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Routing Protocols in Wireless Sensor Networks

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Abstract—

Wireless sensor network consists of a group of spatially distributed sensor nodes which are interconnected without wires. Sensor nodes have constrained due to limited energy, storage capacity and limited power. Data are routed from one node to other node by using different routing protocols. Routing protocols for wireless sensor networks are responsible for maintaining the routes in the network and have to ensure reliable multi-hop communication under these conditions. The focus, however, has been given to the routing protocols which might differ depending on the application and network architecture. Overall, this paper presents the overview on different routing protocols for wireless sensor networks.

Keywords— Sensor, Energy, Routing, Wireless Sensor Network.

I. INTRODUCTION

Wireless sensor network (WSN)[1] is a co-operative network of small size, low power, smart devices named as Nodes or Motes, which have the capability of sensing a physical phenomenon (like temperature, humidity, pressure, vibration etc) and relay the same or processed information to a sink via wireless links possibly with multiple hops between these nodes. The unique characteristics of WSN such as small size, low power consumption, autonomous, mobility, dense in volume, self healing and self-organizing poses some constraints in terms of power consumption, storage, processing capabilities and bandwidth requirement [2]. Sensors are deployed in an ad-hoc manner in the area of interest to monitor events and gather data about the environment. They have the ability of sensing, data processing and communicating with each other in the network environment. Multi-hopping in the WSNs can cause a sensor node to communicate with a node with is far away from it. This allows the sensor nodes in the network to expand the monitored area and hence proves its scalability and flexibility property [3]. The fundamental goal of a WSN is to produce information from raw local data obtained (sensed data) by individual sensor mode by prolonging the life time of WSN as much as possible. The resource constrained nature of sensor nodes pose the unique challenges to the design of WSNs for their applications. The limited power of sensor nodes mandates the design of energy-efficient communication protocol in WSNs [4]. In a WSN the node that gathers the data information refers to sink. The sink may be connected to the outside world through internet where the information can be utilized within time constraints. The main problem in using these networks is limited battery life. This is due to fact that the size of a sensor node is expected to be small and this leads to constraints on size of its components i.e. battery size, processors, data storing memory, all are needed to be small. So any optimization in these networks should focus on optimizing energy consumption in the network [5]. An efficient and beneficial solution from overcoming this problem is to implement routing protocols that perform efficiently and utilizing the less amount of energy as possible for the communication among nodes

II. ROUTING CHALLENGES AND DESIGN ISSUES IN WSNS

The routing protocols designed for WSN should consider the goal, application area, and architecture of the network. The design of routing protocols is influenced by many challenging factors caused by the nature of the WSNs. These factors must be overcome before efficient communication can be achieved in WSNs. Some of these factors will be reviewed in this paper.

A. Node Deployment

In WSNs, the node deployment can be either deterministic or randomized. In deterministic deployment, the sensors are manually placed and data is routed through pre-determined paths. In random node deployment, the sensor nodes are distributed randomly creating an infrastructure in an ad hoc manner. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network operation.

B. Energy considerations

The energy consideration has a great influence on route design because the life-time of the WSN depends on energy resources and their consumption by sensors. During transmission of any node, the greatest portion of energy is consumed. Direct communication consumes more power than multi-hop communication.

C. Data delivery model

Data delivery model depends on the application and can be continuous, event-driven, query-driven, or hybrid. In continuous model of delivery, each sensor sends the data periodically. In event-driven and query driven data delivery models, the transmission is triggered by an event or a query generated by the sink.

D. Fault Tolerance

In wireless sensor networks, some sensor nodes may fail or be blocked due to environmental interference, lack of power or physical damage. The failure of sensor nodes should not affect the overall task of the sensor network. This may require actively adjusting transmit powers and signaling rates on the existing links to reduce energy consumption, or rerouting packets through regions of the network where more energy is available. Therefore, in a fault-tolerant sensor network, multiple levels of redundancy may be needed. The routing protocol has to be dynamic; failures of specific nodes should not affect network operation.

E. Scalability

The number of sensor nodes deployed in the sensing area may be in the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes. In addition, sensor network routing protocols should be scalable enough to respond to events in the environment.

