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A Survey on the Mobile Sink Hierarchical Routing Protocols in the Wireless Sensor Networks

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ABSTRACT

The wireless sensor/actor network (WSAN) is a network of many small nodes in which there are a number of sensor/actor. The sensor/actor has intense interaction with the physics environment. It receives the information of the environment through the sensors and then reacts through the actors. The relation between the nodes is wireless. Each node works independently and without the interference of human and is usually small with limitations in the processing power, memory capacity, power supply, etc. The main task of a wireless sensor network is gathering information from the under covered area. These information are gathered by the sensors and are transferred based on the routine algorithms to the sink. The sensors in the sensor wireless networks have limitations such as energy and computational power. We explain a general review of the mobile sink hierarchal routing protocols in the wireless sensor networks and then compare each of these methods.

Keywords - **Wireless sensor networks, Hierarchical, Sink, Routing protocols.**

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1. INTRODUCTION

The wireless sensor network is a distributed, autonomous and self-organizing system which is comprised of many small sensor nodes with the operation which need low energy [1]. The sensor networks have limitation in energy resources, processing and computation. These networks in items have function in areas such as monitoring the environmental conditions, gathering data like temperature and pressure and militaristic applications [2], [3]. The the gathered data is sent by the sensors to the base station or the sink. For administering this congested and distributed networks, challenges such as scalability, fault tolerance, strength and presenting energy solutions should be considered [4]. The main responsibility of a wireless sensor network is gathering data in the covered area. These information are gathered by sensors and are transferred based on routing algorithms to the sink. The sensors which are used in the wireless sensor networks have a series of limitations such as energy and computational power. The sensors are established in areas that are not accessible. Therefore changing or recharging their batteries is not possible. Therefore the issue of optimum energy consumption in the wireless sensor networks is one of the important challenges in this field which many researches are conducted about it. In a wireless sensor network, the nodes cooperate with each other for transferring the information to the sink and transfer the data to the sink. If the sink is static meaning that during the time, its location does not change, the nodes near the sink should transfer the data to the sinks which are distant to the node. In this paper we conduct a general review on the mobile sink hierarchical protocols and analyze each of them. The rest of the structure of the paper is so that in the second section, the hierarchical routing methods are explained, in the third section we focus on the comparison of routing methods in hierarchal sink in wireless sensor networks and finally in the fifth section a conclusion is done from the mentioned subject.

2. MOBILE SINK HIERARCHICAL ROUTING PROTOCOLS

There are many methods for solving the routing problem in the wireless sensor networks with mobile sink but the most important and widest methods are based on hierarchical structures. The hierarchical methods are for decreasing the overload of sending packages based on the sink position in the network and a hierarchy of nodes are formed in the network and the structure of this hierarchy can be consisted from two or three layers. The nodes in in the virtual overlapping structure receive the position of the sink while other nodes receive the position of the sink whenever needed. The hierarchical methods can be categorized to methods based on grid, tree, clustering, backbone, factor, environment and mixed and sone of the protocols used in these categories will be introduced [5].

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2.1 METHODS BASED ON GRID:

Protocols based in this class are created at the highest level of virtual hierarchy of a grid structure. The grids which are located at the highest level, form the junction of the grid network. For forming the grid, various shapes such as square, triangle, hexagon, etc can be used.

TTDD: Dissemination of two layer data in the large scale wireless sensor network [6] is one of the hierarchical methods. This method is based on the virtual grid on the beginning. In this protocol when the source node produces data, it begins to create a virtual grid around itself and a junction node is formed in the whole virtual grid network. For creating grid, the nodes should be aware of their position. When a sink/sinks request data, this request disseminates locally among the cells (in the cell which the source created as the grid around itself) and this request is sent towards the source through middle nodes. Then the data are sent from the source to the sink reversely. In order to move the sink, the forward tracing chain strategy [7] is used. The problem of this method is that if several nodes, produce data simultaneously, the number of virtual grids increases and the increasing of the control data for the grid network occurs. Therefore there would be huge overload from the mobile sink for gathering the data from the two nodes and this issue increases the energy consumption.

GBEER: This method is similar to the TTDD method with the difference that unlike the TTDD, a virtual grid is created for all sources [8]. For creating the virtual grid, the nodes should be aware of their location. The request for data from the sink to the origin and dissemination of data from the origin to the sink are done in this grid. Dissemination of data is sent horizontally in the grid network but the data requests are sent vertically.

