Wireless Sensor Network Classification: A Review

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Abstract: ***In Wireless Sensor Networks (WSNs) energy is most important resource. Maximum utilization of energy of every node is a critical factor. In the routing main purpose is to optimize the network architecture for various applications and maximize the utilization of all resources. The framework and architecture of every wireless sensor networks are different. In this paper, we show the difference between traditional, internet and conventional routing. We also show the Review on routing model, deployment topology, Homogeneous and Heterogeneous network and its routing protocols with various design factors.***

Keywords: WSN, Conventional Network, Routing Model, Homogeneous Network, reactive and proactive Network.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are highly distributed wireless networks of small, lightweight sensor nodes which is deployed in large numbers. Wireless Sensor Networks mainly consist of low power, limited memory and smaller size sensor nodes, used for sensing, processing and communicating the data over the wireless sensor network. Sensor node is made with various components like sensing unit (sensor and ADC), processing unit (processor and storage), power unit, transceiver (antenna), mobilize and location finding system (figure 1).

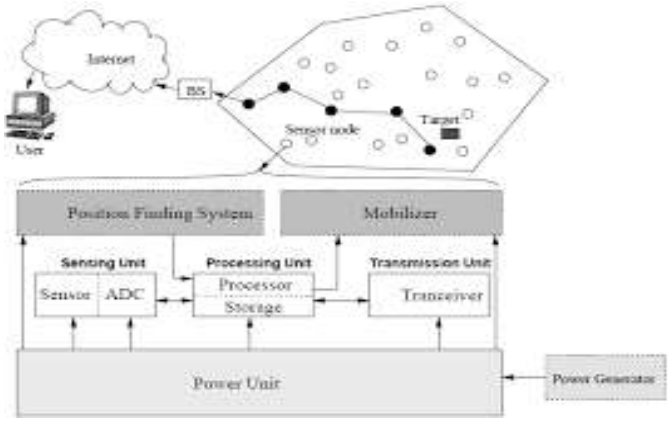


Figure 1: wireless sensor network with node architecture

The main goal in conventional wireless networks is providing high quality of service and high bandwidth efficiency when mobility exists. In contrast, in a sensor network conservation of energy is considered to be more important than the performance of the network. Therefore, the current routing protocols designed for traditional networks cannot be used directly in a sensor network due to the following reasons [1].

- In conventional routing, data is a requested from a specific node and is requested based on certain attributes whereas sensor networks are data centric.
- Sensor network is application-specific as these days the network needs to be changed according to the application.
- Adjacent nodes may have similar data. All similar data must be aggregated and sent.
- Similar data do not use separate path for sending data.
- In traditional routing, unique global ID to each node was given which is not possible today because of the large number of nodes which are deployed in the today's sensor network.
- Conventional routing does not depend upon the energy constraint.
- In the conventional routing, topology is fixed, whereas in the case of WSN topology frequently changes.

The fundamental aim of any routing protocol is to furnish the network useful and efficient. A routing protocol organizes the activities of individual nodes in the network to achieve global goals and do so in a proficient manner.

1.1. Sensor node deployment [10]

Sensor node deployment basically deals with the connection and organization of various nodes over the sensor field. It

deals with physical connectivity of nodes. Topology is basically depends on the deployment of nodes over the network. Deployment of nodes can be in random location or at the specific fixed location. The number of nodes in the network can also be fixed or variable depending upon the application, routing protocol and node properties. There are three kinds of deployment presentation in WSNs.

(a) Pre-deployment or deployment phase: In this deployment phase sensor node can be placed in mass or placed one by one in the sensor network region.

(b) Post-deployment phase: when sensor node is deployed over the network region, it may be changed due to various reasons like low power, data calculation, scalability or failure.

(c) Redeployment phase: after the deployment of sensor node in network if some additional nodes are added than sensor node and the network is redeployed or re-arranged. Organizing the network is based on the addition of node, Failure of any existing node, routing and application requirement [10].

1.2. Types of Routing Models

All existing routing protocols used various models for data delivery. Following three routing models are used by routing protocols [1].

