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Routing Protocols in Wireless Sensor Networks A Survey

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Abstract: Wireless Sensor Networks (WSN) contains hundreds or thousands of sensor nodes with great capabilities like sensing, computation, wireless communications and these sensors have the ability to communicate either among each other or directly to an external Base Station. These Sensor nodes will collect information and also plays an important role of a Router by communicating through wireless channels. WSN ismainly intended for gathering and sensing information in remote locations (required). Design Goal of WSN is to 1) Transmit data 2) Increase Network Life Time by employing Energy Efficient Routing Protocols.

Wireless networks are constrained by energy, storage capacity, and power. To increase the lifetime of networks, It is must to consider energy awareness. If we analyze routing protocols, these are in charge of discovering and maintaining the routes in the network. However, the appropriateness of a particular routing protocol mainly depends on the capabilities of the sensor nodes and on the application requirements.

This paper presents a review of the main routing protocols proposed for wireless sensor networks.

Index Terms: wireless Sensor networks, classification of routing protocols, Routing protocols.

I. INTRODUCTION

Wireless Sensor Networks (WSNs), is one of the most important technologies for the twenty - first century. The deployment of wireless sensor networks has grown dramatically during the recent years, as they are increasingly used in many applications. The medical, environmental and military sectors are some of the most important areas, where the recent developments in WSNs technology have seen a wide use. WSNs consist of inexpensive, low power sensor nodes, which collect and disseminate data [1]. Due to various limitations arising from their inexpensive nature, limited size, weight, and ad hoc method of deployment, each sensor has limited power capabilities.

Wireless Sensor Networks (WSN) is mainly intended for monitoring an environment. The main task of a wireless sensor node is to sense and collect data from a certain domain, process them and transmit it to the server where the application resides. However, ensuring the direct communication between a sensor and the server may force nodes to emit their messages with such a high power that their resources could be quickly depleted. Therefore, the collaboration among the nodes to ensure that distant nodes communicate with the server is required.

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In this way, messages are propagated by intermediate nodes so that a route with multiple links or hops to the sink is established. Taking into account the reduced capabilities of sensors, the communication with the sink could be initially conceived without a routing protocol.

The Advantages of WSN includes (i) Network setups can be done without Fixed infrastructure. (ii) Implementation cost is cheap. Some disadvantages of WSN are (i) Security issues (ii) slower than wired networks (ii) Configuration is very complex when compared with Wired Networks.

The rest of the paper is structured as follows. In Section 2 we present the most popular classification schemes for routing protocols in this kind of networks, Finally, Section 3 draws the main conclusions of this work.

II. ROUTING PROTOCOLS IN WSN

Routing in WSN differs from conventional routing .There is no infrastructure, wireless links are unreliable, sensor nodes may fail ,and routing protocols have to meet strict energy saving requirements. [2] Many routing algorithms were developed for wireless networks. When sensor nodes are static, it is preferable to have table driven routing protocols rather than using reactive protocols. a significant amount of energy is used in route discovery and setup of reactive protocols. All major routing protocols classified into seven main categories. They are shown in table1

Category	Representative Protocols
Location-based Protocols	MECN, SMECN, GAF, GEAR, Span, TBF, BVGF, GeRaF
Data-centric Protocols	SPIN, Directed Diffusion, Rumor Routing, COUGAR, ACQUIRE, EAD, Information-Directed Routing, Gradient-Based Routing, Energy-aware Routing, Information-Directed Routing, Quorum-Based Information Dissemination, Home Agent Based Information Dissemination
Hierarchical Protocols	LEACH, PEGASIS, HEED, TEEN, APTEEN
Mobility-based Protocols	SEAD, TTDD, Joint Mobility and Routing, Data MULES, Dynamic Proxy Tree-Base Data Dissemination
Multipath-based Protocols	Sensor-DisjointMultipath, Braided Multipath, N-to-1 Multipath Discovery
Heterogeneity-based Protocols	IDSQ, CADR, CHR
QoS-based protocols	SAR, SPEED, Energy-aware routing

Table 1. Classification of Routing Protocols

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2.1 Location Based Protocols

The location information based routing protocol uses location information to guide routing discovery and maintenance as well as data forwarding, enabling directional transmission of the information and avoiding information flooding in the entire network. Location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be estimated [3].

