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A Survey on Wireless Sensor Networks Routing Algorithms

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Abstract: This paper presents a comprehensive survey of routing techniques in wireless sensor networks (WSN) and studies the advantages and performance issues of routing techniques with tradeoffs between energy and communication overhead savings. Based on the underlying network structure WSN routing algorithms can be categorized in flat, hierarchical, and location-based routing algorithms.

1. Introduction

One of the most important issues in WSN is Energy consumption without losing data [Biradar2005]. In hierarchical arrangement environment where data is sent by Multihop mechanism, node acts as data transmitter and receiver both. The early network disintegration can cause significant topological changes and may need rerouting of packets and reorganization of network. Nodes may fail due to power failure, physical damage etc. This requires dynamic topology change and rerouting packets through regions of the network where more energy is available. These routing techniques have considered the inherent features of WSNsThe survey also concludes that swarm intelligence based routing protocols can eliminate many limitations of existing routing protocols. Section II of the paper surveys the state-of-the-art routing protocols for WSNs. The paper ends with specification of conclusion & future scope.

2. Routing Protocols In WSNs

Different types of routing techniques can be classified according to network structure or network operation as shown in table 1. Here the routing protocols based on network structure we shall deal in detail are explained in detail.

Table 1. Comparison of different routing algorithm

Routing Protocol	**Characteristics**	**Data aggregation**	**Scalability**	**Over head**	**Delivery model**
SPIN: Sensor Protocols for Information via Negotiation	Flat/data-centric/Query Based	Yes	Ltd	Low	Event driven
DD: Directed Diffusion	Flat/data-centric/Query Based	Yes	Ltd	Low	Demand driven
RR: Rumour Routing	Flat/Query Based	Yes	Good	Low	Demand driven
COUGAR	Flat/Query Based	Yes	Ltd	High	Query driven
ACQUIRE: Active Query forwarding in WSN	Flat/Data-centric	Yes	Ltd	Low	Complex query
LEACH: Low Energy Adaptive Clustering Hierarchy	Hierarchical/Node centric	Yes	Good	High	Cluster Head
TEEN&APTEEN: Energy Efficient sensor Network	Hierarchical	Yes	Good	High	Active threshold
VGA: Virtual Grid Architecture Routing	Hierarchical	Yes	Good	High	Good
SOP: Self Organizing Protocol	Hierarchical	No	Good	High	Continuously
GAF: Geographic Adaptive Fidelity	Hierarchical/Location	No	Good	Mod	Virtual grid
SPEED: Real time routing protocol	Location/Data- centric	No	Ltd	Less	Geographic

A. Flat networks

In flat networks, each node typically plays the same role and sensor nodes collaborate together to perform the sensing task. In this type of network it is not possible to assign a global identifier to each node due to large number of nodes. Therefore, base station send queries to different part of the field and waits for the data from sensors in selected parts of the field. This approach is called data centric routing [Karaki2004]. SPIN (Sensor Protocols for Information via Negotiation) [Heinzelman1999] and DD (Direct Diffusion) [Intanagonwiwat2003] are two examples of the data centric routing protocols that save energy by data negotiation and omitting the redundant data. Other protocols in this category are Rumor routing, Minimum Cost Forwarding Algorithms (MCFA).

SPIN protocol disseminates all the information at each node to every node in the network assuming that all nodes in the network are potential base stations. The protocol starts when a SPIN node obtains new data that it is willing to share. It does so by broadcasting an ADV message containing meta-data. It provides much energy savings than flooding and metadata negotiation almost halves the redundant data but it cannot guarantee the delivery of data. Directed Diffusion is another data centric (DC) algorithm to combine the data coming from different sources, en route by eliminating redundancy, minimizing the number of transmissions; thus saving network energy and prolonging its lifetime. Directed diffusion allows on demand data queries while SPIN allows only interested nodes to query and there is no need to maintain global network topology in directed diffusion but it may not be applied to applications that require continuous data delivery to the BS such as environmental monitoring.

The MCFA algorithm [Ye2001] assumes that the direction of routing is always known and a sensor node need not have a unique ID nor maintain a routing table. Instead, each node maintains the least cost estimate from itself to the base-station. Under COUGER approach [Yao2002], the network is foreseen as a distributed database where some nodes containing the information are temporary unreachable. Since node stores historic values, the network behaves as a data warehouse. COUGAR provides a SQL-like interface extended to incorporate some clauses to model the probability distribution. The sink is responsible for generating a query plan which provides the hints to select a special node called the leader. The network leaders perform aggregation and transmit the results to the sink. One of the limitations of this is extra overhead & energy consumption required due to the extra query layer also the synchronization is required for data aggregations. ACQUIRE (Active Query Forwarding in Sensor Networks) algorithm [Sadagopan2003] also considers the wireless sensor network as a distributed database. In this scheme, a node injects an active query packet into the network. Neighboring nodes that detects that the packet contains obsolete information, emits an update message to the node. Then, the node randomly selects a neighbor to propagate the query which needs to resolve it.

B. Hierarchical Routing

In a hierarchical architecture, higher energy nodes can be used to process and send the information while low energy nodes can be used to perform the sensing in the proximity of the target. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Some of the protocols in case of Hierarchical Routing networks are Threshold-sensitive Energy Efficient Protocols (TEEN) and Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network protocol (APTEEN), Virtual Grid Architecture routing (VGA), Hierarchical Power-aware Routing (HPAR)[Li2001], Two-Tier Data Dissemination (TTDD) [Luo2005]..

