Survey of routing protocols in wireless sensor networks

Hussein Mohammed Salman[1, 2]

[1]College of Material Engineering, Babylon University, Babil, Iraq
[2]Babylon University, Babil, Iraq

Email address:
hus12m@yahoo.com

Abstract: WSN is one of the most commonly communication tools used in many areas at the life, in both civilians and militaries. These networks composite from a large number of very small devices called sensor nodes. The sensor nodes communicate together by many wirelessly strategies. These communication strategies administrated by routing protocols. There are different types of routing protocol. This paper present and classify these protocols into many categories depending on set of metrics like their infrastructure, their functionalities, the level of privacy and security, or the application which used for it. This paper studied the availability and the reliability of each class of these routing protocols, and the energy consumption of each protocols. Depending on these criteria and other criteria, any future works may use this study to improving these protocols and used them in another types of networks.

Keywords: WSN, Routing Protocols, Sensors, Wireless Communications

1. Introduction

The original motivation for WSN research stemmed from the vision of Smart Dust in the late 1990s. This vision entailed an integrated computing, communication, and sensing platform consisting of many tiny devices, enabling applications such as dense environmental monitoring and smart home/office.[1]

A typical WSN encountered in the research literature consist of a large number of small, cheap, and resource-constrained sensor as well as a few base stations or sinks. In most WSN settings sensors collect data from the environment and forward it hop by hop to the sink. A sink is a powerful entity that may serve as a gateway to another network, a data processing or storage center, or an access point for human interface. WSN deployment can be ad hoc. The WSN might be often deployment on a large scale throughout a geographic region in hostile environments.

While many sensors connect to controllers and processing stations directly (e.g., using local area networks), an increasing number of sensors communicate the collected data wirelessly to a centralized processing station. This is important since many network applications require hundreds or thousands of sensor nodes, often deployed in remote and inaccessible areas [2]. A wireless sensor has not only a sensing component, but also on-board processing, communication, and storage capabilities. With these enhancements, a sensor node is often not only responsible for data collection, but also for in-network analysis, correlation, and fusion of its own sensor data and data from other sensor nodes. When many sensors cooperatively monitor large physical environments, they form a wireless sensor network (WSN). Sensor nodes communicate not only with each other but also with a base station (BS) using their wireless radios, allowing them to disseminate their sensor data to remote processing, visualization, analysis, and storage systems.

Wireless networks is an emerging new technology that will allow users to access information and services electronically, regardless of their geographic position.[3]

The sensor nodes have significantly lower communication and computation capabilities than do the full-featured computers participating in ad hoc networks. The problem of energy resources is especially difficult [4]. Due to their deployment model, the energy source of the sensor node is considered nonrenewable (although some sensor nodes might be able to scavenge resources from their environment). Routing protocols deployed in sensor networks need to consider the problem of efficient use of power resources.

Sensor networks are composed of resource constrained sensor nodes and more resourced base stations. All nodes in a network communicate with each other via wireless links, where the communication cost is much higher than the

computational cost. Moreover, the energy needed to transmit a message is about twice as great as the energy needed to receive the same message. Consequently, the route of each message destined to the base station is really crucial in terms network lifetime: e.g., using short routes to the base station that contains nodes with depleted batteries may yield decreased network lifetime. On the other hand, using a long route composed of many sensor nodes can significantly increase the network delay.[5]

In the section 2; the paper discuss the components of wireless sensor networks, the section 3 review and classify the routing protocols into many categories, and there are

some subsections. The conclusions will be at the end of this paper in section 4.