GBEER: In order to decrease the overload of TTDD, this method was created in a way that a grid structure is developed in the network but the node which create the grid might be hotspot or lose their energy quicker. For preventing this problem, the grid structure should change once in a while which is time-consuming and costly. Other methods which fit into this category include CMR [9], HPDD [10], HexDD[11].

2.2 METHODS BASED ON CLUSTERING:

The protocols which belong to this category, use clustering for dividing the network and are placed in the highest level of clustered nodes. Creating the clustering method is more complex than creating the grid structure. But since the structure clustering mechanism is aware of the topology, it gives us a more efficient hierarchical structure. Some of the methods based on clustering are as follows.

HCDD: is similar to the GBEER method which creates a hierarchical structure for all the nodes. The cluster heads are called routing factors because they are responsible for dissemination of the data requests. For determining the cluster heads the Max-Min D-Cluster Formation Algorithm is employed [12]. The advantage of this method is that it can create a hierarchical structure without the need to know the location of the nodes. But the problem of this method is that it have huge overload.

EEMSRA: This method is based clustering which is similar to the LEACH method. LEACH is a method for randomly selecting the cluster heads which are used as a gate for sending the information to the sink. In order to prevent the hotspot problem, the cluster heads should change periodically. The cluster heads create the TDMA scheduling for determining the time of dispatching the data of the nodes. From this viewpoint, the EEMSRA algorithm is a cross-layer protocol which synchronize in the man level. Also the aggregation of data is done in the cluster heads. The sink disseminates the address of clustering which should be met in the network in order for other nodes to update their route toward the sink in their table. Although this method consumes high amount of energy, but it needs the sink to know its shortest route. Also there has been proposed a method for determining the route of the sink with regards to the energy of the cluster head in a way that the sink chooses from the nearest cluster heads which has the highest energy. Since EEMSRA should be formed the scheduling time of TDMA in the clusters, it needs mac layer requirements so it can not be employed in the large networks with many sensors. The other limitation of the EEMSRA is the fact that the movement of mobile sink should be controlled. In order to prevent creation of hotspot, the cluster heads should change. With regards to all the objections to this method, from the energy consumption viewpoint it is a very efficient method.

MSRP [13]: Is very similar to the EESMRA method with the difference that the aggregation of data in the cluster heads are done when the sink reaches the cluster head therefore MSRP is only appropriate for delay-tolerant applications in addition that the protocol does not guarantee that the sink meets all the cluster heads at a time.

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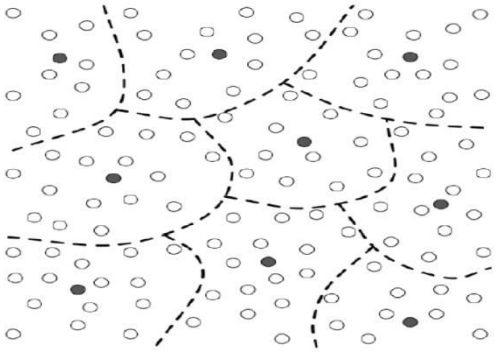


Figure 1. (HCDD, EEMSRA, MSRP), Methods based on clustering [13]

2.3 METHODS BASED ON TREE:

These category of protocols, create a overlapping virtual tree structure. The sink declaration is usually transmitted from the root to the leaves.

SEAD[1] [14]: Uses minimum-cost weighted Steiner trees. This method is similar to the TTDD method which creates a separate tree for each source. For creating tree and disseminating the data, the nodes should be aware of their location and also for determining the sink route they use forward tracing chain strategy. The overload of this method is very high because the creation of separate trees for each node but this method creates an intelligent virtual structure in the second layer of the same Steiner tree.

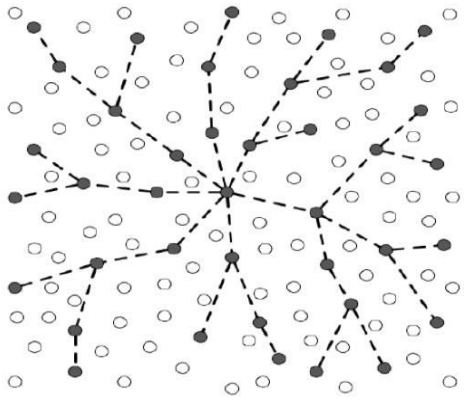


Figure 2- Tree based method (SEAD) [14]

2.4 BACKBONE BASED METHODS:

The protocols of this class, create a backbone for all the network which includes nodes with several roles.