2.1.1 GAF

GAF is used for WSN because it favors energy conversation. As shown in Fig.1, the state transition diagram has three stages, discovery, active and sleeping. When a sensor enters the sleeping state, it turns off radio for energy saving .In discovery state, a sensor exchange discovery messages to learn about other sensors in the grid. In active state, a sensor periodically broadcast its discovery message to inform equivalent sensors about its state.

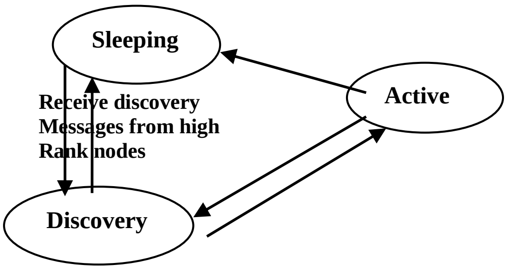

Fig 1.State Diagram of GAF

2.2 Data-Centric Protocols

In traditional routing protocols for WSNs, also known as address - centric protocols, when the sink sends out a query for collecting data, each source sensor that has the appropriate data responds by sending its data to the sink independently of all other sensors. Data - centric protocols differ from address - centric protocols in the manner that the data is sent from source sensors to the sink. In data – centric protocols, when the source sensors send their data to the sink, intermediate sensors can perform some form of aggregation on the data originating from multiple source sensors and send the aggregated data toward the sink. This process can result in energy savings because less transmission are required to send the data from the sources to the sink.

2.2.1 SPIN

SPIN is a family of protocols used to efficiently disseminate information in a wireless sensor network. Conventional data dissemination approaches like flooding and gossiping waste valuable communication and energy resources sending redundant information throughout the network. In addition, these protocols are not resource-aware or resource-adaptive. SPIN solves these shortcomings of conventional approaches using data negotiation and resource-adaptive algorithms. Nodes running SPIN assign a high-level name to their data, called *meta-data*, and perform meta-data negotiations before any data is transmitted. This assures that these are no redundant data sent throughout the network. In addition, SPIN has access to the current energy level of the node and adapts the protocol it is running based on how much energy is remaining. Simulation results show that SPIN is more energy-efficient than flooding or gossiping while distributing data at the same rate or faster than either of these protocols.

2.3 Hierarchical Protocols

In hierarchical protocols, all nodes forward a message for a node (also called aggregator) that is in a higher hierarchy level than the sender. Each node aggregates the incoming data by which they reduce the communication overload and conserve more energy. Therefore, these protocols increase the network lifetime and they are also well-scalable. The set of nodes which forward to the same aggregator is called cluster, while the aggregator is also referred as cluster head. Cluster heads are more resourced nodes, where resource is generally means that their residual energy level is higher than the average. The reason is that they are traversed by high traffic and they perform more computation (aggregation) than other nodes in the cluster. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other layer is used for routing.

2.3.1 LEACH

LEACH Low-energy adaptive clustering hierarchy (LEACH) [4] is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. Optimal number of cluster heads is estimated to be 5% of the total number of nodes.
All the data processing such as data fusion and aggregation are local to the cluster. Cluster heads change randomly over time in order to balance the energy dissipation of nodes. This decision is made by the node choosing a random number between 0 and 1. The node becomes a cluster head for the current round if the number is less than the following threshold

$$T(n) = \frac{p}{1-p}[r \bmod(1/p)],\ n \in G = 0, \text{otherwise}$$

Where p is the desired percentage of cluster heads (e.g. 0.05), r is the current round, and G is the set of nodes that have not been cluster heads in the last 1=p rounds. LEACH achieves over a factor of 7 reduction in energy dissipation compared to direct communication and a factor of 4–8 compared to the minimum transmission energy routing protocol. The nodes die randomly and dynamic clustering increases lifetime of the system. LEACH is completely distributed and requires no global knowledge of network. However, LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not applicable to networks deployed in large regions. Furthermore, the idea of dynamic clustering brings extra overhead, e.g. head changes, advertisements etc., which may diminish the gain in energy consumption.

