International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

A Study on Wireless Sensor Network and Routing Strategies

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Abstract: ***Wireless Sensor Networks have encouraged more work to bring out new application for the environment and for the betterment of the existing application. On the basis of the applications, different specifications are provided to the sensor nodes with battery being one of the major constraints. This article provides a Study Of Wireless Sensor Network, Routing in Wireless Sensor Network and its Challenges. The primary focus of the article is to provide a survey that may help for the better selection of the routing protocol for better transmission. The article also includes the related work done in the field of Wireless Sensor Network. Finally, some open issues in the field which may be responsible for inefficient data transmission using routing strategy in future are discussed and few ideas that may help in resolving them are mentioned.***

Keywords: Wireless Sensor Networks (WSNs), Sink, Routing Protocol, Sensor Nodes

1. Introduction

A Wireless Sensor Network [1] has come out as one of the most rapidly emerging technology that has helped in developing many promising applications. Typically, they are not limited to, data collection, monitoring, surveillance and medical telemetry. WSNs are composed of a massive amount of sensor nodes that are deployed in the network. The nodes in the network are deployed either deterministically (i.e. manually) or randomly. In order to perform any application oriented task nodes in the network communicate directly or indirectly with each other and then to the base station (i.e. the main storage location for the data).

The sensor nodes in the network are the primary components which are small in size, with low power capability and small storage space. Their fundamental role is to monitor real world physical condition such as sound, temperature, humidity, intensity, vibration, pressure, motion etc. at various locations [2]. The sensor nodes have the characteristic of communicating without changing their geographical location. Figure 1 demonstrates the arrangement of sensor nodes in the Wireless Sensor Network. The main features of Sensor Nodes can be defined as [3]:

- All Sensor nodes are battery operated and has very less power, and once the nodes have been deployed in the network the batteries cannot be recharged.
- Nodes have symmetric links, i.e., the transmission power is same in all the nodes that have participated in the communication.
- Initially, all nodes in the network are provided with the same amount of communication and battery power.
- Generally sensor nodes are quasi-stationary but they have the capability of varying their mobility according to the application.
- Senor nodes are not equipped with GPS; therefore it is not possible to track them once deployed.

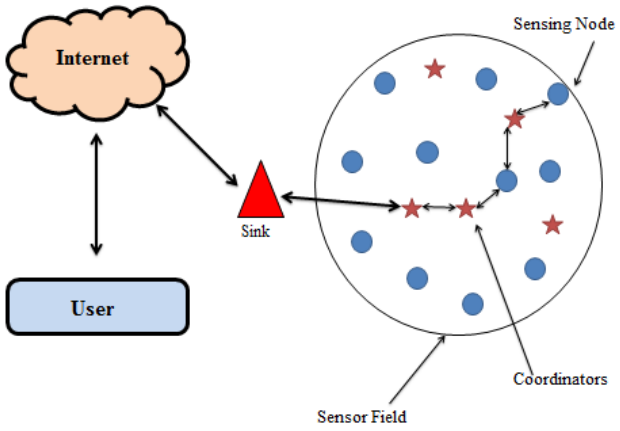

Figure 1: Wireless Sensor Network

Wireless Sensor Network has some unique characteristics which are as follows [4]:

- Dynamic Network Topology: with the increase or decrease in the number of nodes the topology of the network changes frequently. Nodes failure, energy depletion in the node or, if the channel fading occurs they can also cause change in network.
- Application Specific: Wireless Sensor Network is application dependent. The constrained resources like storage, processing limits sensor nodes in WSNs to contain a wide variety of application as the traditional network does. The design of application and management architecture in WSN are both dependent on application semantics. As a result, application designers have to develop various complex and special program to execute node localization, data routing and data aggregation tailored to specific sensor applications. Thus, it is not likely that those programs can carry over directly from one application to another, since the application-specific requirements on WSNs are varied in terms of resource usage and communication patterns.
- Energy Constrained: Nodes are portable and have limited energy; the computation capability and the storage space

are low. These are very important design consideration of WSNs.
- Self-Configurable: once the nodes are randomly deployed in the network they then configure themselves automatically.

