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A Review on Various Routing Protocols, Applications, and Challenges

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Abstract: A Wireless Sensor Network (WSN) is a collection of nodes which have limited energy capabilities and these nodes can be mobile or stationary. These are spatially distributed autonomous sensors used to monitor physical and environmental conditions like temperature, pressure, sound and many more. It is also used to transmit data from various nodes to the sink. In this paper, WSN architecture, its applications, challenges and various routing protocols has been discussed.

Keywords: *WSN, routing protocols, challenges in WSN, architecture of WSN, node deployment in WSN*

1. INTRODUCTION

The most common architecture in WSN follows OSI Model. This architecture details are taken from [1]. It requires five layers along with three cross layers planes as shown in Fig.1

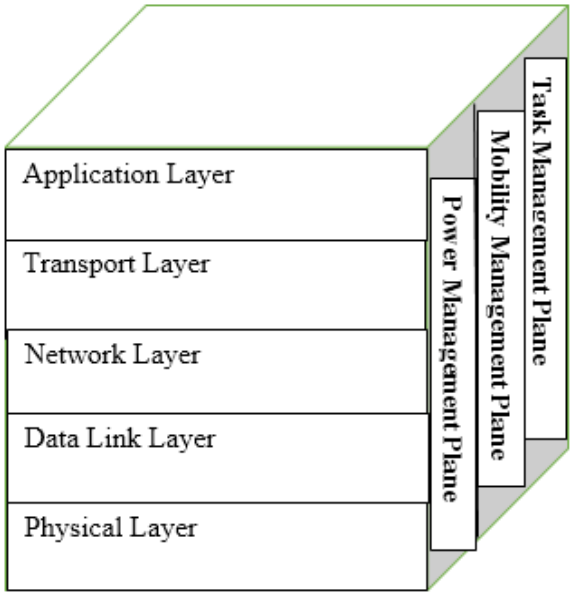

Fig. 1 Architecture of WSN

A. *Cross Layers*

These layers are used to manage the network and to make the sensors work together in order to increase the overall efficiency of the network [2].

B. *OSI Layers*

OSI layer consists of five layers as described below:

Physical Layer - It provides an interface to transmit bit stream over a physical medium. It is responsible for frequency selection, frequency generation, signal detection, modulation and encryption.

Data Link Layer - It is responsible for multiplexing data streams, data frame detection, MAC and error control. It ensures reliability for point-to-point or point-to-multipoint communications.

Network Layer - It is used for routing. The major challenges are in memory buffers and power saving. We have to deploy redundant sensors to achieve data aggregation and data fusion.

Transport Layer - This layer is used to provide reliability and congestion avoidance. The protocols designed for these functions are either applied on upstream or downstream. They use different mechanism for loss detection and loss recovery. This is used when a system is organized to access other networks.

Application Layer - It provides software for applications that converts data into understandable form and to send queries to collect information. It is responsible for traffic management.

2. NODE DEPLOYMENT

WSN is being applied everywhere in this world in different applications such as vehicle tracking, monitoring, earthquake observation, biomedical and health care etc. The effectiveness of WSN is influenced by the coverage of sensor deployment scheme. To achieve the collective

information using routing WSN, coverage of deployment scheme becomes an essential part to make use of node deployment in order to get good connectivity and energy saving performance [3].
There are two types of deployment found out through the researches done:-

A. Static deployment

In this, nodes do not change its position, it chooses the best location according to the optimization strategy and the location doesn't affect the lifetime in WSN. It includes the deterministic deployment and the randomly deployment.

- In deterministic deployment, initially meshing of surveyed area is done and then the network node deployment is carried out. Algorithms used for it are Genetic algorithm, Watershed algorithm etc.
- Randomly deployment is backed to the deployment of the robot. Sensor node needs to move to proper location and start working in order to increase sensor network's performance. Algorithms used for it are Virtual force algorithm, simulated annealing algorithm, Particle swarm optimization algorithm etc.

B. Dynamic deployment

In this, sensor nodes are initially located in the area randomly. These sensors change its position by using the knowledge of other sensors, if they are mobile. This leads to increase the coverage rate of sensors. Algorithms proposed for this problem are Artificial Bee Colony algorithm (ABC), Artificial Fish School Algorithm (AFSA) etc.

3. APPLICATIONS OF WSN

Some of the major applications of WSN are listed[4].

A. Area Monitoring

Nodes are deployed in a region and some phenomenon is to be monitored. The most common example is in military (enemy intrusion is detected through sensors).