2. The Components of WSN

The main components of a general WSN are the sensor nodes, the sink (Base Station) and the events being monitored. Where the communication among the nodes is low-power wireless link while the communication between the base stations low latency and higher bandwidth link, as shown in the fig.1 [6,7].
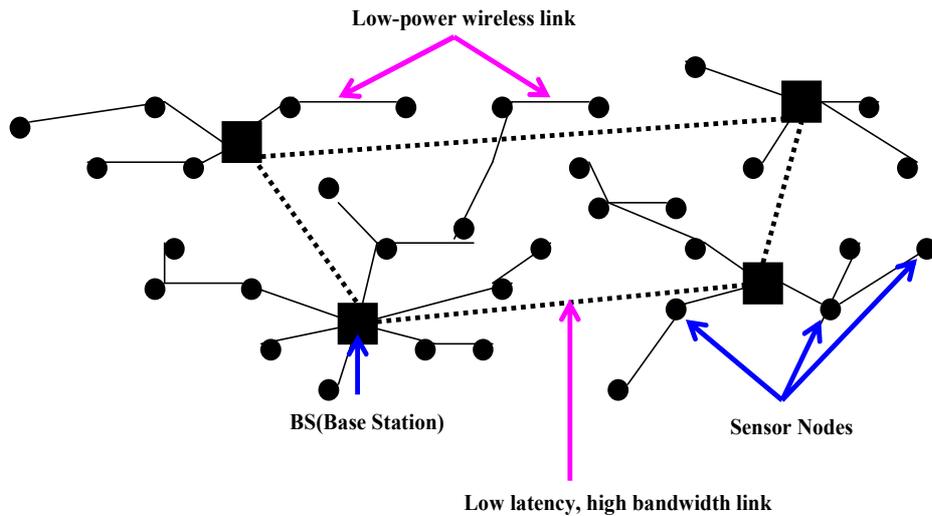

Fig. 1: A Representative Sensor Network Architecture

2.1. Base Station (Sink) (BS)

The sink (some time cluster head) is an interface between the external (management center) world and computational world (sensor network). It is normally a resourceful node having unconstrained computational capabilities and energy supply. There can be single or multiple base stations in a network. Practically, the use of multiple base stations decreases network delay and

performs better using robust data gathering [7].

2.2. The Sensor Nodes

As shown in the Fig. 2, a sensor node is composed of four basic components: sensing unit, processing unit, transceiver unit and a power unit [2].
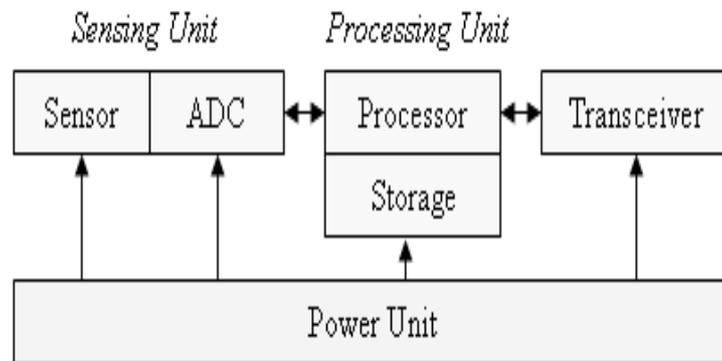

Fig. 2: Components of a Sensor

The sensing units are usually composed of two sub-units: Sensors and analogy-to-digital converters (ADCs). The analogy signals perceived by the sensor which are based in

the observed phenomenon are converted to digital signals by the ADC, and then they are nourished to the unit of processing. The process unit, that is generally associated to

a little storage device, manages / handles the procedures which make the sensor node collaborates with the others nodes in order to carry out the assigned sensor task.

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 implement the routing of the incoming data. It is known that generally in multi-hop networks the source node cannot reach the sink directly. So, intermediate sensor nodes have to relay their packets. The implementation of

