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A Survey of Routing Protocols in Wireless Sensor Networks

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Abstract
wireless sensor networks is one of the most common communication tools used in many areas such as military, environment, health, and commercial applications. The wireless sensor network comprised of huge number of sensor nodes. The sensor nodes communicate by means of many communication strategies. Then, the data exchange is supported by multi-hop communications. Routing protocols are responsible for discovering and maintaining the routes in the network. The correctness of a particular routing protocol mainly depends on the capabilities of the nodes and on the application requirements. This paper presents a analysis of the main routing protocols proposed for wireless sensor networks
Keywords: *wireless sensor network, routing protocol*

1. INTRODUCTION

Wireless sensor network (WSN) consists of a huge number of sensor nodes. A sensor node is a small, wireless device, able to responding to one or more than a few stimuli, processing the data and transmitting the information over a short distance using radio frequencies. The sensor actually senses the physical phenomenon close to the point of their occurrence and then converts these measurements into signals that can be processed to expose some characteristics about phenomena located in the area around these sensors. The types of observable fact that can be sensed include acoustics, light, humidity, temperature, imaging, any physical phenomenon that will make a transducer respond. Sensor node contains sensors, processor, memory, communi-cation system, mobilizer, position finding system, and power unit. WSN collects data from target area and then forwards towards an infrastructure processing node or base station (BS.) A BS and sensor nodes might be a fixed or mobile. The WSNs may contain thousands of nodes, which can be installed in very high density, in homes, roads, buildings, cities, and infrastructures for monitoring and controlling purposes.

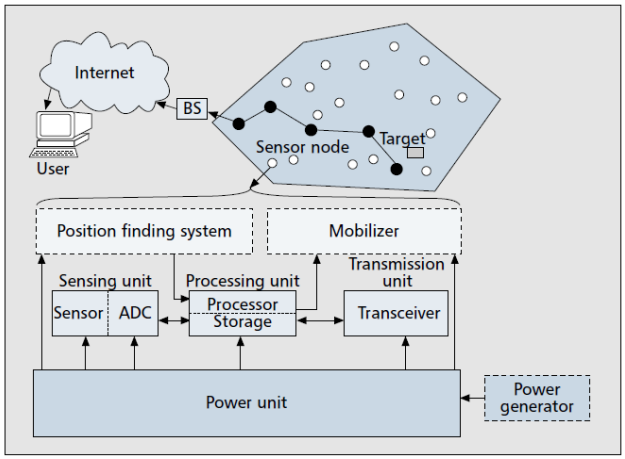


Figure 1 reproduces a schematic diagram of sensor node components and WSN [2].