B. Health care monitoring

There are two types of devices: **Wearable devices** are used on the body surface of a person. **Implantable devices** are those which are inserted inside the human body. These devices collect the information about a person's fitness, health etc. It includes monitoring of ill people in hospitals and detecting the location and body position measurements.

C. Environmental Applications

Nodes in WSN are also used to monitor environmental parameters. It helps in tracking the movement of small animals and insects inside the water, in sky or even on earth surface.

D. Home Applications

Almost every electrical appliance near us is an application of WSN. Smart sensor nodes and actuator are used in these appliances. The interaction takes place with the help of satellites. It includes Air condition systems, vacuum cleaner, microwave ovens etc.

E. Other commercial Applications

All the day today applications including robotics and Artificial Intelligence come under it. For example- virtual keyboards, building smart offices, vehicle tracking, transportation, factory instruments etc.

4. ROUTING IN WSN

WSN is classified in various types based on the location of nodes as nodes are initially static that results in the non-frequent topological changes as shown in Fig. 2. Position awareness is important to collect data or useful information for e.g. GPS (Global Positioning System). WSNs applications are user-specific; it fulfills all the requirements as per user demands. All these points are concluded in [5].

A. Network Protocol

It depends on the structure of a network. The arrangement of nodes in a network depicts the uniformity of nodes inside a system. All the data transfer and communication takes place according to their position [6].It is further classified in two categories:

- Flat Protocol- In this all the nodes are treated equally, they held same position in terms of priority. It helps in decreasing the overhead and maintenance.
- Hierarchical Protocol-In this type of network nodes are assigned different duties and clusters are formed. For e.g. in a cluster, cluster head is elected that has more energy power than other nodes. It is done to increase the energy efficiency, stability and scalability of the network.

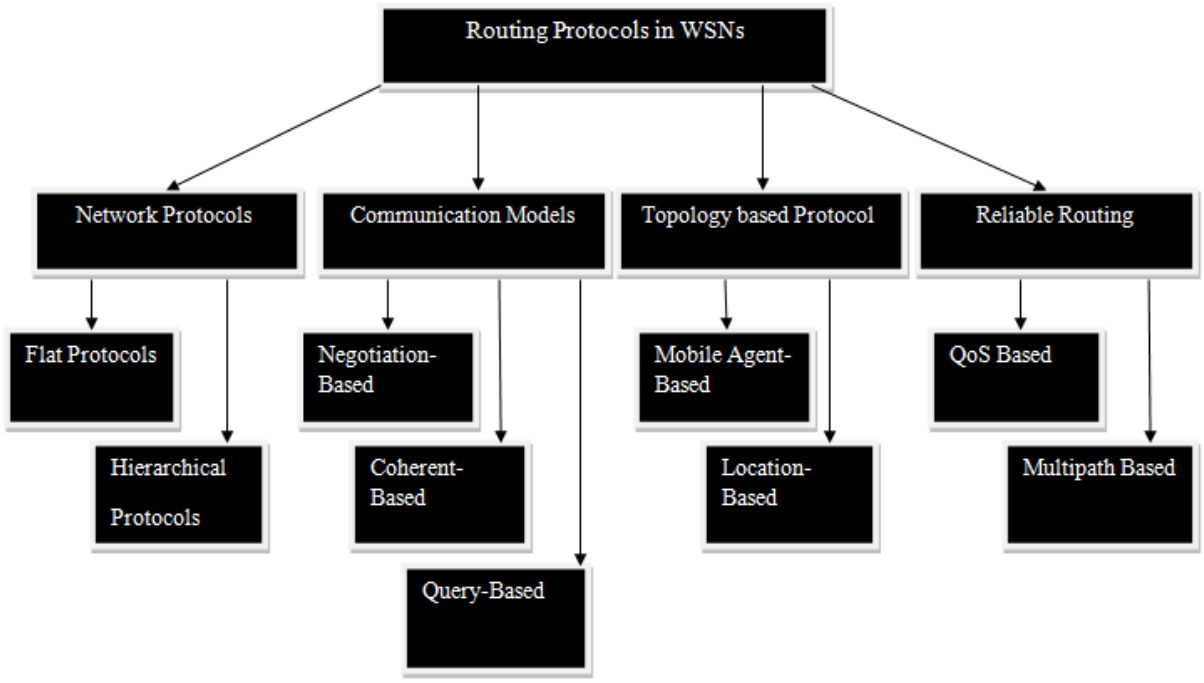

Fig. 2: Classification of protocols

B. Communication Model

In this type of model the communication of nodes i.e., packets sent over a network channel. Point to point connection and broadcasting is done to complete the transfer process for the given amount of energy. It can be further classified into three categories:

- Query Based Protocol- A query is sent from the destination node to the other node that is having the data. That node sends the data according the query. If the data sent matches the query then that query is initiated.
- Coherent and Non-Coherent- In coherent data is passed to other nodes for further processing. In non-coherent raw data is initially processed on the same node rather than passing it over.
- Negotiation Based Protocol- Reduction of redundant data is managed with the help of meta-data negotiations.

