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A Survey on Routing Protocols for Wireless Sensor Networks with Mobile Sink: Application

Farhoud Jafari Kaleibar[1*], Mazaher Kianpour[2] and Saba Darvishi[3]

1-P.h.D Student Computer Science and Engineering Faculty Shahid Beheshti University Tehran, Iran
2-M.Sc Student Computer Science and Engineering Faculty Shahid Beheshti University Tehran, Iran
3-Dept. Agro-Technology, College of Abouraihan, University of Tehran, Tehran, Iran

Corresponding Author: Farhoud Jafari Kaleibar

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A B S T R A C T

Wireless sensor networks, includes thousand's of sensor nodes which usually use multi-hop communication to transmit sensed data to base station. As a result sensors near the sink will deplete their energy quickly and the sink will be isolated from the network. To mitigating this problem one of the possible solutions is to move sink all around the network. Sink mobility causes some challenging issues in WSNs which make it impossible to use classic routing protocols of Wireless sensor networks with static sink. In this paper, we listed several routing protocols for WSNs with mobile sink to see how they deal with challenges. The aim of this survey is to consider, best solutions for challenges and important factors in developing new protocols. Finally, we have comparative analysis of mobile sink routing protocols

Keywords: *wireless sensor networks; routing protocols; mobile sink; energy-efficiency.*
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INTRODUCTION

Wireless sensor networks consist of hundreds or thousands of sensors that cooperatively send the sensed data to base station. There are many applications for wireless sensor networks, including: military, environmental, health and so on (1). The main constraints of WSNs are that, the sensors are limited in battery power which leads to reduction of network lifetime.

Routing protocols can improve energy consumption by reducing the hop count and optimizing other network parameters. However the one-hop neighboring sensors of a sink participate more in data transmission, hence deplete their battery power quickly and results in isolation of the sink. This phenomenon is called the energy hole problem (2). One way to address this issue is sink mobility. Due to the unlimited energy source of sink, most researches conducted using mobile sink.

Mobile sink can balance energy consumption among sensors and prevent sink isolation, but it introduces new challenges. Numbers of protocols have been proposed for WSNs with mobile sink and each handles sink mobility challenges differently (3-6).

In this paper, we will categorize these protocols using different parameters and challenges. Then, a comparative analysis of protocols will be done. The main goal of this paper is to show the weaknesses and strengths of existing routing protocols for wireless sensor networks with mobile sink.

The remainder of the paper is organized as follows: In section 2 we review related works. The most challenging issues for WSNs with mobile sink are discussed in section 3. Section 4 reviews existing routing protocols for WSNs with mobile sink. Section 5 compares and categorizes above protocols on the basis of challenges and section 6 concludes the paper.

RELATED WORK

This section summarizes similar studies of analyzing routing protocols of wireless sensor networks with mobile sink or sinks. It also elaborates different approaches used to categorize routing protocols.

Waghole) (7) focused on data collecting challenges and investigated impacts of different states of sink (static, mobile and multiple sinks. They evaluated some performance parameters, for static, multiple and mobile sinks in WSNs. This paper focused on data collection or dissemination using static & mobile sinks with effective result of QOSs. However, they ignored some challenges like moving patterns for mobile sink, number of sinks for multiple sink modes etc.

In (8) Shrivastava) presented a survey of the sink deployment techniques in the wireless sensor networks. They provided a complete analysis of the metrics supported by each technique during sink reposition and presented the limitations of each technique. Though this paper, presents a thorough study of sink repositioning techniques, it cannot cover all aspects of routing protocols for WSNs with mobile sinks.

There are little survey works in the mobile sink routing protocols topic. Existing survey on sink mobility in WSNs consider only the limited parameters to compare routing protocols. Hence the main purpose of this paper is to provide a comprehensive survey on routing protocols for WSNs with mobile sink.

Challenging issues and Factors

This section presents important challenges and main factors that should be considered in designing routing protocols. Furthermore sink mobility cause some challenging issues that should be addressed. The factors and challenges are as follows:

Strategies of data collection

There are three ways of collecting data from sensor nodes: Proactive, reactive and hybrid. In proactive approach, routing information is set up and maintained all the time, therefore when a sensor needs to send data to base station, there is always a path to it. In reactive protocols, the paths are set up only when it's needed. There is another approach that combines reactive and proactive techniques and hence called hybrid. In hybrid protocols some nodes usually, have routing information and other nodes need to ask them about paths.

Network structure

In WSNs, the structure of the network can play an important role in the performance of routing protocols. Based on network structure, routing protocols fall into three categories: Flat, hierarchical and location based. In flat networks, each node has the same role and they collaborate together to deliver data to base station. Hierarchical or cluster-based routing, tries to differentiate higher energy nodes from low energy nodes and use just higher energy nodes to send information to the base station. In location based routing protocols, sensor nodes are aware of the location of all other nodes within the network.

