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A SURVEY ON WIRELESS SENSOR NETWORKS ROUTING PROTOCOLS

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ABSTRACT: This paper presents a survey of state-of-the-art routing techniques in Wireless Sensor Networks (WSNs). Compared with traditional wireless networks, WSNs are characterized with denser levels of node deployment, higher unreliability of sensor nodes and severe power, computation and memory constraints. Various design challenges such as energy efficiency, data delivery models, quality of service, overheads etc., for routing protocols in WSNs are highlighted. We addressed most of the proposed routing methods along with scheme designs, benefits and result analysis wherever possible. The routing protocols discussed are classified into seven categories such as Data centric routing, Hierarchical routing, Location based routing, Negotiation based routing, Multipath based routing, Quality of Service (QoS) routing and Mobility based routing. This paper also compares the routing protocols against parameters such as power consumption, scalability, mobility, optimal routing and data aggregation. The paper concludes with possible open research issues in WSNs.

Keywords: ***WSN, Routing protocol, QoS, Energy Efficient.***

1. INTRODUCTION

Wireless Sensor Network is a developing technology that restructuring the approaches of collecting, processing and distributing data. The WSN system is capable of deploying in large number of unchained sensors in areas without any infrastructure for monitoring sound, vibration, pressure, motion, pollutants or target tracking. Sensor network facilitate to monitor, discipline, control, or instruct numerous real-time environment domain such as buildings, homes, cities, and forest. In the beginning WSN was developed for military applications like battlefield control [1], [2]. Presently WSN is applicable in many civilian administrations, like monitoring environment and healthcare applications. The major concerning of this research and exploitation of WSNs are data communication and event detection through sensor coordination. Nowadays, the modification of sensor performance brings a range of new multifunctional applications, which embody modern microelectronics and wireless communication technology, to achieve purposes other than merely sensing measurements [3]-[5]. This small peripheral even incorporates multifunctional sensors. It deploys with an average processor and does not have a large memory for processing through a wireless trans receiver in communication with the support of the batteries. Sensor networks can be used for physical asset value measurement to monitor or detect particular areas and to evaluate the occurrence of the events.

In wireless sensors networks because of potentially uncertain and dynamic environments, there are general challenges in data processing, communication, and sensor management [6]. Also with energy and bandwidth constraints, sensor networks have additional technical challenges in network control and routing, data processing, querying, and tasking. The WSNs must deal with resources like energy, bandwidth, and the processing power, which are dynamically changing, and the system should operate autonomously, changing its configuration as required. Since communication links are unreliable and shadow fading may eliminate links, the software and system design should generate the required reliability [7], [8]. This requires

research into issues such as network size or the number of links and nodes needed to provide adequate redundancy. In the routing protocols depending on the applications, the communication distance and energy must be well managed.

2. ROUTING CHALLENGES

Some of the routing challenges in WSN are as follows.

Energy Consumption: As sensor nodes in WSN have limited battery power, it becomes challenging to perform computation and transmission while optimizing energy consumption [9]. In fact the transmission of one bit of data consumes more energy than processing the same bit of data. Sensor node life time strongly depends on its battery life.

Node Deployment: Sensor nodes are usually densely deployed in the field of interest depending on application thus influencing the performance of a routing protocol. The deployment can be either deterministic or self-organizing. In deterministic case, the sensor nodes are manually placed and sensed data is routed through determined paths. In self organizing systems, sensor nodes are scattered randomly and creating a topology in an adhoc manner [10].

Data Delivery Models: Data delivery models can be time driven, data driven, query driven and hybrid (combination of delivery models) depending on the application of sensor nodes and time criticality of data reporting. These data delivery models highly influence the design of routing protocols especially with regard to reducing energy consumption [11], [12].

Node Capability: Depending on the application, a sensor node can have different role or capability such as relaying, sensing and aggregation since engaging all these functions on the same node would drain the energy of that node more quickly. Different capabilities of sensor nodes raise multiple issues related to data routing and makes routing more challenging [13], [14], [15].

Network Dynamics: Most of the network architectures assume that sensor nodes are static but the mobility of base stations and sensor nodes is necessary in some applications [16]. Routing packets in such dynamic architectures becomes challenging in addition to minimizing energy consumption and bandwidth utilization.