2. Routing in WSNs

Routing [5] is the process of forming path between the source and destination for the transmission of the data packets. On the network layer, the routing is mostly concentrated for the incoming packets. In Multi hop network there is no direct communication from source to sink and the replaying of the data packets is done by sensor nodes. The Routing protocols also generates some tables, which enables the algorithms to assist in the creation and maintenance of data packets between source and destination.

Selecting the right routing protocol for designing wireless sensor network is very important. There have been few challenges in order to achieve perfect routing protocol for successful transmission of data packets to the destination, and those challenges are:
- Energy Consumption: The main objective of directing conventions is the effective data communication between source and destination.
- Robustness: Governing the nodes rather than switching like internet work more accurately as to convey the information in a multi hop strategy WSNs depends on the number of nodes in the system.
- Node Deployment: The performance of the routing protocol can be affected by how the nodes are deployed in the network. Selecting the deployment strategy is also very important based on the application to ensure the best performance.
- Quality of Service: The data must be transmitted within a specific time slot as application sensors are time sensitive. The data that must have sensed after a long time might not be relevant to the latency issue.
- Data Aggregation: According to the application the sensor nodes are securely sent in their area of interest and help to achieve a typical detecting message with certain level of connection.

Figure 2 illustrates different Routing Protocols in Wireless Sensor Network [6]. They are categorized as data centric or attribute based if they name the data and query the nodes based on some attributes of the data. Many routing protocols follow the criteria in which the sensor network is combined with the wired network. Examples of Data centric based protocols are: Flooding and Gossiping, Rumor Routing, SPIN (Sensor Protocols for Information via Negotiation) and Directed Diffusion. In case of Hierarchical based Routing, the nodes are deployed in layer (or hierarchical manner). This routing strategy also includes formation of cluster for the data packet transmission. The selection of cluster head amongst all the nodes in the cluster is a challenge as there may be instance when the node with the less amount of energy may be selected as a cluster head. LEACH (Low Energy Adaptive Clustering Hierarchy), PEGASIS (Power Efficient Gathering in Sensor Information System) and TEEN (Threshold Sensitive Energy Efficient Sensor Network Protocol) are few examples of hierarchical protocols. In Location based Routing Protocols, each node in the network has the information of it location via its GPS module or certain localization techniques. Examples for Location Based Protocols are MECN (Minimum Energy Communication Network), SMECN (Small Minimum-Energy Communication Network) and GEAR (Geographic and Energy Aware Routing).

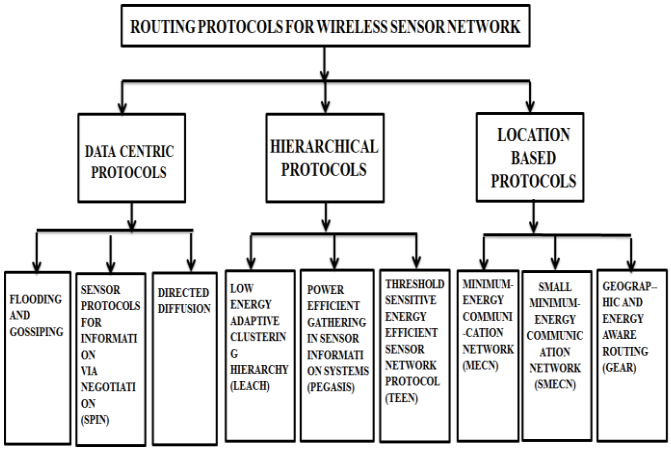

Figure 2: Routing Protocols for Wireless Sensor Network

Flooding [7]: It is one of the oldest techniques used for routing in sensor networks. Every node receives and broadcasts the data packet, until a maximum number of hops for packet are the total number of nodes itself. It is a reactive technique, and it does not require costly topology management and complex route discovery algorithms.

Gossiping [8]: It is a derivation of flooding in which nodes rather than broadcasting the data packet it send the incoming packets to neighbour which is selected randomly. Once the neighbour receives the data it passes the data to another node selected randomly from its neighbours and the process continues.

