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Review Article

A Review of various Energy Efficient Mobile Sink Routing Protocols for Wireless Sensor Network

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Abstract

The wide utilization of Wireless Sensor Networks (WSNs) is obstructed by the severely limited energy constraints of the individual sensor nodes. A critical need in wireless sensor networks is to achieve energy efficiency during routing as the sensor nodes have limited energy resources. The efficient energy consumption is the main problem in wireless sensor network. The efficient protocol should minimize the energy consumption. Several routing, data dissemination and power management protocols have been specifically developed for WSNs where energy consumption is an essential design issue. The main focuses on the routing protocols which are differ depending on the uses, application and network architecture. In this paper, we present a survey of the state-of-the-art routing techniques in WSNs. We first outline the design challenges for routing protocols in WSNs followed by a comprehensive survey of different routing techniques.

Keywords: *Wireless sensor network, routing protocol, Energy efficient*

1. Introduction

A wireless sensor network (WSN) is a wireless network that consisting of spatially distributed autonomous devices which are using sensors to cooperatively monitor or measuring physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations. A Wireless Sensor Networks (WSN) is a set of hundreds or thousands of micro sensor nodes are capable for sensing, to establishing wireless communication between each other and doing computational and processing operations. The most important requirements of a WSN are:

1) Low energy consumption
2) Attachment of a stationary sensors
3) Working with a large number of sensors
4) Self-organization capability
5) Querying ability.
6) Collaboratively signal processing

Some of the other important applications of WSNs are listed below.

- Military environment,
- Disaster management
- Habitat monitoring
- Medical and health care,
- Industrial fields, Home networks
- Biological, radiological, nuclear, and explosive material etc.

Sensor nodes are equipped with small, often irreplaceable batteries with limited power capacities. They can be deployed manually or be randomly dropped. They are self-configuring, containing one or more sensors, with embedded wireless communications and data processing components and a limited energy source. The use of wireless sensor networks is increasing day by day but the problem of energy constraints prevails as there is limited battery life. In order to save energy dissipation caused by communication in wireless sensor networks, it is necessary to schedule the state of the nodes, changing the transmission range between the sensing nodes, use of efficient routing and data routing methods and avoiding the handling of unwanted data. In general, routing in WSNs can be divided into flat, hierarchical, and location based routing depending on the network structure.

In wireless sensor networks (WSNs), energy efficiency is considered to be a crucial issue due to the limited battery capacity of the sensor nodes. Considering the usually random characteristics of the deployment and the number of nodes deployed in the environment, an intrinsic property of WSNs is that the network should be able to operate without human intervention for an adequately long time, since replacing the batteries of the sensor nodes requires

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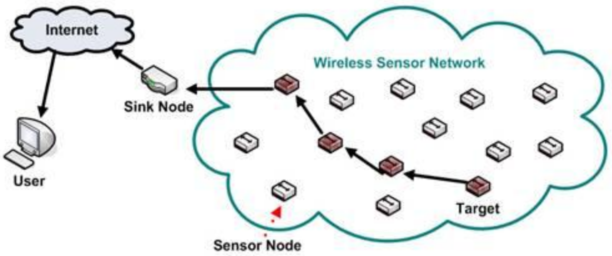
significant effort. Due to the converge cast nature of traditional WSN packet forwarding approaches resulting in the concentration of data traffic towards the sinks, the nodes in the vicinity of the static (immobile) sinks are more likely to deplete their batteries before other nodes, leading to the energy hole problem, disruptions in the topology and reduction in the sensing coverage. Moreover, this problem could lead to the isolation of the sinks, hindering the delivery of the sensor data traffic. Mobile sinks are proposed and explored as a possible solution to this problem.