1.2.1. One - hop model

This is the most elementary approach and corresponds to direct communication as is shown in Figure 2. In these networks each and every sensor node transmits directly to the base station. This mode of communication is not only too expensive in terms of energy consumption, but also it is impractical because every node have restricted or limited transmission and sensing range. Therefore, direct communication is not a feasible model for routing.

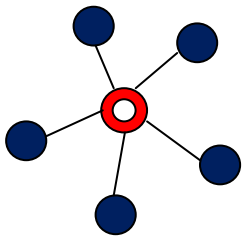
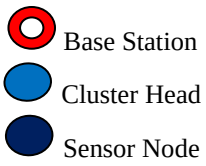


Figure 2: one hop model



1.2.2. Multi-hop Planar Model

In Multi –hop model, a node transmits to the base station by forwarding its data to one of its nearest neighbors, which is closer to the base station. The latter then passes on its neighbor that is even closer to the base station as is denoted in Figure 3. The information travels from source to destination through hop by hop from one node to another until it reaches the base station or sink. Considering the energy and the transmission range node restrictions, this multi-hop planar model is a feasible approach. In a network composed of thousands of sensors, this model will exhibit high data dispersion latency due to the long time needed by the node information to arrive to the base station.

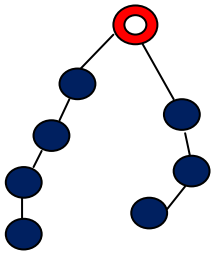


Figure3: multi hop model

1.2.3. Clustering-based Hierarchical Model

A hierarchical approach for the network topology splits up the network into a number of areas called clusters as shown in Figure 4. Nodes are grouped depending on some parameter into clusters with a cluster head, which has the province of routing the data from the cluster to another cluster head or base stations. The data still hop from one node to another,

because it hops from one layer to another it covers larger distances and moves the data faster to the base station than in the previous multi-hop model [1]. The reaction time in this model is theoretically much less than in the multi-hop model. Clustering brings out Built-in optimization potentialities at the cluster heads, what results in a more energy efficient and integrated network topology? [1]. This model is more suitable than the one-hop or multi-hop model.

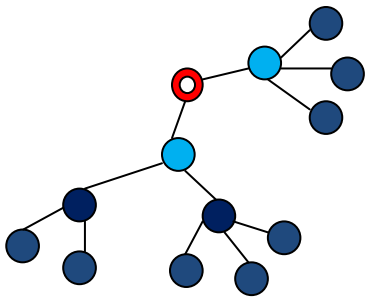


Figure 4: Hierarchical Clustering - based Model.

1.3. Comparison of the routing models

Due to various design factors of WSN, direct communication is not feasible for a large sensor network that is formed by thousands of sensors. The nodes are far away from the base station and do not have enough transmission power to reach the base station what would turn into unreachable the most part of the network. Even though the sensor nodes would be close to the base station, the density of it would create collisions that would critically degrade the network performance and overall efficiency.

The multi-hop model of communication is a more practical approach than the one-hop model. In this case, data are aggregated and forwarded by multiple hops from one node to another until it reaches the base station. It is a feasible approaches which taking into account the energy constraint nodes that comprise sensor networks. The coverage area is improved as compared with the one-hop model since most nodes are able to connect with the network and the amount of collisions is reduced. The multi - hop model also have some drawbacks, for example, higher latency in networks comprised of thousands of sensors and the serious delay that data experiences. The most important drawback is that the closest nodes to the base station would have to act as intermediaries to all traffic being sent to the base station by the rest of the network. Because the closest nodes have to handle all the traffic, the energy utilization is more about this network and, due to continuous communication with these nodes, it will die first and creating a black hole around the base station for incoming traffic over the network. The same situation will appear another time with the new closest nodes to the base station and causing in the midterm that no data arrives to the base station and rendering the entire network useless [1].

In the clustering-based hierarchical model, all data is aggregated in the cluster and send to cluster head node to a higher-level cluster head, thus travelling larger distances as compare with both models explained and reducing time and latency of data flow in the network. Therefore, the clustering-based model is more suitable for time-critical applications where the data are used in defining time or at regular interval. Nevertheless, this model has one drawback since as the spent energy is directly proportional to the square of the distance between two clustering levels. If the distance increased than the energy utilization also increased [1]. Due to this the energy utilization is increased. Despite this drawback, this clustering model offering a better approach to routing for wireless sensor networks.