F. Network dynamics

In addition to energy, bandwidth etc., routing messages from or to moving nodes is more challenging since route stability becomes an important issue. The sensed phenomenon in wsn can be either dynamic or static, e.g., it is dynamic in a target detection/tracking application, while it is static in forest monitoring for early fire prevention.

G. Transmission media

In general, the required bandwidth of sensor data will be low, on the order of 1-100 kb/s. Related to the transmission media is the design of MAC.

H. Data aggregation

Data aggregation is the combination of data from different sources according to a certain aggregation function, e.g., duplicate suppression, minima, maxima and average. Since the sensors are densely deployed by definition, the data gathered from each node are correlated. Therefore data aggregation or in other words data fusion decreases the size of the data transmitted.

I. Quality of service

In many applications, conservation of energy, which is directly related to network lifetime? As energy is depleted, the network may be required to reduce the quality of results in order to reduce energy dissipation in the nodes and hence lengthen the total network lifetime.

III. ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS

The routing protocols for WSNs are classified considering several architectural factors. Routing protocols for Wireless Sensor Networks (WSNs) are mainly classified into two categories: Network Structure Based protocols and Protocol Operation Based protocols [5, 6]. Figure 1 shows the various routing protocols in wireless sensor networks.

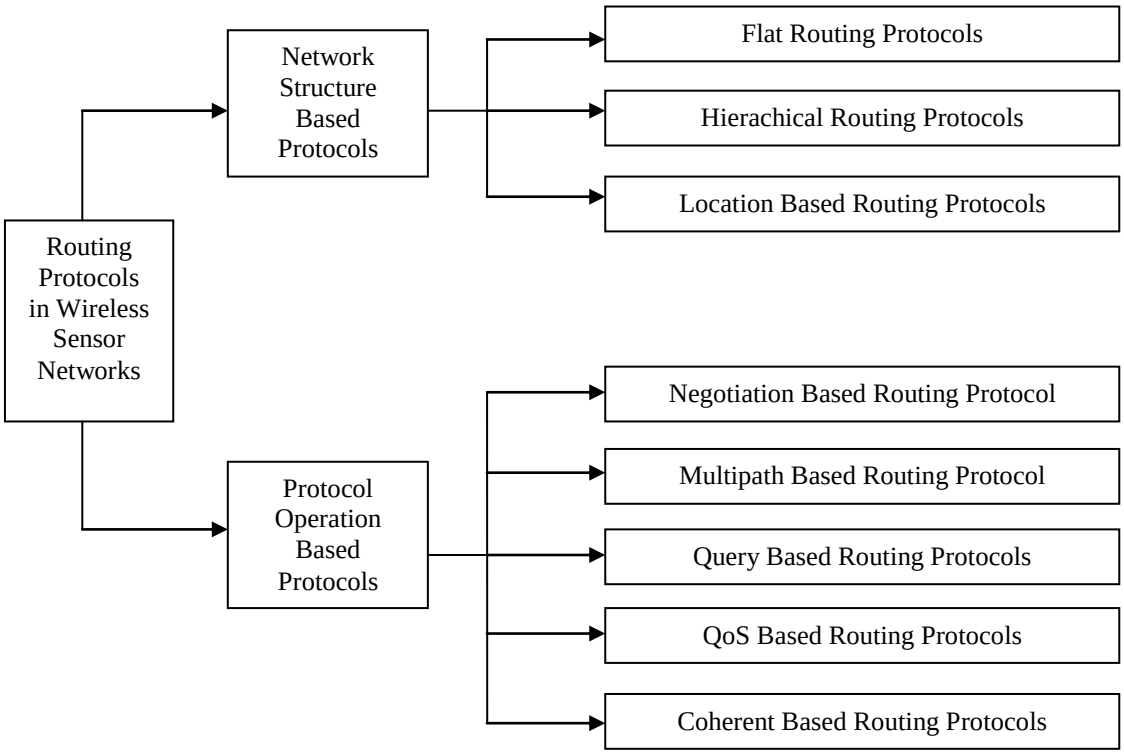

Fig.1. Routing Protocols in Wireless Sensor Networks.