SPIN [5]: It stands for Sensor Protocols for Information via Negotiation designed to solve the problem in flooding techniques like implosion, overlap and resource blindness. This protocol is designed with two basic ideas: sensor nodes operates more efficiently and store energy by sending only the meaningful data. SPIN works on three messages i.e. ADV, REQ and DATA. ADV is the advertisement message in which nodes sends the data about the data. If the node REQ i.e. request back after the ADV message then the DATA is send to the nodes.

Directed Diffusion [9]: The sink node in this routing scheme sends out the interest, which is actually a task description. The task is described by those descriptors, whose names are assigned through attribute-value pair. All sensor nodes store the interest in their cache with the timestamp and gradient. As the interest progresses, gradient is setup back from the source to the sink. As the source has the data of interest, it propagates the data along the gradient interest's path. The interest, aggregation and data propagation are mentioned

locally. This technique is based on data centric scheme where sink broadcasts the interest.

LEACH [10]: LEACH i.e. Low Energy Adaptive Clustering Hierarchy is a hierarchical routing protocol introduced to increase the network lifetime. The routing protocol re-clusters and automatically organizes the sensor nodes for every round. Nodes in LEACH protocol arrange themselves into clusters. These clusters have a node acting as a cluster head, which is responsible for the transmission of the data to the sink. All the data is collected at the cluster head first and then only the useful ones are transferred to the sink. The energy loss by the cluster is more as they have vast role to play and if the node act permanently as cluster head the energy of the network will be lost quickly. LEACH protocol is a single hop routing protocol in which the nodes can directly send data to the cluster head and sink.

PEGASIS [11]: It stands for Power Efficient Gathering in Sensor Information System. The main objective of this protocol are twofold: first, it aims for extending the network lifetime by achieving a high level of energy efficient and uniform energy consumption all across network nodes. Second, PEGASIS aims to reduce the delay of data packet transmission. It basically involves homogeneous nodes and assumes to have knowledge about all sensor nodes' position. Communication is done through the formation of the neighbouring nodes begins right from the start node till the sink node.

TEEN [12]: Threshold Sensitive Energy Efficient sensor Network protocol are specifically developed to deal with reactive networks where sensor nodes continuously sense and transmit the data as soon as the sensing parameter exceed the application specified threshold value. If the threshold value is not achieved, the user will not be able to know the state of the network, making it unreliable to use for the application that require periodic data from the network.

MECN [5]: Minimum Energy Efficient Communication Network constructs an energy efficient subnetwork for broadcasting the data, and SMECN: Small Minimum Energy Efficient Communication Network also provides with the subnetworks but is smaller than those constructed by MECN if the region for broadcasting is circular. SMECN also follow the MECN's property used to construct the subnetwork which is there exist a subnetwork between the every pair of node that are connected to the graph which has less edges than the original graph.

GEAR [13]: Geographic and Energy Aware Routing protocol is a location based protocol works in two phases. In first phase: it uses energy aware neighbour selection to route a packet to target, in second phase: to disseminate the packet either restricted flooding or recursive geographic forwarding is used. It also attempts to balance energy consumption in the network resulting in increase in network lifetime; it also performs better in terms of connectivity after initial partition.

3. Related Work

Following section includes the related work in wireless sensor network.

I.F. Akyildiz *et al.* [3] make a complete survey on design issues and techniques in Wireless Sensor Networks. They have described physical constraints for the nodes and also mentioned all the protocols in the layers of network stack. The applications of the sensor nodes are also discussed. However the survey does not seems to be complete as it does not presents the classification of routing protocols.

Al-Karaki *et al.* [14] presents a survey on Routing Protocols in WSNs. They have classified routing techniques on the basis of their network structure like: flat, hierarchical and location based routing protocols which are further classified into multi path, query, coherent, negotiation and QoS based depending on it operation. They have also discussed routing Challenges and Designs issues which were noticed when implemented in Wireless Sensor Network. Limited computing power, limited bandwidth for connecting nodes and limited energy supply are also described. They have also mentioned the design trade-offs between communication and energy overhead saving in some routing algorithms. They have concluded with advantages and disadvantages of each routing techniques described.