II. WIRELESS SENSOR NETWORKS CLASSIFICATIONS

In this subsection we illustrate a simple classification of sensor networks based on their mode of functioning and the type of the target application.

2.1. Proactive Networks

The nodes of this type of network periodically switch on their sensors and transmitters. It senses the environment and transmits the data of interest. They provide a snapshot of the relevant parameters at regular intervals [1]. It is not continuously transfer the data over the network. They are well suited for applications requiring periodic data monitoring. For example protocol such as LEACH, Direct Diffusion, SAR, TTDD, GBR and PEGASIS protocol are working on proactive concept.

2.2. Reactive Networks

In the reactive networks, nodes sense the value or react immediately as soon as changes occur in networks. It's not work from time to time, but when sudden and drastic changes in the value of a sensed attribute is measured it reported to the base station at any time. Reactive protocol is well suited for those applications where time is critical factor like military field applications. For example MCFA, TEEN, ACQUIRE, PEGASIS, CADR, GEAR and MECN are some protocols works for reactive network.

2.3. Hybrid Networks

It is a combination of proactive and reactive network. The nodes in such a network not only react to time-critical situations, but also work at periodic intervals in a very energy efficient manner for the entire network. The hybrid network enables the user to request past data, present data

and future data from the available network in the form of historical queries, one-time queries and persistent query respectively. In our heterogeneous network, we considered this hybrid form of deployment and functioning. For example GAF, Rumor Routing, HPAR and APTEEN protocols are working for hybrid routing networks because their route selection is based on a mixture of proactive and reactive routing concept.

III. CLASSIFICATION OF ROUTING PROTOCOLS

The design aspect for routing algorithms for WSNs is not limited and it can vary according to requirement and surrounding conditions. Wireless sensor networks use various protocols and algorithms with self-organizing capabilities. We can classify the routing algorithms for WSNs in different ways [2]. Routing protocols are classified as data centric, node-centric, location-aware (geocentric) and QoS based routing protocols. Mostly Ad-hoc network routing protocols are node-centric protocols where destinations are specified on the basis of numerical address (identifiers) of nodes. In wireless sensor network node centric communication protocol is not commonly used.

Routing protocol designed for WSNs is more data-centric or location centric (geocentric). In data-centric routing, the sink node sends queries to certain specific regions and waits for data from the sensors located in the specific regions. While data is being requested through queries, so attribute based naming is necessary to identify the properties of data. Here data are usually transmitted from every sensor node within the deployment region with aggregation and improve redundancy.

In location aware routing nodes know where they are in a geographical region. Location information also used to improve the performance of routing and to provide new types of services like locality management and mobility management. In QoS based routing protocols we mainly focus on the data delivery ratio, latency and energy consumption. For good QoS (Quality of Services), the routing protocols must have more data delivery ratio, less latency and low energy consumption [2].

Routing protocols can also be classified based on whether they are reactive or proactive. In the reactive routing protocol, routing actions are initiated when there is data to be sent and disseminated to other nodes. In reactive protocol, Paths are set up only when network or nodes of the data and forwarded on demand when queries are initiated for data transfer between various nodes. A proactive protocol sets up routing paths and states before there is a demand for routing traffic. Paths are maintained even there is no traffic flow at that time. It defines the path in advance.

Routing protocols are also classified based on whether they are initiated at source side or the destination side. It is also known as source-initiated (Src-initiated) or destination-initiated (Dst-initiated). A source-initiated protocol sets up the routing paths when data are available for transmitting from source side. Data transfer starting from the source node. Here the source advertises the data when available and ready to initiate the data delivery for other nodes. A destination initiated protocol, begin path setup from a destination node when it wants data transfer between other nodes. If a node wants some data from others, it may set up the destination protocol [2].

