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Routing Protocols for Wireless Sensor Network: A Review and Open Research Challenges

Anita[a,1] and Amita Asthana[b]
[a] *PG Student, Department of Electronics & Communication Engineering, Ajay Kumar Garg Engineering College, Ghaziabad, India. anitagovindsingh1998@gmail.com*
[b] *Assistant Professor, Department of Electronics & Communication Engineering, Ajay Kumar Garg Engineering College, Ghaziabad, India. researches555@gmail.com*

Abstract. Wireless sensor network (WSN) is deployed in number of applications for real-time data collection. Sensors that are smaller, cheaper, and more sophisticated have made this possible in recent years. These sensors are outfitted with wireless interfaces through which they can connect with one another to build a network. In the WSN, routing plays an important role to determine the optimal path to successfully deliver the data from source to destination node. In the literature, two types of routing available such as static and dynamic. Out of these, dynamic routing is preferred in the current scenario due to robust, low cost, and node position is dynamic. Further, dynamic nodes are classified into three protocols such as proactive, reactive, and hybrid protocols. Therefore, in this paper, initially, these routing protocols are examined. After that, we have studied and analysed the various research papers are published in these routing protocols. Finally, open research challenges are defined based on the study.

Keywords. APTEEN, LEACH, Routing, TEEN, Wireless Sensor Network

1. Introduction

Hundreds to thousands of low-power multi-functional sensor nodes, working in an unsupervised situation, have detecting, compute, including communication networks in a WSN. A node consists of a sensor unit, an ADC, a CPU, a power unit, and a communication module [1]. When a physiological changes, such as pressure or temperature, a quantifiable response is produced by a MEMS [2]. In order to keep track of a region, sensor networks collect and analyses physiological parameters from it. An ADC transforms the continuous analogue signal detected by that of the sensors into a digital message data, which is then delivered to the control systems for analysis. Sensor networks are compact, lightweight, low-power, as well as capable of operating at high population densities. They could also operate independently or adjust to their surroundings. Sensor nodes in the environment can have a concentration of up to 20 nodes/m3. Due to their compact size, mobile nodes could only be powered by a specific amount of energy [3].

[1] Corresponding Author.

With limited detecting as well as compute capabilities, networking performance as well as power consumption of a single sensor, many sensors are spread across a topic of focus for gathering data. Each unit in a network system operates as a gateway [4] within the system though it may connect with those other parts directly or via relay node. Each sensor network in a system that uses direct interaction routing mechanism does so by sending data to a central command centre known as the Base Station (BS). This is stationary and placed a considerable distance from of the sensors. Throughout a wi-fi network, BS can interact with the final user. The sensor network's structure varies often. It's possible that networks do not have any worldwide identifiers. Direct connection among sensor nodes and the BS consumes a lot of energy because of the length. Information can be transferred to the BS via intermediary nodes in a number of strategies that reduces the power usage of the transmitting node. Nodes connect together via routing protocols [5, 6].

Three kinds of routing algorithms have been described: proactive, reactive, and hybrid in the scholarly papers. The next sections go into considerable detail about each of these procedures [7].

- **Proactive Routing Protocol:** As a result of their proactive nature, Table Driven Protocols are also known as proactive routing protocols [8-10]. In an effort to reduce communication delay, it keeps up-to-date route resources and data out of each node to another. Sending out data about the routing protocol in packet transmission helps.
  Whenever the nodes move owing to dynamic topology or network problems, the revised topology knowledge can be transferred to all entire network [11].
- **Reactive Routing Protocol:** Whenever a node needs a path to a particular destination, it launches a route discovery. They have their operating costs reduced by using on-demand network algorithms, which only keep track of active routes [12]. Routing inside a system is started by the component that needs a path to a certain location. A path has been discovered or all constructive attitude variants explored at this point in the procedure. Till the destination proves unavailable along all the path that led or the approach is no longer deserve, the path is preserved using a reactive routing mechanism. The most common method of discovering new routes is to send out a large number of route discovery process packets. As soon even as source node receives an answer, it is transmitted back to the source server responds through connection reversing or through piggybacking the answer in a routing direct link using flooding [12]. These methods are much more suited for dynamic environments, but they do have a greater delay yet still need news outlet flooding of packet transmission to construct pathways [11].
- **Hybrid Routing Protocol:** Hierarchical networking has been the most common need for these configurations, which mix reactive and proactive features. This method gives intermediary nodes access to the system or nearby node data. In order to specify the length of a region, the hop count is multiplied by an area radius. By combining the best features of both proactive or reactive routing, hybrid routes are able to eliminate the drawbacks of both types of procedures [9].

The main contribution of this paper is to review the wireless sensor routing protocols. To achieve this goal, we have initially analyzed the wireless routing classification. Then, we reviewed and analyzed the most popular routing protocols, including LEACH, TEEN,

and APTEEN. In addition, we have researched and critically analyzed the numerous published research papers on these techniques. In the last, defined the open research challenges.

2. Related Work

In this section, we have studied and analyzed the various routing protocols are deployed in wireless sensor network [13].

- **LEACH (Low Energy Adaptive Clustering Hierarchy)**

LEACH is a clustering mechanism that self-organizes and adapts [14]. It distributes the energy burden across the sensors in the network using randomization. The LEACH methodology is dependent on the following assumptions:

a. The base station can be reached by all nodes with sufficient power.

b. Different MAC protocols may be supported by each node.

c. Data from nodes that are near to one another is likely to be correlated.