Load-balancing is implicitly provided by the sink mobility, shifting the hotspots around the sinks and spread out the increased energy drainage around the sink node, which helps to achieve uniform energy consumption that extends the network lifetime. Sink mobility also has security benefits where the mobility makes the sinks more difficult to compromise than static sinks. The attack on the mobile sinks, e.g., sensitive information retrieval and sink destruction, would require the adversary nodes to locate and chase down a mobile sink carrier. In addition, mobile sinks enhances the network connectivity by accessing the isolated portions of the network to retrieve data that might otherwise be not accessible in the static sink case. Its advantages are the sink mobility brings about problem of sink localization and requiring frequent advertisement of the changing sink node position across the all over network. This operation could result in a significant overhead, which is should be minimized to benefit from the energy savings introduced by the mobile sinks. An effective mobile sink routing protocol should also avoid an extreme increase in the sensor data delivery latencies. Particularly for the time sensitive wireless sensor network applications, the validity of the sensor network data is depends on its freshness.

Layers of WSN

WSN contains four different layers; each of these layers has its own specific and different functions. These layers are namely as processing, communication, sensing actuation and power supply. The core of the wireless senor node is the processing unit. It consist all the vital fornication in this layer. On the other hand, communication unit allows the node to send and receive data to the all other nodes or to a base station, and to the part of a sensor network. The main power supply unit uniformly distributes different voltages to the sensor node. These units add liner regulators and capacitors. The power consumption at that unit it must be optimized. Finally, the sensor nodes can be considered as connection or bridge with the physical world. Almost every physical parameter can be measured and processed in the node, and communicated to the network.

Literature Survey

Several research projects in the last few years have explored hierarchical clustering in WSN from different perspectives. Clustering of sensor node is a most important energy-efficient communication protocol which can be used by the sensors node to report their sensed data to the sink node or base station. In WSNs, routing mechanism of the generated data towards the BS must be efficient. This efficiency relates to less power consumption, limited transmission of messages and lower requirements on memory and computation resources. Typically, hierarchical routing class, which are working in the clustering based networks fashion; it is a better with the scalability and energy efficiency features. In such type of routing class, data are routed in two steps: first is intra and second inter-clusters. Within the each cluster, member sensor nodes transfer their data messages only to the CH node. Each cluster head performs an aggregation operation on received messages and transfer afterwards, after that resulting messages to the BS. The communication between every CHs and BS may pass by the several hierarchical levels. Besides, the non-cluster head nodes which have no data to communicate to their CH (which is already done it) turn off temporarily for particular period their radio devices. This will allow the network lifetime prolonging. The main goal of a hierarchical routing protocol is to specify how the network hierarchy should be formed and then, it dictates the steps of data communication.

Routing is the well-known method with the number special advantages related to the scalability and efficient communication. LEACH, PEGASIS, TEEN and APTEEN use this technique for routing. In hierarchical architecture, higher energy nodes which are used to process and send their information, while low-energy nodes may be used to perform the sensing in the proximity of the target. Location Based Routing Protocols like MECN sensor nodes are addressed by means of their locations. The distance between neighboring sensor nodes is measured on the particularly basis of incoming signal strengths. Relative location of neighboring nodes is gathered by exchanging such type of information between neighbors. The Low-Energy Adaptive Clustering Hierarchy (LEACH) is a mostly used cluster based routing protocol.

Low Energy Adaptive Clustering Hierarchy (LEACH)

Although LEACH is able to increase the network lifetime, there are still a number of issues about the assumptions used in this protocol. LEACH assumes a homogeneous distribution of sensor nodes in the given area. This scenario is not very realistic. LEACH assumes that all nodes can transmit with enough power to reach the BS if needed and that each node has computational power to support different MAC protocols. Therefore, it is not used in networks which are deployed in large regions. It also considered that the nodes are always sending their data and nodes are located close to each other have correlated data. It is not easy to determine how much number of predetermined Cluster Heads is going to be uniformly distributed throughout the network. Therefore, this may have possibility that the elected CHs will be working in one part of the network. Hence, some nodes will not have any CHs in their vicinity.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS)

PEGASIS protocol is a extension of LEACH protocol. It accepts rather a particular hierarchical topology in which, nodes are gathered i.e. organized into chain structure. This structure is set up in a greedy strategy, so that, each sensor node sends their gathered data towards the closest neighbor node in the up level making a chain towards the BS. Data is gradually aggregating and transmit on the established chain. This routing protocol has the most important advantage that it saves the spent energy which required for periodic clusters formation in LEACH. Nevertheless, it suffers from certain anomalies, in terms of the significant delay and the ignorance of the energy status of the next hop node.