2.4 Heterogeneity-based Protocols

All the routing and data dissemination protocols discussed so far assume a homogeneous network architecture, in which all sensors have the same capabilities in terms of battery power, communication, sensing, storage, and processing. Recently, there has been an interest in heterogeneous sensor networks, especially for real deployment.

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2.4.1 Cluster-Head Relay Routing (CHR)

CHR routing protocol [5] uses two types of sensors to form a heterogeneous network with a single sink: a large number of low-end sensors, denoted by L-sensors, and a small number of powerful high-end sensors, denoted by H-sensors. Both types of sensors are static and aware of their locations using some location service. Moreover, those L- and H-sensors are uniformly and randomly distributed in the sensor field. Within a cluster, the L-sensors are in charge of sensing the underlying environment and forwarding data packets originated by other L-sensors towards their cluster head in a multichip fashion. The H-sensors, on the other hand, are responsible for data fusion within their own clusters and forwarding aggregated data packets originated from other cluster heads toward the sink in a multichip fashion using only cluster heads. While L-sensors use short-range data transmission to their neighboring H-sensors within the same cluster, H-sensors perform long-range data communication to other neighboring H-sensors and the sink.

2.5 Multipath-based Protocols

Considering data transmission between source sensors and the sink, there are two routing paradigms: single-path routing and multipath routing. In single-path routing, each source sensor sends its data to the sink via the shortest path. In multipath routing, each source sensor finds the first k shortest paths to the sink and divides its load evenly among these paths. In this section, we review a sample of multipath routing protocols for WSNs.

2.5.1 Braided Multipath Routing Protocol

Braided Multipath Routing Protocol [6**]** is a seminal multipath routing protocol proposed to provide fault-tolerant routing in wireless sensor networks. This protocol uses a similar approach as Directed Diffusion to construct several partially disjoint paths. This protocol utilizes two types of path *reinforcement* messages to construct partially disjoint paths. Path construction is initiated through the sending of a *primary path reinforcement* message by the sink node to its best neighboring node towards the source node.

2.6 Mobility-based Protocols

Mobility brings new challenges to routing protocols in WSNs. Sink mobility requires energy efficient protocols to guarantee data delivery originated from source sensors toward mobile sinks. In this section we discuss sample mobility-based routing protocols for mobile WSNs.

2.6.1 Joint Mobility and Routing Protocol

A network with a static sink suffers from a severe problem, called energy sink-hole problem, where the sensors located around the static sink are heavily used for forwarding data to the sink on behalf of other sensors. As a result, those heavily loaded sensors close to the sink deplete their battery power more quickly, thus disconnecting the network. This problem exists even when the static sink is located at its optimum position corresponding to the center of the sensor field [8].

2.7 QoS-based protocols:

In sensor networks, different applications may have different quality-of-service (QoS) requirements in terms of delivery latency and packet loss. Thus, network protocol design should consider the QoS requirements of specific applications.

2.7.1Sequential Assignment Routing (SAR)

Sequential Assignment Routing (SAR) [7] is the first protocol for WSNs that includes a notion of QoS. Assuming multiple paths to the sink node, each sensor uses a SAR algorithm for path selection. It takes into account the energy and QoS factors on each path, and the priority level of a packet. For each packet routed through the network, a weighted QoS metric is computed as the product of the additive QoS metric and a weight coefficient associated with the priority level of that packet for purposes of performance evaluation. The objective of the SAR algorithm is to minimize the average weighted QoS metric throughout the lifetime of the network.

III. CONCLUSION

We surveyed routing protocols by taking into account several classification criteria, including location information, network layering and in-network processing, data centricity, Mobility-based, Multipath-based Protocols, network heterogeneity, and QoS requirements. For each of these categories, we have discussed a one example protocol
One of the main challenges in the design of protocols for WSNs is energy efficiency due to the scarcity of energy resources of sensors. The ultimate objective behind the protocol design is to keep the sensors operating for as long as possible, thus extending the network lifetime.

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