Recent Developments in Routing Protocols for Wireless Sensor Network

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Abstract – The main aim of this paper is to explore the developments pertaining to routing protocols in wireless sensor network. In this paper we analyze the design issue of sensor networks and present a classification and comparison of existing routing protocols.

Index Terms – Connectivity, Coverage, Topology control, Wireless Sensor Networks, Routing Protocols, Sensor Networks, Classification of Protocols, Design Issues, Applications.

1. INTRODUCTION

Growing innovation in the world represent smart environments and data for this smart world is obtained through Wireless Sensor Networks (WSN) [1], where thousands of sensors are deployed at different locations operating in different modes. A sensor network is capable of sensing, processing and communicating which helps the base station or command node to observe and react according to the condition in a particular environment. Sensor nodes have an in-built processor, using which raw data are processed before transmission.

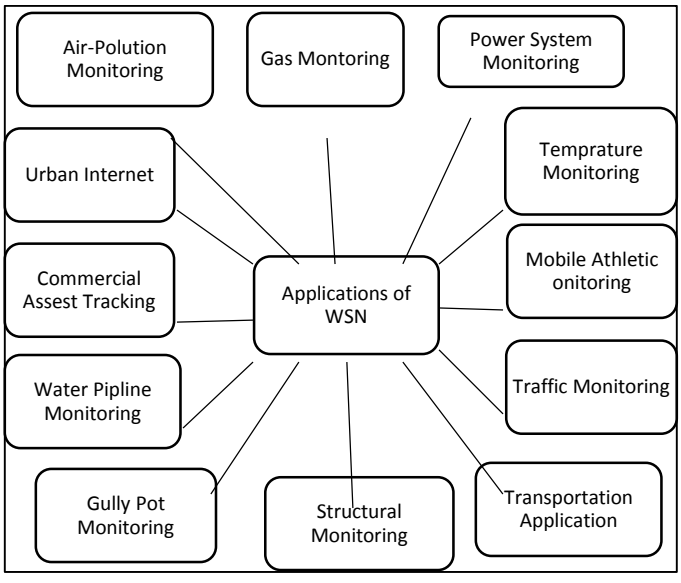

Figure 1: Applications of WSN

WSN Provide a bridge between the real and virtual worlds. It is having a wide range of potential applications [2] in industry, science, transportation, civil infrastructure, and security. Figure 1 depicts the wide range of applications being catered by WSN.

The paper has been structured into five sections: Section 2 details about existing routing protocols. Section 3 highlights various design issues in WSN. Section 4 acknowledges the work of eminent researchers and presents a comparative study of routing protocols. Section 5 finally concludes raising the feasible solutions to issues raised in the paper.

2. ROUTING PROTOCOL

A routing protocol [3] specifies how routers communicate with each other, disseminating information that enables them to select routes between any two nodes on a computer network. Routing algorithms [4] determine the specific choice of route. Each router has a priori knowledge only of networks attached to it directly. Figure 2 demonstrates the classification of routing protocols [5] on the basis of their mode of functioning, participation style of node and the network structure. Further, each type has specialized protocols. For instance, based on the mode of functioning and type of target applications, the routing protocols are classified to be proactive, reactive and hybrid protocols [6]. In contrast to proactive protocol [7] which requires the nodes to switch on their sensors and transmitters, sense the environment and transmit the data to a base station through the predefined route, the nodes in reactive protocol [8] reacts if and only if there are sudden changes in the sensed attribute beyond some pre-determined threshold value.

Hybrid protocols [9] incorporate both proactive and reactive concepts. They first compute all routes and then improve the routes at the time of routing. Although there exist many protocols in each of the above listed category, but LEACH [10], TEEN [11] and APTEEN [12] are few of the popular protocol in each category respectively.

Direct communication, flat and clustering protocols [13] belong to the family of protocols based on participation behavior of the sensor node. While direct communication protocols [14] allow any node to send information to the base station directly, it offers the quick drainage of node energy when applied in a very large network. SPIN protocol [15] is an example of this type of protocol. The flat routing protocols initiate by searching for a valid route to the base station and

later allow transmitting the data. Nodes around the base stations usually drain their energy quickly. Its scalability is average. Rumor routing [16] is an example of this type of protocol. Clustering protocols [17] are the most popular category of protocols. According to the clustering protocol, the total area is divided into numbers of clusters. Each and every cluster has a cluster-head and this cluster-head directly communicates with the base station. All nodes in a cluster send their data to their corresponding cluster-head. LEACH and TEEN are examples of this type of protocol.