J. Yick *et al.* [15] presented a top down approach of several applications and review them on the aspect of Wireless Sensor Network. They have presented issues by classifying them into different categories, those are: 1) internal platform and underlying operating system, 2) communication protocol stack, and 3) network services, provisioning and deployment. They have also discussed types of sensor nodes on the basis of different WSNs like terrestrial WSN, underground WSN, underwater WSN, multi-media WSN, and mobile WSN. The applications of sensor nodes are presented in brief. They discussed about the internal sensor system, for a sensor to operate in WSNs, there are several internal system issues that they have addressed through the system platform and operating system support. They have discussed all the parameters with the research issues. They have concluded with the comparison table of all the WSNs described earlier on the basis of their design, application and challenges and also one comparison table for application and communication protocol.

G. Anastasi *et al.* [16] have presented a survey on energy consumption based on the hardware components of the sensor nodes. They have described the sensor node on the basis of four components: sensing subsystem including one or more sensor for data acquisition, a processing subsystem, memory for local data processing and a power supply unit. They have also discussed about the architecture and power breakdown as the solution to reduce power consumption in WSNs. They have focused on the classification and advantages of taxonomy of the energy conservation scheme. The protocols are then classified as duty-cycling, data driven and mobility based. They have also provided observation about how a different approach helps in energy management

and mentioned that energy consumption of the radio is much higher than that of the data processing. They have observed a new interest in sparse sensor network architecture. They have concluded by informing about the time needed for communication is less than that for the sampling of data.

4. Open Issues and Future Work

In Wireless Sensor Network, routing is a very attractive phase of successful communication [17]. Several issues have not still sufficiently addressed or we can say are remaining open, like:

- Uncertainty: it is basically because of the nature of WSNs and also relates to the situation such as data delivery, event recognizing etc. With the use probabilities associated with these events few attempts to models such events have been made. The problem in taking uncertainty into account is because of two main factors, which are: measuring the distribution of events depends on both environment as well as application, and despite of there have been advances in optimization handling such as optimization probabilistic is difficult.
- Dynamicity: if integrated with the optimization, the problems because of dynamicity are more challenging.
- Scalability: the change in the network dimensions may sometimes lead to resolve the problem or to sufficiently increase the computation time. In theoretical studies, problems for multi sink/multi-commodity WSNs design are not considered which comes with scalability.

The challenges that have been addressed in the present routing algorithm can be resolved with the help of soft computing and computational intelligence. Future scope can be as follows:

- Design and applications: Wireless Sensor Network is used in many areas including monitoring of biological system, forest fire etc. Few applications require sensor nodes to be positioned at fixed location whereas some application does not require nodes to be fixed on particular location. Therefore, it is important to design the type, location and the number of sensor nodes for future application.
- Sensor localization: it refers to the awareness of location in sensor nodes deployed in the network at a specific point. Accurate information can be obtained with the help of Geometric-aware routing. In WSNs, localization methods that utilize the time of arrival of the signals from the base station is also used.
- Routing based on energy awareness: maximizing the network lifetime is a point of primary focus. Recharging the battery again and again is not possible because of its cost. Routing involves the extraction of path of a message, which is transmitted from the source to the sink. In proactive routing a table is used to store the route whereas in reactive routing, the routes are subjected to computation. Additionally, hybrid of both the routing is applied in the heavily deployed network to avoid large memory usage of the tables and can also be reduced through clustering.
- Quality of Service aware Routing: the measure of the service quality that is interested in end-to-end application/users is defined as QoS. The parameters are packet loss, jitter, delay, available bandwidth and fairness. The increase in the network utilization should be dependent on the application requirement and QoS parameter.

5. Conclusion

Wireless Sensor Networks are application specific, and selecting the best route for the transmission of the data is the primary point of concern which is dependent on different parameters. Because of restricted resources, the communication in the network is very challenging and in designing routing techniques topologies have a very crucial role. The article discuss about the various features of the wireless sensor network as well as routing strategies. Additionally, the characteristics and challenges of WSNs are also discussed to provide better understanding of the Wireless Sensor Network, the routing strategies. Finally, the paper is concluded with few open issues which still exist followed by the future scope in the field of Wireless Sensor Network.

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