A. Network Structure Based Protocol

The network structure based protocols depend on the system architecture of the network. These protocols are divided into three categories: Data centric or flat routing protocols, Hierarchical routing protocols, and Location based routing protocols.

1) Data Centric or Flat Routing Protocols:

In this routing protocol each node plays the same role and sensor nodes collaborate to perform the sensing task. Due to the large number of such nodes, it is not feasible to assign a global identifier to each node. This consideration has led to data centric routing, where the BS sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute-based naming is necessary to specify the properties of data.

2) Hierarchical Routing Protocols:

Hierarchical routing is an efficient way to lower the energy consumption within a cluster with the help of performing data aggregation and fusion within the different clusters in order to decrease the number of transmitted messages to the sink node. 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.

3) Location Based Routing Protocols:

In this type of protocol sensor nodes are addressed by means of their locations. The distance between neighboring nodes can be estimated on the basis of incoming signal strengths from the source nodes. Relative coordinates of neighboring nodes can be obtained by exchanging such information between neighbors or by communicating with a satellite using GPS.

B. Protocol Based Protocol

Protocol operation based protocols are classified into five categories: Negotiation based routing protocol; Multi-path based routing protocol, Query-based routing protocol, Qos-based routing protocol, and Coherent-based routing protocol

1) Negotiation Based Routing Protocol:

This negotiation based routing is done in order to eliminate redundant data transmissions. In this communication decisions are also made based on the resources available in the network scenario. the main idea of negotiation based routing in WSNs is to suppress duplicate information and prevent redundant data from being sent to the next sensor or the base-station by conducting a series of negotiation messages before the real data transmission begins.

2) Multi Path Based Routing Protocol:

It uses multiple paths rather than a single path in order to enhance network performance. For instance the fault tolerance can be increased by maintaining multiple paths between the source and destination at the expense of increased energy consumption and traffic generation. In [7], multipath routing was used to enhance the reliability of WSNs. It is known that network reliability can be increased by providing several paths from source to destination and by sending the same packet on each path.

3) Query Based Routing Protocol:

In this kind of routing, the destination nodes propagate a query for data (sensing task) from a node through the network and a node having this data sends the data which matches the query back to the node, which initiates the query

4) QoS Based Routing Protocol:

In QoS-based routing protocols, the network has to balance between energy consumption and data quality. In particular, the network has to satisfy certain QoS metrics, e.g., delay, energy, bandwidth, etc. when delivering data to the BS.

5) Coherent Based Routing Protocol:

The entity of local data processing on the nodes is being distinguished between the coherent (minimum processing) and the non-coherent (full processing) routing protocols. In coherent routing, the data is forwarded to aggregators after minimum processing. The minimum processing typically includes tasks like time stamping, duplicate suppression, etc. To perform energy efficient routing, coherent processing is normally selected. Non-coherent functions have fairly low data traffic loading. On the other hand, since coherent processing generates long data streams, energy efficiency must be achieved by path optimality. In non-coherent processing, data processing incurs three phases:

- Target detection, data collection, and preprocessing (phase 1)
- Membership declaration, (phase 2)
- Central node election (phase 3)

During phase 1, a target is detected, its data collected and preprocessed. When a node decides to participate in a cooperative function, it will enter phase 2 and declare this intention to all neighbors. This should be done as soon as possible so that each sensor has a local understanding of the network topology. Phase 3 is the election of the central node. Since the central node is selected to perform more sophisticated information processing, it must have sufficient energy reserves and computational capability.

IV. CONCLUSION

Routing in sensor networks is a new area of research, with a limited, but rapidly growing set of research results. In WSNs many energy efficient routing protocols are available now-a-days. Routing in wireless sensor networks differs

from conventional routing in fixed networks in various ways. There is no infrastructure, wireless links are unreliable, sensor nodes may fail, and routing protocols have to meet strict energy saving requirements. One of the main challenges in the design of routing protocols for WSNs is energy efficiency due to the scarce energy resources of sensors. Overall, the routing techniques are classified based on the network structure into three categories: flat, hierarchical, and location based routing protocols. Furthermore, these protocols are classified into multipath-based, query-based, negotiation-based, or QoS-based routing techniques depending on the protocol operation.

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