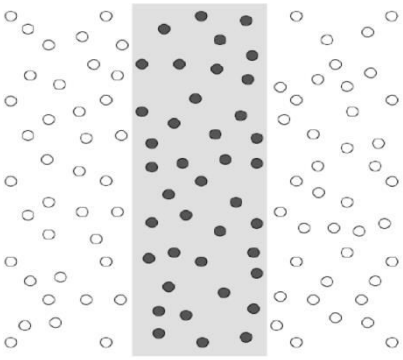
DDB [15]: Creates a backbone as the second layer. This backbone includes head nodes and gateways. The head nodes create a cluster around themselves and organize for transmitting the data in their cluster. The head nodes are in relation with each other through gateways and maintain the structure of the backbone. The sink is connected to the head nodes for receiving the data and sending the requests. In this method if the network is very large, a backbone with many branches is created that causes a large overload for transmitting the packages in the network. But the overload of backbone change for preventing the creation of the hotspot is low.

2.5 ENVIRONMENT-BASED METHODS:

In these methods a series of nodes in the environment with specific border for the higher layer are used instead of complex structures. The cost of creating hierarchy is minimum in these methods to prevent from creating hotspot instead of structure change, the size of the environment is considered large to distribute the load on an appropriate number of nodes.

LBDD [16]: A narrow vertical strip of nodes are selected which divides the network into two equal sections (figure. 3). The nodes in this strip are called in-line. The data sensors, transmit the data to the in-line sensors and then these nodes transmit the data directly to the sink and in case the sink wants to sent, transmits to these nodes. The implementation of this method is very simple and access to this strip is easy for the nodes, hence the overload of this method is easy. But because the in-line nodes use broadcast method the energy consumption of this method is quite high.

Figure 3- Environment-based method [16]



Railroad [17]: Creates a virtual structure named rail. This rail is a closed loop of a number of nodes which form a whole network (figure 4). The nodes in the rail are called rail nodes. When a source identifies the data, the information about this data (metadata) is transmitted to the nearest rail node. When a rail node receives this data, it creates a station which is comprised of a number of nodes with the lowest communicational width and with the center of the rail node. Metadata is shared between the nodes in a station and sink requests for the metadata and when this request reaches the rail node, the rail node informs the location of the sink to the

[1] Minimum-Energy Asynchronous Dissemination to Mobile Sinks in WSNs

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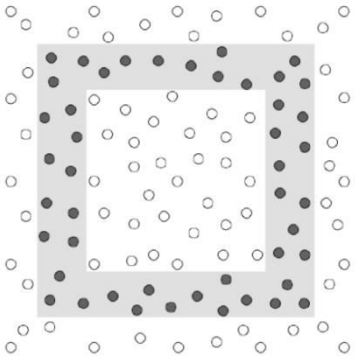
source and the source can transmit the requested data directly to the sink.
The railroad has solved the broadcast problem in the LBDD but its delay in transmitting the data to the sink is more. Also using metadata leads to energy saving and increasing the delay.

Figure 4- Environment-based method (railroad) [17]



Ring protocol: Another method called ring routing [18] resides in this category which creates a loop of single nodes (figure 5) and the sink announces its location to the nodes. Since these nodes are always aware of the position of the sink the nodes which want to transmit the data to the sink, send request to these nodes and ask about the location of the sink. In order to prevent creation of hotspot, the loop between the nodes changes. This method has low overload and the structure is simple and the delay of the data is low. The problem of this method is the scalability issue. In very large networks the overload of creating the nodes is high.

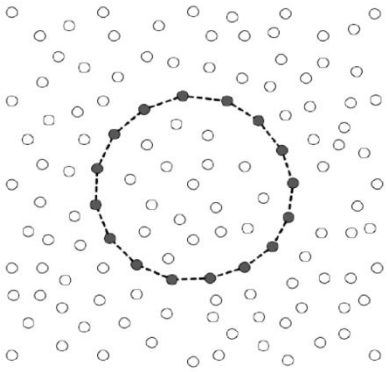


Figure 5- Environment-based method (ring protocol) [18]

2.6 COMBINED METHODS:

As it is obvious from the name of this class of the protocol, in this category, one or several virtual structures are combined.