2. ROUTING CHALLENGES

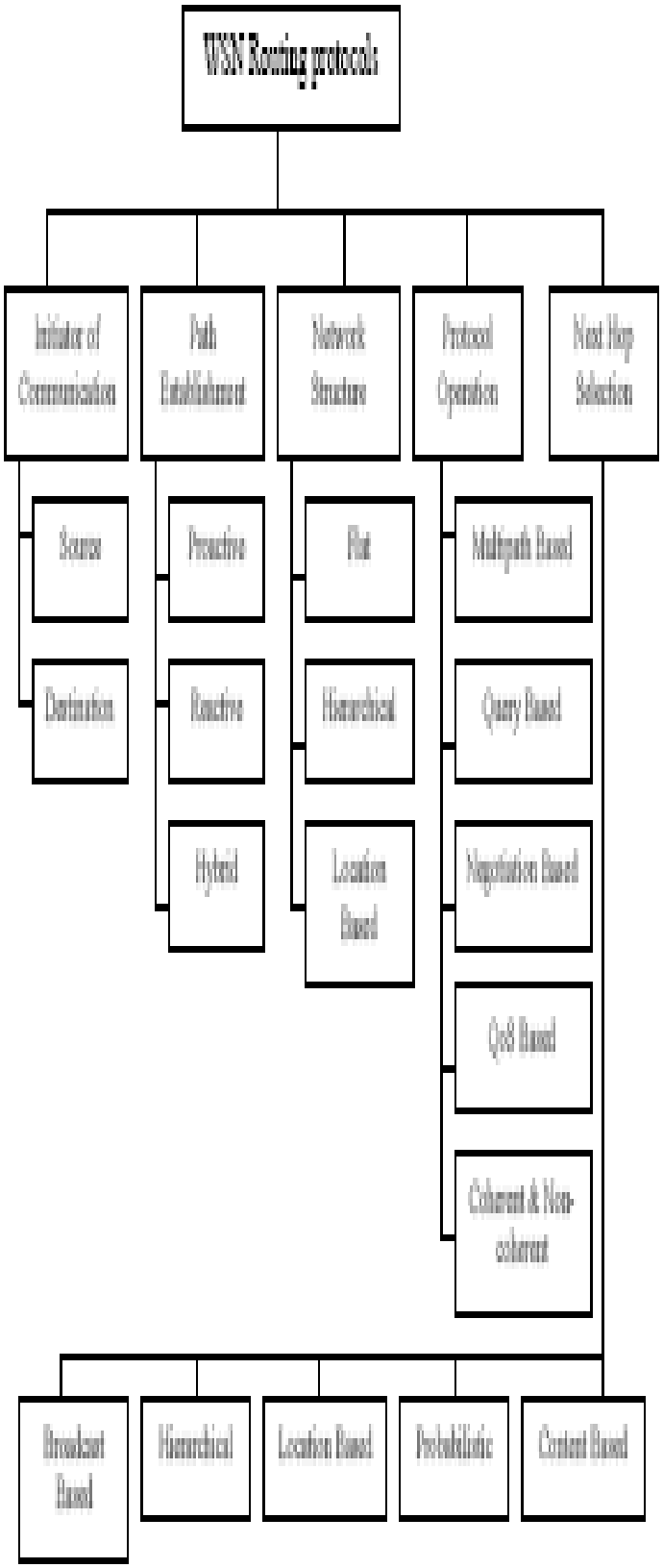
Routing is a process of determining a path from a source node to its destination for data transmission. Routing in WSN is very demanding owing to the resource constraint characteristics that differentiate these networks from other wireless networks like mobile ad hoc networks or cellular networks. In WSN, the routing protocols are application specific, data-centric, and location based. The important uniqueness of a good routing protocol for WSN are simplicity, energy awareness, adaptability and scalability due to limited energy supply, limited computation power, limited memory and limited bandwidth of WSN [5, 6, 7]. The main design goal of WSNs is to carry out data communication while trying to extend the lifetime of the network. The routing protocol design in WSNs is influenced by many challenging factors as summarized below:

- Massive and random node deployment
- Network characteristics and changeable environment
- Data Aggregation
- Fault tolerance
- Limited energy capacity
- Limited hardware resources
- Scalability
- Sensor Network Topology
- Quality of Service
- Transmission media

3. WSN ROUTING PROTOCOLS

Routing is a process of determining a path between the source node and the sink (destination) node upon request of Data transmission. In WSNs, the network layer is mostly used to employ the routing of the arriving data. It is recognized that usually in multi-hop networks the source node cannot arrive at the sink directly. So, intermediate sensor nodes have to dispatch their packets. The execution of routing tables gives the solution. These consist of the lists of node option for any given packet destination. Routing table is the task of the routing algorithm along with the help of the routing protocol for their construction and maintenance [2].

WSN Routing Protocols can be classified into five ways, according to the way of set up the routing paths, according to the network structure, according to the protocol operation, according to the initiator of communications, and according to how a protocol selects a next hop on the route of the forwarded message, as shown in fig. 2. Almost all of the routing protocols can be classified as data-centric, hierarchical or location-based although there are a small number of distinct ones based on network flow or QOS alertness. Data-centric protocols are query-based and depend on the naming of desired data, which helps in eradicating many redundant transmissions. Hierarchical protocols intend at clustering the nodes so that cluster heads can do some aggregation and reduction of data in order to save energy. Location-based protocols employ the position information to relay the data to the desired regions rather than the whole network. The last category includes routing approaches that are based on general network-flow modeling and protocols that attempt for meeting some QOS requirements along with the routing function. In this paper, we will survey the routing mechanisms for sensor networks developed in recent years. Each routing protocol is discussed under the proper category. Our aim is to help better understanding of the current routing protocols for wireless sensor networks and point out open issues that can be a subject matter of further research.


WSN Routing protocols
Initiator of Communication
Path Establishment
Network Structure
Protocol Operation
Next Hop Selection
Source
Destination
Proactive
Reactive
Hybrid
Flat
Hierarchical
Location Based
Multipath Based
Query Based
Negotiation Based
QoS Based
Coherent & Non-coherent
Broadcast Based
Hierarchical
Location Based
Probabilistic
Content Based

3.1. Path establishment Based Routing Protocols

Routing paths can be established in one of the three ways, namely proactive, reactive or hybrid. Proactive protocols compute all the routes before they are really needed and then store these routes in a routing table in each node.