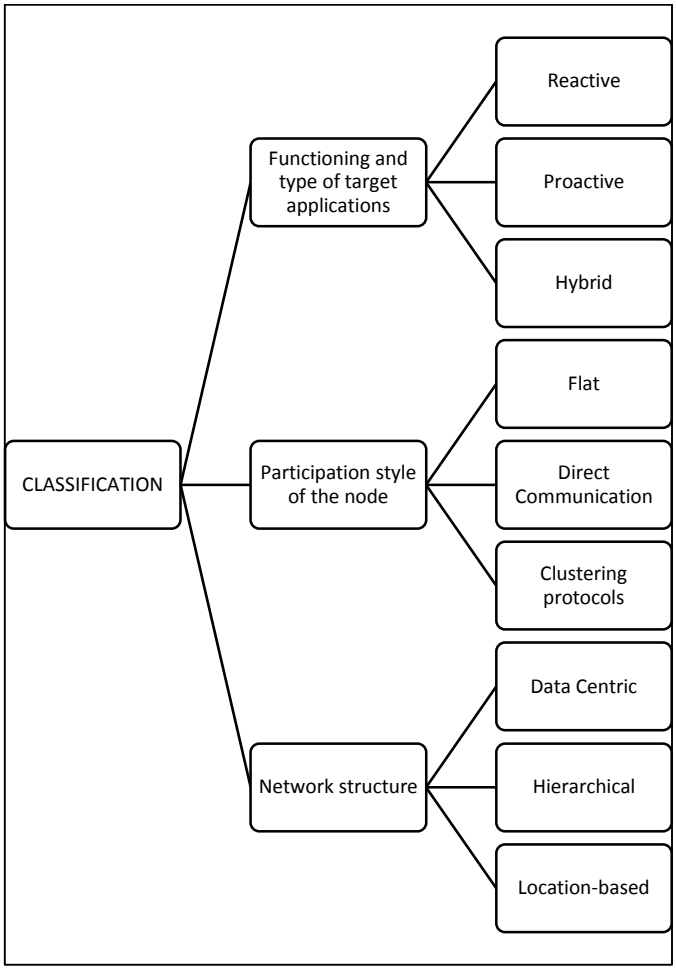

Figure 2: Classification of Routing Protocols

Data centric protocols [18] are query based and they depend on the naming of the desired data, thus it eliminates much redundant transmissions. The base station sends query to a certain area for information and waits for reply from the nodes of that particular region. Since data is requested through queries, attribute based naming is required to specify the properties of the data. Depending on the query, sensors collect a particular data from the area of interest and this particular information is only required to transmit to the base station and thus reducing the number of transmissions. Flooding [19] was the first data centric protocol. On the other hand, hierarchical routing [20] is used to perform energy efficient routing, i.e., higher energy nodes can be used to process and send the information: low energy nodes are used to perform the sensing in the area of interest thus offering a longer life time to network. Hierarchical protocols include LEACH, TEEN, and APTEEN, just to list a few. Location based routing protocols [21] need some location information of the sensor nodes. Location of the nodes can be obtained from GPS (Global Positioning System) signals, received radio signals strength etc. Using location information, an optimal path can be formed without using flooding techniques. GAF (Geographic Adaptive Fidelity) [22] is one of popular protocol of this category.

Although the above mentioned classification enlightens the fact that much work has already been done in the domain of routing in WSN, however, there still exist many design challenges pertaining to improving the efficiency of WSN. Next section elaborates on design issues in WSN.

3. DESIGN ISSUES IN WIRELESS SENSOR NETWORK

In WSN there are number of issues which affects the performance and efficiency of the WSN. Since the WSN is smaller in size, having limited memory, computation and battery power. Figure 3 illustrates various issues [23] and is being discussed as follows.

Network Dynamics: Most of the network architecture assumes that the sensor nodes are stationery and sometimes the mobility of the sink or the cluster-head is necessary. Here the most challenging issue is routing the messages from or to moving nodes. Since the sense event can be either dynamic or static depending on the applications. For example target detection/tracking applications is an example of dynamic event where as forest monitoring for early fire prevention is an example of static event.

Node Deployment: Nodes can be deployed in either deterministic or self-organizing manner. In deterministic situations, the sensors are manually placed and data is routed through pre-defined path. However in self-organizing system, the sensor nodes are scattered randomly creating an infrastructure in an ad-hoc manner.

Limited Energy of Sensor nodes: Nodes in WSN can use their limited supply of energy performing computation and transmitting information in wireless environment. Energy conserving forms of communications and computation are essential. In a multi-hop WSN, each node plays a dual role as a data sender and data router. The malfunctioning of some sensor nodes due to power failure can cause significant topological changes and might require re-routing of packets and re-organization of the network.