routing tables gives the solution. These contain 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 establishing 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. 3.
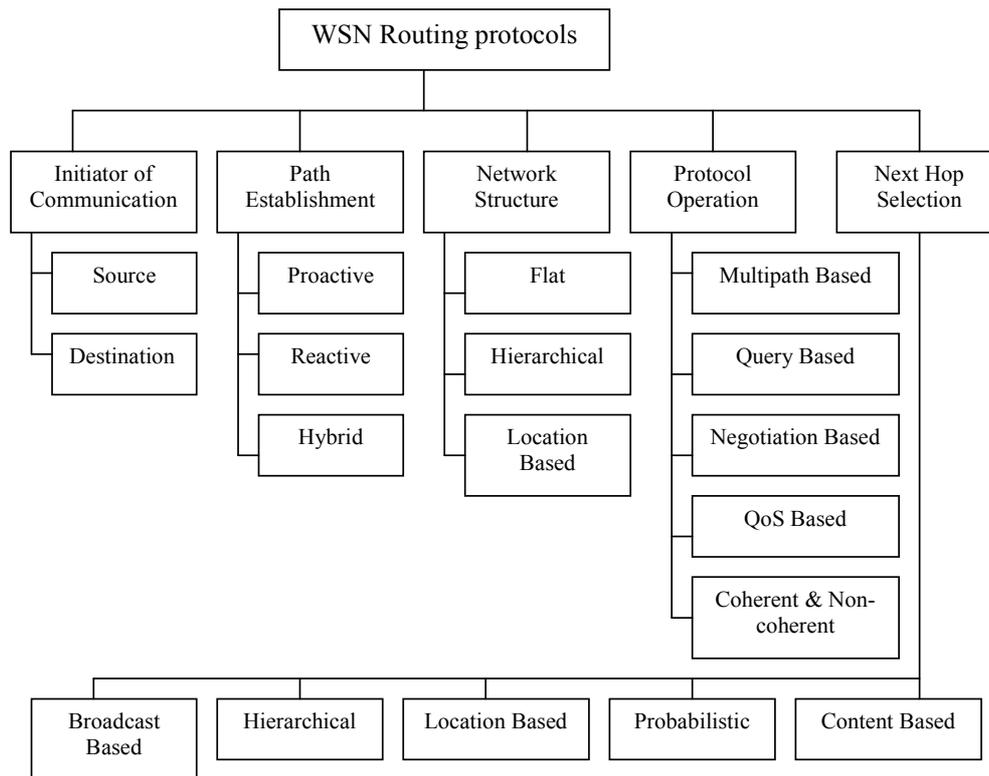

Fig. 3: *WSN Routing Protocols*

3.1. Path establishment Based Routing Protocols

Routing paths can be established in one of 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 maintain consistent and accurate routing tables of all network nodes using periodic dissemination of routing information. In this category of routing all routes are computed before their needs. Most of these routing protocols can be used both in flat and hierarchal structured networks. The advantages of flat proactive routing is its ability to compute optimal path which requires overhead 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 maintain the global information of all the nodes in a network rather the route establishment between source and destination is based on its dynamic search according to demand. In order to discover route from source to destination a route discovery query and the reverse path is used for the query replies. Hence, in reactive routing strategies, route selection is on demand using route querying before route establishment. These strategies are different by two ways: by re-establishing and re-computing the path in case of failure occurrence and by reducing communication overhead caused by flooding on networks [8].

• Hybrid Protocols

This strategy is applied to large networks. Hybrid routing strategies contain both proactive and reactive routing strategies. It uses clustering technique which makes the network stable and scalable. The network cloud is divided into many clusters and these clusters are maintained dynamically if a node is added or leave a particular cluster. This strategy uses proactive technique when routing is needed within clusters and reactive technique when routing is needed across the clusters. Hybrid routing exhibit network overhead required maintaining clusters [8].