Data Aggregation: Since sensor nodes generate redundant data, cluster heads or base stations may receive similar packets from multiple nodes and these packets need to be aggregated before being forwarded to the base station. Signal processing methods can also be used for data aggregation [17].
Other routing challenges in WSNs are scalability, coverage area [18], transmission media [19], fault tolerance and QoS [20].

3. TAXONOMY OF ROUTING PROTOCOLS

We present taxonomy of routing protocols for WSNs based on various classification criteria such as data centric, hierarchical, location based, negotiation based, multipath based, quality of service and mobility based as shown in figure 1. The objective of taxonomy is twofold: (1) to provide a framework Wireless Sensor Network in which routing and data dissemination protocols for WSNs can be examined and compared; and (2) to gain new insights into the routing and data dissemination protocols and thereby suggests avenues for future research.

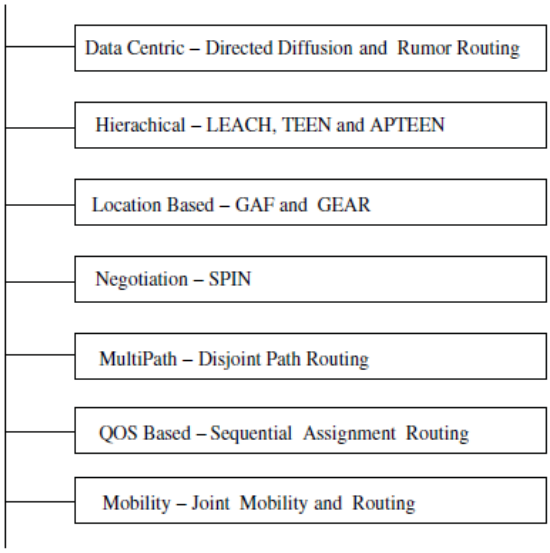

Fig. 1: Taxonomy of Routing Protocols in WSN

A. Data Centric Routing

Lack of global identification along with random deployment of sensor nodes makes it hard to select a specific set of sensor nodes to be queried. Since data is usually transmitted with significant redundancy. This is very inefficient in terms of energy

consumption, routing protocols that are able to select a set of sensor nodes and utilize data aggregation during the relaying of data have been considered. This consideration has led to data-centric routing, a new communication paradigm where attribute based naming is necessary to specify the properties of data [21].

B. Hierarchical Routing

In hierarchical architecture, sensor nodes are organized into clusters, where a node with lower energy can be used to perform the sensing task and send the sensed data to its cluster head at short distance, while a node with higher energy can be selected as a cluster head to aggregate the data from its members and forward it to the sink [23]. This process can not only reduce the energy consumption, but also balance traffic load and improve the scalability [24]. Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN): A sensing application can be designed in a way where the sensors either sense and transmit data periodically to the sink (proactive) or react immediately to any sudden change in the value of sensed attribute (reactive). For time-critical applications, a reactive network is more suitable than a proactive network. In order to trade-off between energy efficiency, data accuracy and response time dynamically, a communication protocol, named as TEEN has been proposed [25].

C. Location Based Routing

In most cases, location information is needed to calculate the distance between two particular nodes so that energy consumption can be estimated. Geographic Adaptive Fidelity (GAF) protocol [26] is a location based protocol although proposed for Mobile Adhoc Networks (MANETs), it favors energy conservation and thus can be used for WSNs. Geographic Adaptive Fidelity (GAF): If the region to be sensed is known, using the location of sensors, query can be diffused only to that region thus reducing the number of transmissions significantly. It is possible to locate nodes through satellites or GPS (Global Positioning System) on the basis of the signal strength passed between neighbor nodes. The common approach for energy saving is to use sleep modes in nodes expecting no activity in a period of time. This is the main idea behind GAF.

D. Negotiation Based Routing

These protocols use high level data descriptors called metadata in order to avoid redundant data transmissions through negotiation. Communication decisions are also taken based on the resources available. SPIN (Sensor Protocol for Information via Negotiation): For applications like intruder detection, disseminating individual sensor observations to all sensors in a network should be performed as energy efficient as possible. In light of this, a family of adaptive protocols named SPIN has been proposed. The SPIN protocols were designed to overcome the problems of flooding. The SPIN protocols are resource aware and resource adaptive. They can make informed decisions for efficient use of their own resources [27].