Data dissemination

Based on the nature of applications, routing protocols fall into three categories (11):

- ***Event-Driven***: When a node detects an event, it starts to send data to sink, such as intrusion detection, target tracking and military applications.
- ***Periodic sensing***: Sensors continuously monitor the environment and report measurements periodically to sink, such as in precision agricultural application or in weather monitoring application.
- ***Query-based****:* The generated data kept in sensor nodes until they react to the queries of sink by returning requested data, such as in traffic surveillance application.

Sink mobility patterns

One of the main challenges of mobile sink in WSNs is the moving pattern of the sink. Depending on the application and network size, there are different approaches. These approaches are (10):

- *Random mobility:* Sink can move randomly toward all directions. The main features of this pattern are simplicity and unpredictability of sink positions.
- *Controlled Mobility:* Movement of sink is controlled in a way that can achieve better results. An example of this approach is moving sink based on the energy level of sensor nodes.
- *Predictable mobility:* The sink mobility follows certain patterns that are defined and can be computed. Such movement can be movements along a predefined trajectory like a circle, line and so on.

Energy-aware routing

Routing protocols that select path to sink based on energy metrics (e.g., Residual energy of sensor nodes or average Residual energy of cluster) are classified as energy aware protocols. Energy aware routing can lead to uniform energy consumption across the networks and hence prolong the network lifetime. In the case of mobile sink, energy aware routing is to move sink in a way to achieve energy efficiency in the network.

Reliability

In some applications of WSNs reliable transition of event data is essential. Therefore, Due to the error prone nature of wireless sensor networks, reliable delivery of data from sensor nodes to sink is one of the main challenges. In WSNs reliability can be categorized into different levels as follow:

- ***Packet or Event reliability level*:** This level of reliability is concerned with how much information needed to notify the sink of events occurrence.
- ***Hop-by-Hop or End-to-End reliability level*:** In hop-by-hop reliability level, the next hop is responsible for reliable transition of data to sink. However, in an end-to-end reliability level, the end points are responsible for ensuring reliable delivery of data.

Fig. 1 shows classifications of reliability in WSNs.

Delay Tolerance

An application called delay tolerant if generated data by sensors do not have an expiration time. In contrast, some applications (e.g., intrusion detection in military application) needed to deliver generated data immediately. Sink mobility causes delay in locating the sink. So an efficient protocol has to offer minimum delay to acquire sinks location when a sensor needs it.

Single path or multipath routing

Single path protocols can discover one or more routes to the sink and then choose the best path to send data. But some protocols use more than one path to transmit data (multipath routing). This is mostly due to energy or load balance.

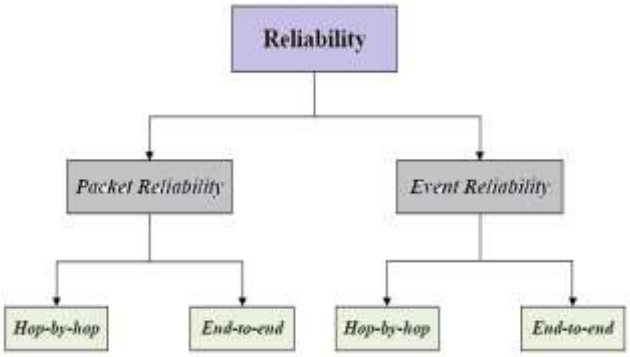


Figure 1. Classification of reliability levels in WSNs (12)

routing protocols for WSns with mobile sink

In wireless sensor networks with mobile sink, the data must be routed from sensors to the moving element. Depending on application scenarios, the sink moving patterns, speed and some challenges should be considered in routing protocols. Some routing protocols for WSNs with mobile sink are introduced below.

LURP

In (4) mobile sink broadcast the location information within a local area instead of whole network. At first the destination area is set and a static sensor inside the area will route data packets to the sink. As the sink moves inside the selected area, it needs only to rebroadcast its position inside the area. Each time the sink moves out of selected area, it needs to broadcast its location information to entire network. So this protocol reduces control message overhead by limiting broadcast messages.

CAEE

CAEE (5) is a cluster based protocol based on discrete sink mobility and it addresses problem of congestion and energy efficiency in WSNs. To achieve data persistency in network, the authors developed in-network storage model which ensures

data persistence under congestion and localizes its effects. In this protocol each node starts to broadcast the collected information to the nearest data collector node which called Mini-Sink (MS). Then MS receive and store data in one of the buffer nodes. The mobile sink stops near each MS and request for data.

EBRAMS

EBRAMS (6) protocol is focused on minimization of latency and energy dissipation. It defines distance of concentric circular rings as a collecting rows and difference of transmitting coordinates of cluster as a parallel column. It has two phases: Clustering phase and data transmission phase. The first phase is used by the Mobile base station to form the cluster and also to construct the chain it uses the greedy algorithms. The second phase is used to transfer data from sensors to mobile sink. Parallel communication is used in this phase to decrease delay and collecting rows is used based on residual energy.

EEMSRA

EEMSRA (13) is a clustering protocol which is based on LEACH (19). Cluster formation in this protocol is similar to LEACH but the main feature of EEMSRA that differentiate these protocols is TDMA Scheduling of cluster heads. It is used to inform sensors when they can transfer data to cluster heads. In this protocol next location of sink will be determined by average residual energy of clusters. The cluster with high average energy will be next target of sink to move.