In this particular protocol, the base station is assumed to be stationary and to be situated some distance away from the sensor nodes. Additionally, the nodes are assumed to be identical and to have limited energy resources. Cluster-head (CH) is the node that serves as the local base station.

TEEN (Threshold sensitive Energy Efficient sensor Network)

The TEEN protocol is a cluster-based hierarchical routing system that is based on the LEACH protocol. This approach is utilised when there is a tight deadline to meet. It is based on the following two presuppositions [15]:

- There is no difference in energy between the BS and sensor nodes at the outset.
- The BS may send data directly to all network nodes.

The medium is continually sensed by nodes in this protocol, while data transfer occurs less often. Components, first and second-level cluster heads, and other nodes make up the network. TEEN forms a cluster by using LEACH's technique. First-level CHs are created far from the BS, whereas second-level CHs are produced close to the BS. It delivers two kinds of data to its neighbours: HT (hard threshold) and ST (soft threshold). The hard threshold lowers the amounts of transmissions by only transmitting data if the detected property falls within the range of interest. There are two modes for transmitting data: hard threshold mode and soft threshold mode. The nodes constantly monitor their surroundings and store the information for transmission. the following requirements must be met before the node sends the value:

a. Sensed value > hard threshold (HT).

b. Sensed value ~ hard threshold >= soft threshold (ST).

- **APTEEN (Adaptive Threshold TEEN)**

TEEN's successor, APTEEN [16], is an enhanced version that retains all of TEEN's functionality. It was designed for hybrid networks and is capable of capturing both periodic data collecting and responding to time-sensitive events. APTEEN is able to answer inquiries such as:

a. An examination of the prior data values using historical analysis

b. A current snapshot of the system.

c. Long-term surveillance of a specific incident.

The cluster head communicates the control variables once each round is decided on the cluster head:

a. Attributes (interested physical parameters),
b. Thresholds (hard threshold value and soft threshold value),
c. schedule (TDMA time slot)
d. keep track of how long it has been since the last time (a node's maximum time interval between sending two consecutive reports).

3. Critical Analysis

The APTEEN protocol contains the properties of both proactive and reactive protocols. Therefore, in this section, we have done the critical analysis of the APTEEN protocols in Table 1.

Table 1 Critical Analysis

Reference	Algorithms	Performance Metrics	Influence Drawn
Wang et al. [17]	Genetic Algorithm, Firefly Algorithm, Density Adaptive Algorithm	Residual Energy, Survival, Number of Nodes Covered, and Overlay Nodes	The hybridization of GA and FA is done to find cluster head first time. After that, density adaptive algorithm is used for find cluster head. The simulation evaluation shows that lifetime and converge increase by 50% and 10%, respectively.
Zhang et al. [18]	Particle Swarm Optimization Algorithm	Network Lifetime and Energy Consumption	Determines the cluster head using PSO to enhance the network lifetime.
Gorgich et al. [19]	Fish Swarm Optimization Algorithm	Average Network Power Consumption, End to End Delay, Medium Access Delay, Throughput, Signal to Noise Ratio,	They have deployed the FSO algorithm for overcome the power consumption issue in WSN. The simulation result shows that sensor node power consumption was reduced 40%, end-to-end delay was reduced by 82.7 percent, multimedia access delay was reduced by 16.8%, signal to noise ratio was improved by 9.77%, data transmission probability was improved by 0.73 percent, and throughput rate was improved by 2.85%.
Fard et al. [20]	Distributed Energy Efficient Clustering Algorithm and	Network life and Energy Consumption	The average lifespan increases by 10%.

	Cuckoo Search Algorithm		
Mittal et al. [21]	Bat, Flower Pollinator, and Fuzzy Logic	Number of alive nodes, average energy	Their proposed method increases the lifetime of the cluster head.
Wang et al. [22]	Genetic algorithm and Density Adaptive Algorithm	Energy Consumption and Network Lifetime	In their method, GA is used to find cluster head first time. After that, density adaptive algorithm is used for find cluster head. The simulation result show that energy consumption reduces.

4. Conclusion and Open Research Challenges

In this paper, we have studied and analyzed the wireless sensor network routing protocols. Routing protocol is classified into proactive, reactive, and hybrid approaches. Out of these, hybrid approach is most preferred due to it contains the properties of proactive and reactive approaches. In the hybrid approach, APTEEN protocol is most preferred. Therefore, we have done the critical analysis of the APTEEN protocol. From the critical analysis, we found that metaheuristic algorithms are deployed for determine optimal cluster head to reduce the energy consumption. After that, we have defined the open research challenges, as explained below.

- In the literature, metaheuristic algorithms are successfully applied for determine the cluster head in the APTEEN routing protocol for reduce energy consumption. The performance of metaheuristic algorithm is dependent on total number of population and iterations which impact the convergence rate of the algorithm to determine the optimal solution. In the literature, which algorithms are deployed for find cluster head facing number of challenges such as local optima and low convergence rate. Therefore, need to explore other metaheuristic algorithms that provides faster convergence rate such as black widow optimization, water strider optimization algorithm.
- The metaheuristic algorithms use the iterative process which takes number of iterations to search the cluster head. Therefore, one approach deploys artificial intelligence algorithms such as fuzzy logic, artificial neural network for determine the cluster head.
- In the most of the research articles, single objective function such as energy consumption is taken as parameter for select the optimal cluster head. Thus, one approach is to design a multi-objective function that enhances number of parameters of the network.

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