E. Multipath Based Routing

These protocols use multiple paths instead of single path to enhance network performance by providing fault tolerance. These alternate paths are kept alive by sending periodic messages. Disjoint Path Routing: In multipath routing, each source sensor node finds the first k shortest paths to the sink and divides its load evenly among these paths. Multipath protocols help find a small number of alternate paths that have no sensor in common with each other and with the primary path. These protocols are said to be sensor-disjoint multipath routing protocols [28].

F. QoS Based Routing

In addition to minimizing energy consumption, it is essential to consider QoS requirements in terms of delay, reliability and fault tolerance for routing in WSNs. Both fault tolerance and reliability require the deployment of more than necessary sensors so that the network can continue to function properly and deliver accurate sensed data to the sink despite some sensor failures [29]. Sequential Assignment Routing (SAR) is one of the first routing protocols for WSNs that introduces the notion of QoS in the routing decisions. Sequential Assignment Routing (SAR): Routing decision in SAR depends on three factors: energy resources, QoS on each path and the priority level of each packet. To avoid single route failure, a multi-path approach and localized path restoration schemes are used.

G. Mobility Based Routing

Some sensor applications require mobile nodes to accomplish a sensing task. Mobility brings new challenges to routing and data dissemination in

WSNs and increases the complexity of implementation. Joint Mobility and Routing Protocol: A network with a static sink suffers from a severe problem, called energy sinkhole problem where the sensors located around the static sink are heavily used for forwarding data to sink. As a result, those heavily loaded sensors close to the sink deplete their battery power more quickly, thus disconnecting from the network. This problem exists even when the static sink is located at its optimum position corresponding to the center of the sensor field. To address this problem, a mobile sink for gathering sensed data from source sensors has been suggested [30].

4. COMPARISON OF PROTOCOLS

The figure 2 shows the similarities between the protocols based on the classification criteria used in the taxonomy.

	Directed Diffusion	LEACH	GAF	SPIN	SAR	GEAR
Energy Consumption	Limited	Maximum	Limited	Limited	Maximum	Limited
Scalability	Limited	Good	Good	Limited	Limited	Limited
Location Awareness	NO	NO	NO	NO	NO	NO
Optimal Routing	YES	NO	NO	NO	NO	NO
Mobility	Limited	Fixed Sink	Limited	Possible	NO	Limited
MultiPath	YES	NO	NO	YES	NO	NO
Data Aggregation	YES	YES	NO	YES	NO	NO
Health	NO	YES	NO	NO	YES	NO
Environment Monitoring	YES	NO	YES	NO	NO	NO
Military	NO	NO	YES	NO	NO	NO
Commercial	NO	NO	NO	NO	YES	NO

Fig. 2: Comparison of Routing Protocols in WSNs

5. CONCLUSION

In recent years, routing in WSN has gained tremendous attention leading to unique challenges and design issues when compared to routing in traditional wired networks. In this paper, we have discussed recent research activities on routing in WSNs and classified the approaches to routing in seven main categories. In case of Data centric routing, naming rules such as attribute-value pairs will not work for complex queries that are application dependent. The building of standard efficient naming schemes is one of the open issues for future research in this category. In case of Hierarchical routing, the nodes are grouped together to form clusters. Cluster heads are responsible for data aggregation and relay of messages to the sink.

The design issues for such protocols are how to form clusters and select cluster heads so that energy consumption in the communication of redundant messages as well as aggregation is reduced. The factors affecting cluster formation and cluster head communication are open future research issues in this category. In case of Location based routing protocols, energy efficient and intelligent utilization of location information is an open research issue. QoS based routing has its own quality requirements when it comes to real time applications like target tracking in battle fields. Handling the QoS requirements in energy efficient way is one of the open research issues in QoS based routing. Many of the current routing protocols in WSN assume that nodes and sink are static. However, there are situations like battle field environments where sinks as well as the sensor nodes need to be mobile. New routing algorithms are required to accommodate mobility and dynamic topology changes in energy constrained environment of WSNs. Another possible future research area for routing protocols is the integration of internet with WSNs so that the data sensed in one part of the world can be sent to the server located in another part of the world for further analysis.

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