SinkTrail

SinkTrail (14) is a proactive data reporting protocol for WSN with mobile sink. The sink moves along the network and broadcast its location information to the whole network and collect data from sensor nodes. It has two key features. One of them is flexibility in the movement of mobile sink (i.e. dynamic adaption). The other one is a logical coordinate system without requirements of GPS device. This coordinate system defined by a history of hop count distances from the sink and can help sensor nodes to select the closest route to sink.

TSA-MSSN

In (15) authors proposed an energy efficient protocol using Transition Scheduling Algorithm (TSA) for WSNs with mobile sink. The idea is using one-hop instead of multi-hop communication to reduce energy consumption of forwarding data through sensor nodes. However, this mechanism has a tradeoff between delay and energy efficiency. So this protocol is suitable for delay-tolerant applications.

DT-MSM

DT-MSM (16) proposes a mechanism to increase the lifetime of wireless sensor network when the applications tolerate delay. Hence, instead of sending data immediately, the node can store it till the sink is in the most favorable location to achieve energy efficiency. This protocol integrates energy efficiency techniques, multi-path routing, delayed data delivery and active region control into one optimization problem.

TTDD

The aim of Two-Tier Data Dissemination (TTDD) protocol (17) is to reduce flooding messages related to sink positions. This protocol uses a grid structure that only sensor nodes at the grid points need to get information about routing path. When sink arrives at any cell of this grid structure, flood its query within cell. This query traverses two tiers to reach a source. This query forwarding mechanism determines the routing path to sink.

MobiRoute

In (18) the authors investigated an approach that uses mobile sink to balance traffic load and prolong the network lifetime. This protocol is a superset of berkeley MintRoute (19). To cope with mobility of sink three techniques has been proposed. The first one is beacon messages to detect broken links, due to sink mobility. The second mechanism is using states to convey topological changes in the network quickly and the last one is minimizing packet lost during moving periods of sink by means of reduction of sending rate at the last hop nodes. To implement this mechanism, using a buffer in last hop nodes has been proposed.

Comparative analysis

We discussed challenging issues arises from sink mobility in previous sections. We also surveyed routing protocols for wireless sensor networks with mobile sink. In this section we try to categorize routing protocols based on challenges and some performance factors. Table 1 summarizes routing protocols for WSN with mobile sink and presents how they handle challenges.

Selected protocols are the famous protocols in the field of WSN with mobile sink. Simulation based analysis of these protocols shows their efficiency. But the way of handling challenges differs in various protocols and it makes them suitable for different applications. On the other hand, applications can play an important role in determining the challenges. For example, application used in (14) is precision agriculture and it dictates sink mobility pattern to be dynamic due to preserving crops.

To compare routing protocols, we should consider all of the challenges and parameters since they may have impacts on each other.

Conclusion

In this paper, we presented a review of the existing mobile sink routing protocols for wireless sensor networks. The challenging issues related to the sink mobility and performance factors are discussed in details to provide an insight into the mechanisms and techniques used in routing protocols.

This survey provides a comprehensive review of routing protocols for WSNs with mobile sink. For each protocol we determined how they address challenges and performance factors. So evaluation of routing protocols can be easily done by comparing parameters.

Table 1. Summary and comparison of mobile sink routing protocols

Protocols / Factors	LURP (4)	CAEE (5)	EBRAMS (6)	EEMSRA (13)	SinkTrail (14)	TSA-MSSN (15)	DT-MSM (16)	TTDD (17)	Mobi-Route (18)
Strategies of data collection	Proactive	Proactive	Proactive	Proactive	Proactive	Proactive	Proactive	Proactive	Proactive
Network structure	Location-based	Cluster-based	Cluster-based	Cluster-based	Flat	Flat	Flat	Location-based	Flat
Data dissemination	Event-based	Query-based	Periodic-based	Periodic-based	Periodic-based	Query-based	Query-based	Query-based	Periodic-based
Sink mobility patterns	Random / Predictable	Predictable	Random/ Predictable	Controlled	Predictable (dynamic)	Predictable	Controlled	Random	Controlled/ predictable
Energy-aware routing	No	No	Yes	Yes	No	No	Yes	No	Yes
Reliability	No	Event level / End-to-End	No	No	No	Packet level / Hop-by-Hop	No	No	Packet level / End-to-End
Delay tolerance	No	Yes	No	No	No	Yes	Yes	No	No
Single path or multipath	Single path	Single path	Single path	Single path	Single path	Single path	Multi-path	Single path	Single path

Therefore, from the table 1 it can be concluded that:

- Some protocols have not any solution to some of the challenges.
- Applications are important factors in how protocols address challenges.
- To evaluate routing protocols, we cannot consider only one parameter. Because addressing challenges may have impacts on other challenges and factors.
- A new energy-efficient routing protocol for WSN with mobile sink must be able to address all challenges and factors effectively.

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