Hybrid Energy Efficiency Protocol (HEEP)

HEEP protocol combines advantages of both LEACH and PEGASIS protocols. This can be achieved through the application of hierarchical chain concept inside clusters, between member nodes and their cluster heads. In each cluster, remaining nodes communicate their data messages to the CH over the chain. The CH doesn't transfer directly his aggregated data to the BS, but it forwards it to a neighbor CH, and reaches the BS after a multi-hop communication. HEEP maintains basic LEACH's principles related to the dynamic establishing of clusters, while reducing the transmission distances, in both intra and inter clusters communications. For this reason, energy consumption at the sensor network and network latency are more likely improved.

Power Efficient and Adaptive Clustering Hierarchy (PEACH).

The PEACH protocol for a WSNs to minimize the energy consumption of each node, and maximize the network lifetime. In PEACH, cluster formation is performed by using overhearing characteristics of wireless communication to support adaptive multi-level clustering and avoid additional overheads. In WSNs, overhearing a node can recognize the source and the destination of packets transmitted by the neighbor nodes. PEACH is applicable in both locations-unaware and location-aware wireless sensor networks. PEACH is designed to operate on probabilistic routing protocols, in order to provide an adaptive multi-level clustering. PEACH is generally more scalable and efficient to the various circumstances than the existing clustering protocols of the wireless sensor networks The PEACH can significantly save energy consumption of each node, prolong the network lifetime, and are less affected by the distribution of sensor nodes compared with other clustering protocols.

Two-Tier Data Dissemination (TTDD)

It is one of the predecessors of the hierarchical approach. It is a virtual grid based approach where each source node with sensor data proactively constructs a rectangular grid around itself and becomes a crossing point of this grid. For grid construction to be possible, position-aware sensor nodes are required. Whenever sinks require data, they query the network by local flooding within a grid cell and these queries are relayed to the source node. Data is then forwarded to the sink using the reverse of the path taken by the data request. For periodic data reporting applications where every sensor in the network report data, the overhead of constructing grids (separate grid for each node) is immense.

Grid-Based Energy-Efficient Routing From Multiple Sources to Multiple Mobile Sinks (GBEER)

To reduce this overhead, a common grid structure for all the sources is proposed in Grid-Based Energy-Efficient Routing From Multiple Sources to Multiple Mobile Sinks (GBEER). Data announcements are propagated horizontally along the shared grid while data requests are propagated vertically, ensuring that these packets intersect at a crossing point. The position of the sink is then delivered to the source node, and data is delivered directly to the sink. Grid-based protocols are advantageous for the easy accessibility of the grid structure. Both the source nodes and the sinks can reach the grid with minimal number of hops. However, construction of the grid is non-trivial. TTDD suffers from the high overhead of constructing a separate grid for each source node especially in applications where numerous sensor nodes generate data. Although GBEER eliminates the high overhead of constructing separate grids for each source, the nodes residing on the grid are likely to become hotspots and deplete their energy quicker than other nodes. To overcome this problem the grid have to be changed from time to time which is cumbersome. Even changing a single crossing point requires informing the four neighboring crossing points which will introduce extra traffic on numerous nodes residing between the crossing points.

Honeycomb Tessellation (HexDD)

A Virtual Infrastructure Based on Honeycomb Tessellation constructs a hexagonal grid which is better than a rectangular grid in providing shorter data and sink advertisement routes. HexDD aims to prevent redundant propagation of the sink's queries over the whole grid by defining query and data rendezvous lines (border lines) along the six directions following the edges of the hexagons. The border lines intersect on a predefined center hexagonal cell. Sensor data are sent towards the closest border line and then propagated towards the center cell. The nodes on the border lines replicate and store the data. Queries are forwarded towards the center cell via the same mechanism. When a query meets data stored on a border line node, it is sent towards the sink through the reverse path. HexDD also faces the hotspot problem: the nodes on the border lines and especially on the center cell handle more traffic. No countermeasure against such hotspots is proposed. Grids are not the only choice for a hierarchical structure. Approaches based on clusters, trees, backbones exist.