Reactive protocols compute routes only when they are needed. Hybrid protocols use a combination of these two ideas [6].

Proactive Protocols

Proactive routing protocols are maintaining constant and accurate routing tables of all network nodes using periodic distribution of routing information. All routes are calculated before their needs in this category of routing. Most of these routing protocols can be used both in flat and hierarchal structured networks. The advantages of flat proactive routing are its ability to calculate an optimal path that requires operating cost for this computation which is not acceptable in many environments. While to meet the routing demands for larger ad hoc networks, hierarchal proactive routing is the better solution [8].

Reactive Protocols

Reactive routing strategies do not keep the global information of all the nodes in a network rather the route organization between source and destination is based on its dynamic search according to demand. To determine a route from source to destination a route discovery query and the reverse path is used for the query replies. Therefore, in reactive routing strategies, route selection is on insisting using route querying before route organization.

These strategies are dissimilar by two ways: by reestablishing and re-computing the path in case of failure occurrence and by dropping communication overhead caused by flooding on networks [8].

Hybrid Protocols

This strategy is useful for large networks. Hybrid routing strategies include both proactive and reactive routing strategies. It employs clustering technique which makes the network constant and scalable. The network cloud is separated into many clusters and these clusters are maintained dynamically if a node is added or leave a particular cluster.

This strategy makes use of proactive technique when routing is needed within clusters and reactive technique when routing is needed across the clusters

3.2. Network Based Routing Protocols

Protocols are divided according to the structure of the network which is very essential for the required operation. The protocols incorporated into this category are further divided into three subcategories according to their functionalities. The protocols are [6]

Flat-Based Routing

When enormous amount of sensor nodes are required, flat based routing is needed where every node plays the same role.

Since the number of sensor nodes is very large therefore it is not possible to allocate a particular identification (Id) to each and every node. This leads to data-centric routing approach in which Base station sends query to a group of particular nodes in a region and waits for the response.

Examples of Flat-based routing protocols are [5,8,9]:

- Energy Aware Routing (EAR).
- Directed Diffusion (DD).
- Sequential Assignment Routing (SAR).
- Minimum Cost Forwarding Algorithm
- (MCFA).
- Sensor Protocols for Information via
- Negotiation (SPIN).
- Active Query forwarding in a sensor network (ACQUIRE).

Hierarchical-Based Routing

When network scalability and well-organized communication is needed, hierarchical-based routing is the best match. It is also called as

cluster-based routing. Hierarchical-based routing is energy competent method in which high-energy nodes are randomly selected for processing and sending data while low energy nodes are used for sensing and send information to the cluster heads. This property improves the network scalability, lifetime and minimizes energy consumption of this routing.

Examples of hierarchical-based routing protocols are [5, 8, 9]

- Hierarchical Power-Active Routing (HPAR).
- Threshold sensitive energy efficient sensor network protocol (TEEN).
- Minimum energy communication network (MECN).

Location-Based Routing

In this kind of network architecture, sensor nodes are spotted randomly in an area of interest and mostly known by the geographic position where they are deployed. They are positioned mostly by means of GPS.

The distance between nodes is predictable by the signal strength received from those nodes and coordinates are calculated by exchanging information between neighboring nodes. Location-based routing networks are [5,8, 9]

- Sequential assignment routing (SAR).
- Ad-hoc positioning system (APS).
- Geographic adaptive fidelity (GAP).
- Greedy other adaptive face routing (GOAFR).
- Geographic and energy aware routing
- (GEAR).
- Geographic distance routing (GEDIR).

3.3. Operation Based Routing Protocols

WSNs applications are classified according to their functionalities. Thus, routing protocols are categorized according to their operations to meet these functionalities. The underlying principle behind their classification is to achieve optimal performance and to save the scarce resources of the network.

Multipath Routing Protocols

- As its name implies, protocols included in this class provides multiple path selections for a message to reach the destination thus decreasing delay and increasing network performance. Network reliability is achieved due to increased overhead. Since network paths are kept alive by sending periodic messages and, therefore, use greater energy. Multipath routing protocols are[8]:
- Multipath and Multi SPEED (MMSPEED).
- Sensor Protocols for Information via
- Negotiation (SPIN).