MGRP[2] [19]: Is a combination of grid-based methods and clustering. A recursive grid network is constructed similar to QDD but the junction points are not the centers for dissemination of data. In each cell of the grid, a distributed clustering algorithm is executed and the cluster heads are selected as the data aggregators nodes. The cells have binary addresses and are easily accessible by the sinks. This method has a simple structure but its overload is high and there has not been proposed a solution for the hotspot problem.

3. COMPARISON OF MOBILE SINK HIERARCHICAL ROUTING METHODS IN WIRELESS SENSOR NETWORKS

In this section of the paper each of the mobile sink hierarchical methods are evaluated and the data type and overload of each of these methods are compared separately. In the table 1 a summary of the hierarchical methods are their comparison are represented.

[2] Multi-tier Grid Routing

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Table 1- A summary of hierarchical methods and their comparison

Protocol	Location awareness	Type of sink motion	Type of virtual structure	Data aggregation	Multiple sink support	Protocol overload	Structure accessibility
TTDD	Yes	Random	Rectangular grid	Yes	Yes	High	Easy
GBEER	Yes	Random	Rectangular grid	No	Yes	Medium	Medium
CMR	Yes	Random	Rectangular grid	No	Yes	Medium	Medium
HPDD	Yes	Random	Hexagonal grid	No	Yes	Medium	Medium
HexDD	Yes	Random	Hexagonal grid	Yes	Yes	Low	Medium
HCDD	No	Random	D-Clusters & MaxMin	No	No	High	Hard
EEMSRA	Yes	Controled	TDMA clusters	Yes	No	Medium	Hard
MSRP	Yes	Controled	Clusters	Yes	Yes	Medium	Hard
SEAD	Yes	Random	Steiner tree	No	Yes	High	Easy
QDD	Yes	Random	Quad-tree	No	Yes	Low	Medium
DBB	Yes	Predictable	Backbone	No	Yes	High	Easy
DQM	Yes	Random	Backbone	Yes	No	High	Easy
LBDD	Yes	Random	Line (wide)	No	Yes	Low	hard
RailRoad	Yes	Random	Rail (wide)	No	Yes	Medium	Medium
Ring protocol	Yes	Random	Ring (one-node)	No	No	Low	Medium
DHA	Yes	Random	Two agents	Yes	No	Low	Easy
OAR	Yes	Random	Single agent	No	Yes	Low	Easy
MGRP	Yes	Random	Grid & clusters	Yes	No	High	Easy
EGRR	Yes	Predictable	Expect areas &grids	No	No	High	Medium
EADA	No	Predictable	Grid & on demand trees	Yes	No	High	Medium
Shared tree	No	Random	Clusters & tree	No	Yes	Medium	Hard

4. CONCLUSION

The sensor network is a network of a great number of small nodes. In each node there are several sensors/actors. The sense/act network has interaction with the physical environment. It receives the information of the environment through the sensors and reacts by the actors. In these kind of wireless sensor networks, the actual time for applications such as monitoring the war field or detecting the fire in jungle, etc, the data gathered by the sensors are received schedule by the sink or sinks. By using the effective methods of data dissemination based on mobile sink the lifetime of the network can be increased. For example, several methods were investigated in this paper that represent the motion of the sink to the data resources or towards the high energy environments or both of them.

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Recently it has been shown that using the mobile sink with causing non-desirable effects, increases the lifetime of the network significantly. When a sink node moves, the hotspot role in created because of the high traffic around the sink node and it circulated among the nodes and leads to balance of energy. Therefore using the mobile sink leads to distribution of energy consumption, decreasing the energy consumed in the network and increasing the network lifetime. But from the other hand moving sinks have faced challenges which are data delay, construction cost and release of data transmission routes by the sensor nodes to the current location of the sink, determining the rate of sink movement and duration of sink residence in various locations for gathering the data. In this paper the hierarchical routing protocols have been investigated and analyzed and each has its advantages and disadvantages but the best decision can be made by using the routing protocols. Also the algorithm which can transmit the produced packets towards the sink and has low overload is important.

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