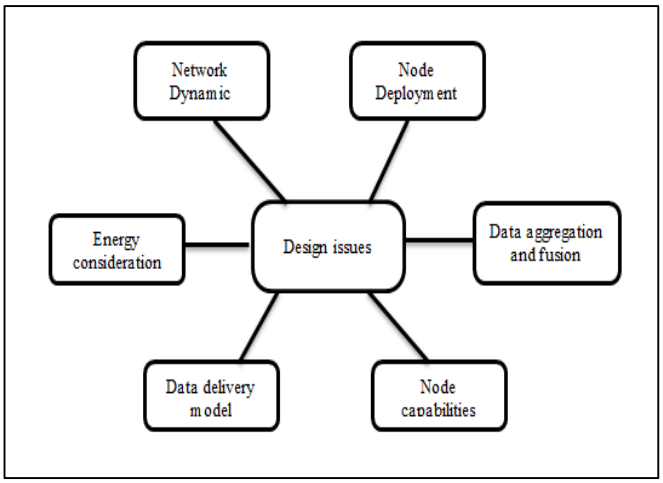

Figure 3: Design Issues in WSN

Data Delivery Model: Depending on the application of the sensor network, the data delivery model to the sink can be continues, event-driven, query-driven and hybrid. In the Continous data delivery model, each sensor sends the data periodically. It is suitable for applications that require periodic data monitoring. In the event-driven model, nodes react immediately to sudden and drastic changes. Query-driven model responds to a query generated by the base station or anther node in the network. Some networks apply a hybrid model using a combination of Continous, event-driven and query-driven data delivery.

Heterogeneous Nodes: Depending on the application, a sensor node can have a different role or capability. The existence of a heterogeneous set of sensors raises many technical issues related to data routing. Even data reading and reporting can be generated from these sensors different rates, subject to diverse QoS constraints and can follow multiple data reporting models.

Redundant Data: Since sensor nodes may generate significant redundant data, similar packets from multiple nodes can be aggregated to reduce the number of transmissions. Data aggregation is the combination of data from different sources according to a certain aggregation function.

An analytical investigation of the above mentioned issues indicates that there has been huge advancement in the field of embedded computer and sensor technology. Still WSN has open research issues to be investigated further. One of the major issues is the rate of energy consumption thus affecting the efficiency of sensors.

4. RELATED WORK

The related work highlights the work of the renowned researches and is being acknowledged in this section. Field of WSN has been populated with lot of work by researchers pertaining to both industry and academia. For instance, Zhenjiang and Vasilakosin [24] proposed taxonomy to classify existing topology control issues. Topological issues include connectivity problem under both spatial and temporal controls. Rajashree et al. [25] identified some of the important design issues of routing protocols for sensor networks and also compared and contrasted the existing routing protocols. The study reveals that it is not possible to design a routing algorithm which will have good performance under all scenarios and for all applications. Akkaya and Younisin [26] summarized research results on data routing in sensor networks. Ghaffari et al. [27] presented a comparison of various routing protocols and concluded that the limited energy of sensors in wireless sensor networks is the main limitation for planning protocols and EAR and GBR are better choices in the case of security, lifetime, consuming energy. The authors advocate using these protocols for directing in wireless sensor networks.

The grilled literature indicates that routing protocols have far-reaching effects on the performance and reliability of a WSN but sorting out the differences between them can be a challenge. On the basis of available literature, a comparison of the routing protocols is being delineated in table 1.

Table 1: Comparison between Routing Protocols

Routing Protocol	**Classification**	**Power Usage**	**Data Aggregation**	**Scalability**	**Query Based**	**Overhead**	**Data Delivery Model**	**QoS**
LEACH	Hierarchical / Destinitiated	High	Yes	Good	No	High	Cluster-Head	No
TEEN & APTEEN	Hierarchical	High	Yes	Good	No	High	Active Threshold	No

PEGASIS	Hierarchical	Max	No	Good	No	Low	Chain Based	No
SPIN	Data Centric	Ltd	Yes	Ltd	Yes	Low	Event Driven	No
FLOODING	Data Centric	High	No	Ltd	No	High	Continuously	No
SPEED	Location / Data Centric	Low	No	Ltd	Yes	Low	Geographic	Yes

5. CONCLUSION

Routing in sensor network has introduced many challenges as compared to traditional wired sensor network. This paper discussed some of the most relevant issues and challenges of WSN, from the application, design and technology viewpoints. In order to resolve the challenges and improve the efficiency of a WSN, the strong requirement is to have a proper network model, attention shall be given to coverage and connectivity and further the protocols shall be designed in a unified mode.

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