C. Topology Based Protocols

In this every node must have the record of topological information. It further helps in processing that is based on topology. It is further categorized in two types:

- Location Based Protocols- The nodes must have knowledge about the position of other nodes so that they can minimize the energy consumption by choosing the shortest path from source to destination.
- Mobile Agent Based Protocols- Mobile agents migrate through the network to each node to get the information to be transmitted. It provides flexibility and new capabilities to the network.

D. Reliable Routing Protocols

As the name suggests that these type of protocols are trustworthy. Because they can handle failures by adding load balancing, QoS metrics methods to the network. Protocols are classified as follows:

- Multipath Based Protocols- Multi pathing helps in load balancing as multiple paths are used to reduce the network congestion.
- QoS Based Protocols- The quality of data is kept in mind when a sink requests for data. The network has to look after the energy consumption as well as quality.

5. CHALLENGES

Designing of a WSN network is closely related to Architectural Model. In this, we strive to capture the main issues that arise in this process. Here are some important challenges and issues [7].

A. Network Dynamics

In most of the network setups the nodes are stationary. But because of the emerging used needs, there is a necessity for mobile sink and gateways.

B. Node Deployment

Deployment of nodes is a very big factor that affects the performance of protocols. It can be either deterministic or self-organizing. In deterministic the nodes are deployed manually and in self-organizing nodes are deployed randomly.

C. Energy Considerations

When an infrastructure is being created, then the most important factor that must be considered is the energy consumption. Multi-hop routing will consume lesser energy as compared to direct routing because in it there is direct communication.

D. Data Delivery Models

Data delivery models can be query-driven, event-driven and continuous. In continuous, data is sent to sink on a regular basis. In contrast, data is triggered to the sink whenever a query emerges or an event occurs [8].

6. DESIGN ISSSUES OF ROUTING PROTOCOLS

WSN topologies might be simple but it includes heterogeneous mobile nodes. The density and scalability change according to applications. Some main issues [9] of these protocols have been discussed:

A. Scalability

With so many mobile nodes it becomes difficult to handle the scalability factor. So the routing schemes must be scalable enough to meet the requirements.

B. Fault Tolerance

The network must be reliable in case of node failures. In the network, the nodes might die due to the lack of energy, environmental causes or physical damage that should not affect the whole network.

C. Cost

Since the network is designed with a number of nodes, that's why the cost of single node must be justified.

D. Open environment

We can set up this network anywhere inside an ocean, in the space, inside a machine, a battle field, in a chemically contaminated field, vehicles, animals, warehouses, forest monitoring etc.

E. Data Fusion

Data Fusion is done by aggregating data from different sources in order to reduce the power consumption and traffic. Redundant data or similar packets are being fused so that, we can reduce the no. of transmissions.

F. Quality of Service

We work upon giving a quality product. A quality product is achieved when it has data reliability, energy efficiency, prolonged lifetime, location-awareness and increased processing power.

G. Overhead and Latency

Some protocols increase the overhead which is not suitable in terms of energy consumption. Data aggregation of multi-hop networks causes Data Latency.

7. CLUSTERED ROUTING PROTOCOLS

In Clustered Routing Protocols [19], sensor nodes are divided into group called clusters. In each cluster, one cluster head is elected that transfers the data to sink. Instead of communicating with each other, all the nodes send data to cluster head. Clustering is an efficient way to reduce the energy consumption and increases the lifetime of the network. Clustering is done with the help of data aggregation and data fusion in order to reduce the no. of transmitted messages [10]. Types of CRP are discussed as follows:

A. LEACH (Low Energy Adaptive Clustering Hierarchy)

It is based on clustered and layered technology. The implementation of LEACH includes rounds. Each round has a set-up phase and data transmission phase. In the first phase, leader is selected dynamically from several nodes and clusters. In second phase, member nodes send data to the cluster-head then the head aggregates the data and forwards it to sink [11]. Some of the advantages offered are [17]:

- LEACH is a distributed protocol. It does not require any external control i.e., control information from base station, and nodes do not require network information.
- It helps in reducing the communication energy by 8 times as compared to other protocols.