Hierarchial Cluster-based Data Dissemination (HCDD)

It uses a clustering approach to determine high-tier nodes. Like GBEER and HexDD a combined hierarchical structure for all data sources is constructed. The distributed clustering algorithm utilized in HCDD has the ability to operate without position-information of sensor nodes. Clustering allows a better choice of high-tier nodes; however, the distributed algorithm's overhead is high and running it again in case the batteries of the cluster head nodes are about to deplete is very inefficient.

Quad-tree Based Data Dissemination Protocol (QDD)

It partitions the network into successive quadrants defined by a quad-tree structure. The center point of each quadrant becomes a high-tier node. The quadrants are recursively divided further into smaller quadrants until the resolution of the high-tier nodes are sufficient for quick access to the virtual structure. Data announcements and queries are sent to the center points of quadrants in a recursive manner until they rendezvous. The overhead of constructing the quad-tree structure in QDD is minimal compared to most of the other hierarchical approaches; however, no countermeasures against the hotspot problem are proposed.

Dynamic Directed Backbone (DDB)

It constructs a backbone as the high-tier structure. The backbone is composed of leader and gateway nodes. Leader nodes form clusters of nodes in their own neighborhoods and coordinate data traffic associated with all nodes in their clusters. Leader nodes communicate with each other by gateway nodes which complete the connectivity of the backbone structure. The sink connects to the backbone, and data dissemination is performed over the backbone. Changing the proposed backbone structure to avoid hotspots has relatively low overhead since only the immediate neighbors have to be informed if a backbone node switches roles with a regular node. However, in order to cover the whole network, a large backbone with many branches have to be established, which will cause redundancy of sink data queries and data announcements and thus increase the overall energy consumption. Hybrid protocols, employing the combination of various types of structures also exist.

Line-Based Data Dissemination (LBDD)

It defines a wide vertical strip of nodes horizontally centered on the area of deployment. The nodes on this strip are referred to as in-line nodes. Sensor data are sent to the line and the first in-line node encountered stores the data. The sink sends a data query to the line and the query is propagated through the line until the in-line node storing the data is reached. The data is then directly forwarded to the sink, and data dissemination is completed. The line structure can be established very easily with low overhead. The nodes can access the line via a straightforward mechanism. Despite its advantages, LBDD still relies on broadcasts for propagating data queries along the line. The line has to be wide enough to mitigate hotspots; therefore, especially for large networks, the flooding on the line will cause a significant increase in the overall energy consumption.

Proposed Work

In this section, we propose Ring Routing protocol; it is a hierarchical routing protocol for the wireless sensor networks with a mobile sink. Ring Routing establishes a ring like structure which goal is to combine and aggregating the easy-accessibility of the grid structures (e.g., TTDD, HexDD) with the easy-changeability of the backbone structures (e.g., DDB). It also aims is to decrease the redundancy of routing control packets by incorporating minimum number of nodes in ring structure, and devising a straightforward and efficient mechanism for sharing sink position advertisement packets among the ring nodes. The ring can be established with low overhead like the structures which are utilized in the area-based approaches. On the other hand, Ring Routing protocol is relies on fewer amounts of inefficient broadcasts which are extensively used in the area-based protocols. LBDD and Railroad are the most efficient and has less overhead among the all of the above-mentioned protocols since they successfully alleviate hotspots on the hierarchical structures, which of the most protocols are suffer greatly from, by utilizing structures covering maximum areas and distributing the large traffic load on numerous nodes. LBDD and Railroad also have less hierarchical structure construction overhead.

The ring routing protocol perform three roles on sensor nodes: regular node, ring node and anchor node. Role of ring nodes is to form a ring structure which is a closed loop of single-node. The basis of Ring Routing is (i) produce advertisement of sink node position to the ring; (ii) every regular node receive the sink position advertisement message from the ring whenever required, and (iii) nodes disseminating their information through the anchor nodes, which role is to serve as intermediary agents connecting the sink node to the network.

