink in time. Below we will introduce some existing delay-sensitive routing algorithms in details.

1) Joint Sink Mobility and Routing: Luo and Hubaux in [2] analyzed the network energy consumption when mobile sink moves in different trajectory. They researched in theoretical analysis and mathematic simulation, and then found that when sensors are deployed in circle, the most energy efficient moving trajectory for mobile sink is to move along the edge of the network.

Advantages and drawbacks: They proposed a theoretical proof on sink mobility can improve network performance; however, in large scale WSN, this approach will give rise to data latency.

2) GMRE and MILP: Greedy Maximum Residual Energy (GMRE) [10] and Mixed Integer Linear Programming (MILP) [11] are both motion control strategy to transform single sink. In GMRE, sink will move to the high residual energy area to balance network energy consumption. In MILP, it provides a centralized solution. It needs to have a global view of network topology, communication costs, etc.

Advantages and drawbacks: Both of them can improve the performance of the network; However, For GMRE, updating residual energy of the whole network will bring great communication overhead. For MILP, centralized management is hard to conduct and it requires large calculation.

3) VGDRA: Khan et al. present A Virtual Grid-Based Dynamic Routes Adjustment Scheme [5] to balance energy consumption and data latency with one mobile sink. The network was divided into K uniform sized cells; each cell has a fixed cell-header, which is used for collect data from member nodes and transmits data to mobile sink.

Advantages and drawbacks: By using proposed rules, only limited cell-headers need to reconstruct routes. This approach can effectively reduce communication costs; however, cell heads will die quickly because of communication overhead.

4) EECLA: Nagamalar et al. propose an Energy Efficient Cluster based Approach for Data Collection with Multiple Mobile Sink [12], it is an improved approach based on VGDRA. The key idea of this approach is optimizing routing scheme by using multiple mobile sink.

Advantages and drawbacks: Using residual energy as a metric can prolong the lifetime of sensor nodes and improve the performance of WSN; however, mobility moving speed is not under consideration in this approach.

4 Conclusion

In this paper, we present a review of energy efficient strategies in WSNs with mobile sink. We classify the movement patterns into three categories: Random Mobility, Predictable Mobility and controllable Mobility. Each of them has its advantages and weaknesses. Then we investigate data gathering approaches: delay-torrent routing and delay-sensitive routing. The former approach focuses on energy efficient the latter concentrates on decrease data latency. Finally, we present some aspects need to be further explored.

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