Query Based Routing Protocols

This category of protocols works by sending and receiving queries for data. The destination node sends the query of interest from a node through network and nodes with this interest matches the query and sends back to the node which initiated the query. The query generally uses high-level languages. Query based routing protocols are [8]:

- Sensor Protocols for Information via
- Negotiation (SPIN).
- Directed Diffusion (DD).
- COUGAR.

Negotiation Based Routing Protocols

This class of protocols employs the high-level data descriptors to eradicate redundant data transmission through negotiation.

These protocols make intelligent decisions either for communication or other actions based on facts such that how much resources are available. Negotiation based routing protocols are [8]: Sensor Protocols for Information via

- Negotiation (SPAN).
- Sequential assignment routing (SAR).
- Directed Diffusion (DD).

QOS Based Routing Protocols

In this type of routing, network needs to have a balanced approach for the QOS of applications. In

this case, sensor application can delay sensitive so to achieve this QOS metric network have to look also for its energy consumption which is another metric when communicating with the base station. So to achieve QOS, the cost function for the desired QOS also needs to be considered. Examples of such routing are: [8]

- Sequential assignment routing (SAR).
- Multipath and Multi SPEED (MMSPEED).

Coherent and non-coherent processing:

Data processing is a major component in the operation of wireless sensor networks. Thus, routing techniques use special data processing techniques. There are two ways of data processing based routing [6].

Non-coherent data processing: In this, nodes will locally process the raw data previous to being sent to other nodes for additional processing. The nodes that perform additional processing are called the aggregators.

Coherent data processing: In coherent routing, the data is forwarded to aggregators following minimum processing. The minimum processing typically includes tasks like time stamping, duplicate suppression, etc. When all nodes are sources and send their data to the central aggregator node, a large amount of energy will be devoted and hence this process has a high cost. One way to lower the energy cost is to limit the number of sources that can send data to the central aggregator node.

3.4. Initiator of Communication Based Routing Protocol

In this type of routing protocol, it depends on the communication between network components, where they usually in sleep mode temporary. When any part of a network, the sink (destination, base station) node or the source node needs service from other part, it will initiate the routing with another part to send or/and receive the control or data packets [6].

- Source Initiator Routing Protocol.
- Destination Initiator Routing Protocol.

3.5. Next-Hop Selection Based Routing Protocols

Content-based routing protocols

These protocols determine the next-hop on the route purely based on the query content. This type of routing protocols fits the most to the architecture of sensor networks since the base station do not query specific nodes rather it requests only for data regardless of its origin [5, 9].

- Directed Diffusion.
- GBR.
- Energy Aware Routing.

Probabilistic routing protocols

These protocols think that all sensor nodes are homogeneous and randomly deployed. Using this routing protocol, sensor nodes randomly choose the next-hop neighbor for each message to be forwarded. The probability of choosing a certain neighbor is inversely proportional to its cost [5].

- Energy Aware Routing Protocol.

Location-based routing protocols

These protocols choose the next-hop towards the destination based on the identified position of the neighbors and the destination. The position of the destination may denote the centroid of a region or the exact position of a specific node. Location-based routing protocols are able to avoid the communication overhead caused by flooding, but the computation of the positions of neighbors may result from an extra overhead. The local minimum problem is general to all decentralized location-based routing protocols: it might occur that all neighbors of an intermediate node are beyond from the destination than the node itself. In order to avoid this problem, every protocol uses differently routing techniques [5].

GEAR (Geographical and Energy AwareRouting).

Hierarchical-based routing protocols

In a case of hierarchical protocols, all nodes forward a message for a node (also called an

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 save 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 whereas the aggregator is also referred as cluster head. Cluster heads are more resourced nodes, where resource is common means that their residual energy level is higher than the average. The reason is that they are passing through by high track and they perform more computation (aggregation) than other nodes in the cluster. Hierarchical routing is primarily two-layer routing where one layer is used to decide on cluster heads and the other layer is used for routing. [5, 9]

- LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol.

Broadcast-based routing protocols

The operation of these protocols is very straight forward. Each node in the network decides individually whether to forward a message or not. If a node makes a decision to forward, it simply rebroadcasts the message. If it refuse to forward, the message will be dropped [5]

- MCFA (Minimal Cost Forwarding Algorithm).

4. CONCLUSIONS

In this paper, the researcher study the routing protocols in wireless sensor networks and classify them into many categories depending on many metrics, and concludes that there are many differences between these protocols and there are many application for some classes while other classes apply to special decide applications, because of the nature of these protocols.

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