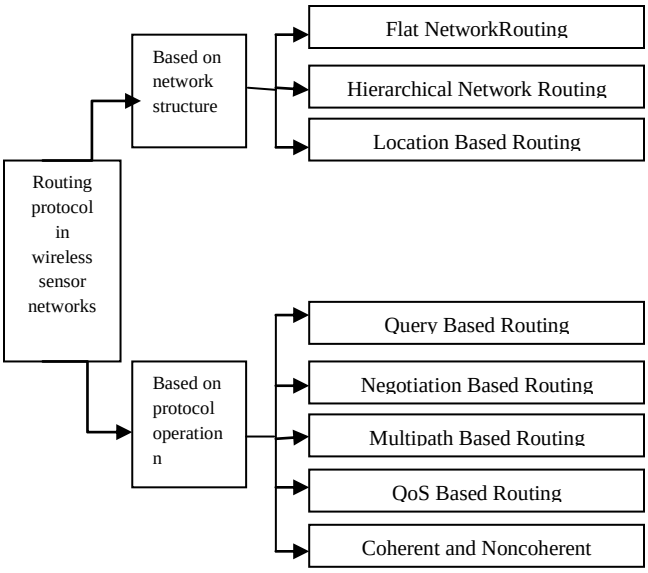


Figure 5: Routing Protocols in Wireless Sensor Network

Routing protocols are also classified based on sensor network architecture [2]. Various WSNs consist of homogeneous nodes, while some WSNs consist of heterogeneous nodes. On the basis of different nodes (homogeneous and heterogeneous) we can check for which topology, routing protocol will work whether they are operating on a flat topology or on a hierarchical topology.

In Flat routing protocols all nodes in the network are having equal properties (Range, Energy etc.). Whenever a sensor node wants to deliver data, it may find a route consisting of other hops towards the sink.

A hierarchical routing protocol is an approach used for heterogeneous networks where some of the nodes are more powerful than the other nodes in the network. The hierarchy does not always depend on the power of nodes. In Hierarchical (Clustering) protocols different nodes are grouped to form clusters and data from nodes belonging to a single cluster can be grouped in single node (aggregated). The hierarchical protocols have several advantages like scalability, energy efficient in Finding routing routes and easy to manage the path [3].

IV. COMPARISON OF HOMOGENEOUS AND HETEROGENEOUS NETWORKS

4.1. Homogeneous Sensor Networks

A homogeneous sensor network consists of identical nodes, i.e. all the sensor nodes have same hardware complexity, battery energy and sensor range.

In a homogeneous network, it is evident that the cluster head nodes will be over-loaded with the long range transmissions to the re-mote base station, and the extra processing mandatory for data aggregation and coordination of protocol. As a result the cluster head nodes expire before other nodes. However, it is desirable to ensure that all the nodes run out of their battery at about the same time, so that very little residual energy is exhausted when the whole system expire [4].

Using a homogeneous network and role rotation, all the nodes should have the capability of acting as cluster heads, and all the nodes possess the necessary hardware capabilities and other characteristics.

With the advancement in the wireless sensing networks (WSN) various kinds of application specific routing protocols have been developed [4].

The Table 1 shows the comparison of existing routing protocols for homogeneous networks with the consideration of design factors like Scalability, Power Usage, Mobility, overheads, Query-based, Data Aggregation and Localization [5].

Protocols of routing for Homogeneous Networks

TABLE 1 VARIOUS ROUTING PROTOCOLS FOR HOMOGENEOUS NETWORKS [5]

ROUTING PROTOCOLS	Classification	Scalability	Power usage	Mobility	Over - head	Query based	Data aggregation	Locali-zation
MECN	Location-based	No	Max	No	Moderate	No	No	Yes
SMECN	Location-based	No	Max	No	Moderate	No	No	Yes
GAF	Location-based	Good	Limited	Limited	Moderate	No	No	Yes
GEAR	Location-based	Limited	Limited	Limited	Moderate	No	No	Yes
GBF	Location-based	Limited	Limited	Limited	Moderate	Yes	No	Yes
GeRaF	Location-based	Limited	Limited	Limited	Low	No	No	No
SPIN	Data-centric	Limited	Limited	Possible	Low	Yes	Yes	No
Direct Diffusion	Data-centric	Limited	Limited	Limited	Low	Yes	Yes	Yes
Rumor	Data-centric	Good	Low	Limited	Low	Yes	Yes	No
COUGAR	Data-centric	Limited	Limited	No	High	Yes	Yes	No
ACQUIRE	Data-centric	Limited	Low	Limited	Low	Yes	Yes	No
LEACH	Hierarchical	Good	Max	Fixed BS	High	No	Yes	Yes
PEGASIS	Hierarchical	Good	Max	Fixed BS	Low	No	No	Yes
HEED	Hierarchical	Good	Max	Fixed BS	Moderate	No	Yes	Yes
TEEN	Hierarchical	Good	Max	Fixed BS	High	No	Yes	Yes