3.2. Network Based Routing Protocols

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

- Flat-Based Routing

When huge amount of sensor nodes are required, flat-based routing is needed where every node plays same role. Since the number of sensor nodes is very large therefore it is not possible to assign 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 response. Examples of Flat-based routing protocols are[5, 8, 9]:
  - o Energy Aware Routing (EAR).
  - o Directed Diffusion (DD).
  - o Sequential Assignment Routing (SAR).
  - o Minimum Cost Forwarding Algorithm (MCFA).
  - o Sensor Protocols for Information via Negotiation (SPIN).
  - o Active Query forwarding In sensor network (ACQUIRE).
- Hierarchical-Based Routing

When network scalability and efficient communication is needed, hierarchical-based routing is the best match. It is also called cluster based routing. Hierarchical-based routing is energy efficient 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 of hierarchical-based routing contributes greatly to the network scalability, lifetime and minimum energy. Examples of hierarchical-based routing protocols are; [5, 8, 9]
  - o Hierarchical Power-Active Routing (HPAR).
  - o Threshold sensitive energy efficient sensor network protocol (TEEN).
  - o Power efficient gathering in sensor information systems.
  - o Minimum energy communication network (MECN).
- Location-Based Routing

In this kind of network architecture, sensor nodes are scattered randomly in an area of interest and mostly known by the geographic position where they are deployed. They are located mostly by means of GPS. The distance between nodes is estimated 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]
  - o Sequential assignment routing (SAR).
  - o Ad-hoc positioning system (APS).
  - o Geographic adaptive fidelity (GAP).
  - o Greedy other adaptive face routing (GOAFR).
  - o Geographic and energy aware routing (GEAR).
  - o Geographic distance routing (GEDIR).

3.3. Operation Based Routing Protocols

WSNs applications are categorized according to their functionalities. Hence routing protocols are classified according to their operations to meet these functionalities. The rationale 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 selection for a message to reach 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 hence consume greater energy. Multipath routing protocols are [8] :
  - o Multi path and Multi SPEED (MMSPEED).
  - o Sensor Protocols for Information via Negotiation (SPIN).
- Query Based Routing Protocols

This class of protocols works on sending and receiving queries for data. The destination node sends query of interest from a node through network and node with this interest matches the query and send back to the node which initiated the query. The query normally uses high level languages. Query based routing protocols are [8] :
  - o Sensor Protocols for Information via Negotiation (SPIN).
  - o Directed Diffusion (DD).
  - o COUGAR.
- Negotiation Based Routing Protocols

This class of protocols uses high level data descriptors to eliminate 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]:
  - o Sensor Protocols for Information via Negotiation (SPAN).
  - o Sequential assignment routing (SAR).
  - o Directed Diffusion (DD).
- QoS Based Routing Protocols

In this type of routing, network needs to have a balance approach for the QoS of applications. In this case the

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 to 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]

- o   Sequential assignment routing (SAR).
- o   SPEED.
- o   Multi path and Multi SPEED (MMSPEED).
- Coherent and non-coherent processing:

Data processing is a major component in the operation of wireless sensor networks. Hence, routing techniques employ different 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 before being sent to other nodes for further processing. The nodes that perform further processing are called the aggregators.

- Coherent data processing: In coherent routing, the data is forwarded to aggregators after 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 consumed 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 a 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 other 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].

- o   Directed Diffusion.
- o   GBR.
- o   Energy Aware Routing.
- Probabilistic routing protocols

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

- o   Energy Aware Routing Protocol.
- Location-based routing protocols

These protocols select the next-hop towards the destination based on the known 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 can avoid the communication overhead caused by flooding, but the calculation of the positions of neighbors may result extra overhead. The local minimum problem is common for all decentralized location-based routing protocols: it might happen that all neighbors of an intermediate node are farther from the destination than the node itself. In order to circumvent this problem, every protocol uses different routing techniques[5].

- o   GEAR (Geographical and Energy Aware Routing).
- Hierarchical-based routing protocols

In case of 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 track 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. [5, 9]

- o   LEACH (Low Energy Adaptive Clustering Hierarchy) protocol.
- Broadcast-based routing protocols

The operation of these protocols is very straightforward. Each node in the network decides individually whether to forward a message or not. If a node decides to forward, it simply re-broadcasts the message. If it declines to forward, the message will be dropped [5].

- o   MCFA (Minimal Cost Forwarding Algorithm).

4. The 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 differents between these protocols and there are many application for some classes whereas other classes apply in special determine applications, because of the nature these protocols.

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