B. LEACH-C (Centralized)

It is a kind of improved LEACH. In this, at the beginning of each round location information and residual energy value is sent to the base station. After receiving the information, base station calculates average energy value. The nodes having a value greater than the average value are considered. The base station selects the cluster-head (node having highest residual energy) and broadcasts the message to every node [12].The main advantages are:

- It can control message complexity very easily.
- It requires location information of nodes in order to track the nodes and their functioning.

C. SEP (Stable Election Protocol)

This type of protocol looks into the heterogeneity of the network. In this protocol, some nodes of high energy are considered as advanced nodes [13]. The chances to become cluster-heads of these nodes are higher compared to the remaining nodes. The protocol offers the following advantages:

- It does not require any global information of energy after every round.
- It prolongs the stability period of the nodes (higher energy).

D. DEEC (Distributed Energy Efficient Clustering)

In this protocol, all the nodes use initial and residual energy levels in order to select the cluster-heads. To calculate the reference energy of each node in every round, DEEC estimates the ideal value of network's lifetime [14]. The protocol offers the following advantages:

- It does not require any global knowledge of energy after every round.
- Unlike other protocols it can work very efficiently in multi-level Heterogeneous network.

E. TEEN (Threshold Sensitive Energy Efficient Routing Protocol)

The nodes react immediately to sudden and drastic changes in the value of a sensed attribute.At every cluster change time, the cluster-head broadcasts to its members [15].

- Hard Threshold (HT) - This is a threshold value for the sensed attribute. It is the absolute value of the attribute beyond which, the node sensing this value must switch on its transmitter and report to its cluster head.
- Soft Threshold (ST) - This is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit.

The first time a parameter from the attribute set reaches its hard threshold value, the node switches on its transmitter and sends the sensed data. The sensed value is stored in an internal variable in the node, called the sensed value (SV). The nodes will next transmit data in the current cluster period, only when both the following conditions are true:

1) The current value of the sensed attribute is greater than the hard threshold.
2) The current value of the sensed attribute differs from SV by an amount equal to or greater than the soft threshold.

The protocol offers the following advantages:

- LEACH based Clustering
- Smart data transmission (Saves Power)
- Nodes dynamic reconfiguration ability
- Suits for Time-Critical applications

TABLE 1: Comparison of CRPs

Criteria	**LEACH [11]**	**LEACH-C [12]**	**SEP [13]**	**DEEC [14]**	**TEEN [15]**
Type of System	Homogenous WSN	Homogenous WSN	Two-Level Heterogeneous	Multi-Level Heterogeneous	Single Level Homogenous
Energy Efficiency	Lower than others	Moderate	Moderate	High	Very High
Stability Period	Very Low	Moderate	Moderate	High	High
Rate of Transfer	Very Low	Low	Moderate	High	High
Cluster Stability	Low	Moderate	Moderate	High	Moderate
Network Lifetime	Lower than SEP and DEEC	Better than LEACH	Moderate	Higher than LEACH & SEP	Best

To check the feasibility of different clustering techniques against modeled framework, we selected LEACH, LEACH-C, TEEN, SEP and DEEC in Table 1. A similar comparison has been done in [16] where they have compared LEACH, SEP and DEEC. It is concluded from our review results that DEEC is the most energy efficient protocol for heterogeneous node energy network. However, TEEN is more energy efficient [20] and attain highest value of K due to its hard and soft threshold based communication. The energy consumption of TEEN is better than others due to its less data transmission to BS. Whereas, DEEC is efficient in sending maximum information to BS, while TEEN lacks due to its restriction on communication. SEP is good in selection of optimum number of CHs, and therefore produces small variations in CH selection. Thus overall DEEC outperforms among selected protocols by providing feasible optimum solutions against constraints of modeled frame work.

8. CONCLUSION

In this paper, we have discussed various applications and design issues including challenges of WSNs. WSNs possible today due to technological advancement in various domains. It is envisioned to become an essential part of our lives. Design Constraints need to be satisfied for realization of sensor networks. Tremendous research efforts being made in different layers of WSNs protocol [18] stack. The various clustered routing protocols and their working has been discussed followed by their comparison according to different criteria. In future, we would design a new energy efficient routing protocolfor mobile networks.

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