4.2. Heterogeneous wireless sensor network

In Heterogeneous wireless sensor network (heterogeneous WSN) different sensor nodes have different computing power and sensing range and therefore provide more flexibility in deployment. For example, if there are two types of sensor nodes: the high-end ones have higher process throughput and longer communication or sensing range; the low-end ones are much cheaper and with limited computation and communication/sensing abilities. A mixed deployment of these nodes can achieve a balance of performance and cost of WSN [6]. As compared to homogeneous WSN, deployment and topology control are also more complex in heterogeneous wireless sensor network.

Node deployment in heterogeneous WSN has to consider the topology control between different types of sensor nodes. For example, to maintain a symmetric communication, the communication distance between high-end nodes and low-end sensor nodes cannot be larger than the maximum communication range of the low-end sensor nodes [6]. Also, if the sensor nodes have different detection and communication range, the coverage area of low-end nodes cannot be fully covered by the high-end node [6].

In a Heterogeneous sensor network, two or more different types of nodes are having different battery energy, range and functionality for various purposes. The motivation being that the more efficient hardware, long range of communication and the extra battery energy can be embedded in few cluster head nodes, thereby reducing the hardware price of the rest of the network. However, fixing the cluster head nodes means that role rotation is no longer possible. When the other sensor nodes use single hopping to reach the clustering head, the nodes that are far away from the cluster heads always utilized more energy than the nodes that are closer to the cluster heads. On the other hand, cluster head is reached when nodes use multi-hopping, the nodes that are nearest to the cluster head has the highest energy load due to relaying. Consequently, there always exists a non-uniform energy drainage pattern in the entire network [7].

In Heterogeneous sensor network architecture, there are two types of sensors used first one is line-powered sensors which have no energy constraint, and the other one is battery-powered sensors having a limited lifetime of energy [7]. With the help of heterogeneity in WSNs we can extend network lifetime. IDSQ, CADR, CHR are few Heterogeneity-based Protocols used in wireless sensor network [8].

4.2.1. Routing protocols for Heterogeneous networks

Information-Driven Sensor Query (IDSQ): IDSQ addresses the problem of heterogeneous WSNs of maximizing information gain and minimizing detection latency and energy consumption for target localization and tracking through dynamic sensor querying and data routing. In IDSQ protocol, the first step is to select a sensor node as a leader (cluster head) from the all nodes present in the cluster. This cluster head will be responsible for selecting optimal sensors based on some information utility measurement [8].

4.2.2. Cluster-Head Relay- Routing (CHR):

CHR routing protocol 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 few numbers of powerful high-end sensors, denoted by H-sensors. All the sensors are static and aware of their locations using some location service [8, 9]. The CHR protocol partitions the heterogeneous network into groups of sensors (or clusters), and every cluster have an H- senor node and rest are L-sensor nodes [8, 9]. Within a cluster, the L-sensors are in charge of sensing the underlying environment and forwarding data packets originated by another L-sensors toward their cluster head in a multi hop model. The H-sensors, on the other hand, are responsible for data fusion and aggregation within their own cluster region and forwarding aggregated data packets originated from other cluster heads toward the sink in a multi hop fashion using only cluster heads [9].

V. CONCLUSION AND FUTURE WORK

In WSN energy efficient routing is very important for data delivery over the network for a long time. This survey paper shows various design parameters for homogeneous network for improving the energy utilization of the network. The routing topology and node deployment are important for using network for specific purposes. With the help of the design challenges and operational challenges we can create energy efficient routing protocols. The data security and integrity is always important for communication medium.

The various deployment environments of wireless sensor networks require more security and robustness of these systems. Data security, integrity and confidentiality always important factors whenever we design new routing protocol.

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