In TEEN, sensor nodes sense the medium continuously, but the data transmission is done less frequently. A cluster head sensor sends its members a hard threshold, which is the threshold value of the sensed attribute and a soft threshold, which is a small change in the value of the sensed attribute that triggers the node to switch on its transmitter and transmit. While in APTEEN, the cluster-heads broadcasts various parameters such as Attributes, Thresholds, Schedule& Count Time. Once a node senses a value beyond hard threshold (HT), it transmits data only when the value of that attributes changes by an amount equal to or greater than the soft threshold (ST). If a node does not send data for a time period equal to the count time, it is forced to sense and retransmit the data. The two approaches are the overhead and complexity associated with forming clusters at multiple levels, the method of implementing threshold-based functions, and how to deal with attribute based naming of queries.

VGA is an energy-efficient routing paradigm that utilizes data aggregation and in-network processing to maximize the network lifetime. Due to the node stationary and extremely low mobility in many applications in WSNs, a reasonable approach is to arrange nodes in a fixed topology. A group of sensor nodes is made as square clusters, from which an optimally selected node acts as cluster head which perform the local aggregation, while a subset of these LAs are used to perform global aggregation. Determination of an optimal selection of global aggregation points, called Master Aggregators (MAs) is NP-hard problem.

Hierarchical Power-aware Routing (HPAR) protocol divides the network into groups of sensors. Each group of sensors in geographic proximity are clustered together as a zone and each zone is treated as an entity. To perform routing, each zone is allowed to decide how it will route a message hierarchically across the other Zones such that the battery lives of the nodes in the system are maximized. Messages are routed along the path which has the maximum over all the minimum of the remaining power, called the max-min path.

C. Location based routing protocols

In this kind of routing, sensor nodes are addressed by means of their locations. Some of the protocols in case of Location based routing networks are Geographic Adaptive Fidelity (GAF), Geographic and Energy Aware Routing (GEAR) [Yu2001], SPAN [Chen2002], The Greedy Other Adaptive Face Routing (GOAFR) [Kuhn2003].

Geographic Adaptive Fidelity (GAF)is an energy-aware location-based routing algorithm. The network area is first divided into fixed zones and forms a virtual grid. Inside each zone, nodes collaborate with each other to play different roles. For example, nodes will elect one sensor node to stay awake for a certain period of time and then they go to sleep. This node is responsible for monitoring and reporting data to the BS on behalf of the nodes in the zone. GAF performs at least as well as a normal ad hoc routing protocol in terms of latency and packet loss and increases the lifetime of the network by saving energy.

Geographic and Energy Aware Routing (GEAR) protocol uses energy aware and geographically informed neighbor selection heuristics to route a packet towards the destination region. The key idea is to restrict the number of interests in directed diffusion by only considering a certain region rather than sending the interests to the whole network. GEAR reduces the energy consumption for the route setup. The simulation results show that for an uneven traffic distribution, GEAR transfers effectively more number of packets as compared to other routing techniques.

D. Heuristic based routing protocols

A new class of algorithms, inspired by swarm intelligence (SI), is currently being developed that can potentially solve numerous problems of modern WSNs requirement. These algorithms rely on the communication of a massive amount of simultaneously interacting agents. A survey of such algorithms and their performance is presented here.

The ant colony optimization (ACO) based routing scheme has been motivated by functioning principles of ants foraging behavior [Wang2008], allowing an ant colony to perform complex tasks such as nest building and foraging [Wang2008]. Energy efficient ant-based routing algorithm (EEABR) is developed by T. Camilo in 2006 [Selvakennedy2006].

In every node, a data structure, stores ant information, whereas the routing table stores the previous node, the forward node, the ant identification and a timeout value. When a forward ant is received, the node looks at its routing table and searches the ant identification for a loop. If the ant identification is not found, the node stores the necessary information, restarts a timer and forwards the ant to the next node. If ant identification is found, the ant is eliminated. Ant colony optimization-based location-aware routing (ACLR) is another algorithm developed by Xiaoming Wang in 2008 as a new communication protocol [Wang2008] for WSNs called ant colony optimization-based location-aware routing (ACLR), which is based on the ant colony optimization (ACO). There are another set of protocols which are inspired from honeybees foraging behaviors. The routing in computer networks has several resemblances with honeybee's behavior [Farooq2009].

Honeybees in particular have mechanisms for WSNs such as self-organization and division of labor. There are a few routing protocols for WSNs, inspired from bees behavior. Saleem and Farooq [Farooq2009], implemented bee-hive routing protocol which is an algorithm based on the foraging principles of honey bees with an on-demand route discovery (AODV). Approach has three types of bee agents. These are packers, scouts and foragers bees. Packers locate appropriate foragers for the data packets at the source node, while scouts are responsible for discovering the path to a new destination. Foragers have a major function carrying the data packets to a sink node. This approach is based on the interactions of scouts and source routing by which small forwarding tables are built during the return of a scout.

3. CONCLUSION & FUTURE DIRECTIONS

Routing in sensor networks is a new area of research, with a limited, but rapidly growing set of research results. This paper presented a small survey of routing techniques in wireless sensor networks. They have the common objective of trying to extend the lifetime of the sensor network, while not compromising on other concerns data delivery or security.

Multimedia driven quality of service issues demands new research. Other concerns are node mobility and topology changes in such energy constrained environment. Fault tolerant routing techniques demands efficient exploitation of spatial diversity and density of sensor to achieve energy efficient communication and desired global behavior with

adaptive localized algorithms. Current routing protocols also need to be optimized for the limited capabilities of the nodes for security consideration.

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