Load-balancing feature is implicitly provided by the sink node mobility, shifting of hotspots around the sinks and distributing the increased energy drainage around the sink, which helps to achieve a uniform energy consumption that improves the network lifetime. Sink mobility also provides security benefits where the mobility makes the sinks are more difficult to compromise by attacker than static sinks. An attack on the mobile sinks, e.g., sensitive information retrieval and sink destruction, would require an adversary to locate and chase down a mobile sink carrier. In addition, mobile sinks enhances the network connectivity by accessing the isolated portions of the network to retrieve data that might otherwise be inaccessible in a static sink case. Despite its advantages, the sink mobility brings about the problem of sink localization, requiring frequent advertisement of the changing sink position across the network.

This operation may result in a significant overhead, which should be minimized to benefit from the energy savings introduced by the mobile sinks. An effective mobile sink routing protocol should also avoid an extreme increase in the sensor data delivery latencies. Especially for the time sensitive WSN applications, the validity of the sensor data depends on its freshness. The three sensor roles are not static, meaning that sensor nodes can change roles during the operation of the WSN. Three simple assumptions are made before going into the details of the protocol:

- Sensor nodes are aware of their own positions. The position information may be based on a global or a local geographic coordinate system defined according to the deployment area. Determining the position of the nodes might be achieved using a satellite based positioning system such as global positioning system (GPS) or one of the energy-efficient localization methods proposed specifically for WSNs.
- Every sensor node should be aware of the position of its neighbors. This information enables greedy geographic routing and can be obtained by a simple neighbor discovery protocol.
- The coordinates of a network center point has to be commonly known by all sensor nodes. The network center does not have to be exact and can be loaded into the sensors' memories before deployment. The ring structure encapsulates the network center at all times, which allows access to the ring by regular nodes and the sink.

Key features and the contributions of Ring routing as follows:

1) Ring Routing is a routing protocol targeted for large scale WSNs deployed outdoors with stationary sensor nodes and a mobile sink.
2) Ring Routing establishes a virtual ring structure that allows the fresh sink position to be easily delivered to the ring and regular nodes to acquire the sink position from the ring with minimal overhead whenever needed.
3) The ring structure can be easily changed. The ring nodes are able to switch roles with regular nodes by a straightforward and efficient mechanism, thus mitigating the hotspot problem.
4) The mobile sink selects anchor nodes along its path and the anchor nodes relay sensor data to the sink.
5) In case the sink position information obtained by a sensor node loses its freshness, the sensor data is relayed through the old anchor nodes to the current anchor node, preventing packet losses. This mechanism is based on progressive footprint chaining.
6) Ring Routing relies on minimal amount of broadcasts; therefore, it is applicable to be used for sensors utilizing asynchronous low-power MAC protocols designed for WSNs.
7) Ring Routing does not have any MAC layer requirements except the support for broadcasts. It can operate with any energy-aware, duty cycling MAC protocol.
8) Ring Routing is suitable for both event-driven and periodic data reporting applications. It is not query based so that data are disseminated reliably as they are generated.
9) Ring Routing provides fast data delivery due to the quick accessibility of the proposed ring structure, which allows the protocol to be used for time sensitive applications.
10) No information about the motion of the sink is required for Ring Routing to operate. It does not rely on predicting the sink's trajectory, and is suitable for the random sink mobility scenarios.

Conclusion and Feature Work

In this paper we studied important issues of routing which influencing sensor network design. Although many existing energy saving routing protocols have been proposed for wireless sensor networks. We have reviewed several different protocols in terms of energy efficiency. From the review protocols, it is clearly seen so far that, data reporting delay is high and the performance of protocols is worth promising in terms of energy efficiency. But it is not possible to design a routing protocol which will overcome all designing issues of WSN, as well as have good performance for all wireless sensor networks applications. In feature we want to develop energy efficient and reliable routing protocol with multiple mobile sink that provides fast delivery of data.

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