Routing in Wireless Sensor Networks: A survey

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***Abstract*--**Routing is one of the main problems in wireless sensor networks and many solutions have been developed to address this problem. The main objective of the routing protocols is efficient delivery of information between sensors and the sink. Many routing protocols require that each node should exchange the information between neighbors. The information to be exchanged can vary according to routing techniques. Ensuring development of efficient routing faces many challenges due to both wireless communication effects and the peculiarities of sensor network. These challenges preclude existing routing protocols developed for wireless ad hoc networks from being used in wireless sensor networks. Instead, novel routing protocols are required. In this paper discussion on various routing approaches has been done and some important routing protocols in wireless sensor network have been described.

Keywords **-** Routng, hierarchical, wireless sensor network, QoS

1. Introduction

Routing is a process of determining a path between the source and destination upon request of data transmission. Routing in wireless sensor networks differs from conventional routing in fixed networks in various ways: There is no infrastructure; wireless links are unreliable; sensor nodes may fail; and routing protocols have to meet strict energy savings requirements. Different design constraints along with different architecture have been considered for the wireless sensor network based on the applications [1]. There are several key challenges faced during the implementation of Routing protocols for wireless sensor networks like the huge number of application scenarios, redundant data traffic, frequent topological changes in case of mobile nodes, the complexities in the design of the operating system and the network protocols for wireless sensor network.

II. Routing Challenges and Design Issues In WSNs

Routing is a process of determining a path between the source and destination upon request of data transmission. Routing in wireless sensor networks differs from conventional routing in fixed networks in various ways: There is no infrastructure; wireless links are unreliable; sensor nodes may fail; and routing protocols have to meet strict energy saving requirements. Different design constraints along with architectures have been considered for sensor networks based on applications [2]. Following are the various routing challenges faced during implementation of this emerging technology:

i. Energy Consumption

The main objective of the routing protocols is efficient delivery of information between the sensor and the sink[3]. Because of the limited energy resources of the sensor nodes, data need to be delivered in the most energy-efficient manner without compromising the accuracy of the information contents.

ii. Data Aggregation

Sensor nodes may produce significant redundant data, when they are densely deployed or are in close proximity to each other. Similar packets or redundant information from multiple nodes can be grouped in order to reduce the amount of transmission [4].

iii. Node/Link Heterogeneity

In theory, most of the nodes in WSNs are homogeneous. Homogeneous nodes are that have identical capability in terms of computation, communication and power. However, in practice it requires that nodes have diverse roles [5]. Hence the implementation of heterogeneous nodes is known to increase network reliability and lifetime. The presence of heterogeneous sensors elevates many technical issues connected to data routing and also enhances its performance.

iv. Scalability

A WSN can consist of hundreds or thousands of sensor nodes, densely deployed in a regional area. Any routing scheme must thus scale well with the number of nodes. This is often achieved by using distributed and localized algorithms, where sensor

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network routing protocols are scalable enough to communicate with nodes in their neighborhood. To sum up, a system should operate efficiently in any network size.

v. Network Dynamics

In most of the network dynamics the network architectures undertake that sensor nodes are stationary. However, in many applications a system should be able to retrieve and adapt to the current network state or changing network conditions, and mobility of both BS's and sensor nodes is sometimes desirable. It is very challenging to handle the routing messages from or to moving nodes since route stability becomes a key issue.

vi. Fault Tolerance

The reliability of WSN is affected by faults that may occur due to various reasons such as lack of power, malfunctioning hardware, software glitches, physical damage, or environmental hazards. The overall task of the sensor network should not get affected by the failure of the sensor nodes.

vii. Coverage

In WSNs, each sensor node accomplishes a certain view of the environment. A given sensor's view of the environment is insufficient in range and in accuracy so, it can only cover partial physical boundary therefore there will be limited information about the surroundings. Hence, area coverage is also an essential design parameter in WSNs.

viii. Connectivity

High node density in sensor networks prohibits them from being completely isolated from each other. Hence, sensor nodes are anticipate to be highly connected.However, this high connectivity may not prevent the network topology from being variable Structure and Protocol Operation. Routing algorithms based on network structure further sub categories into flat routing protocols , hierarchical routing protocols, location based routing protocols and negotiation based routing protocols. [6]. Routing algorithms based on the protocol operation further sub categories into, Multipath based routing protocols, Query based routing protocols, QoS-based routing protocols and coherent based routing and the network size from being shrunk due to sensor node failures.

ix. Quality of Service

In Real Time applications, information must be provided within a certain period of time from the moment it is sensed; otherwise the data will be useless. However, in many applications, energy preservation, is considered relatively more important than the quality of data sent, where the application demands prolonged network lifetime. As the energy gets dissipated every time the sensor nodes sense the information, it is desirable to reduce the quality of the resultant information in order to reduce the energy dissipation in the nodes and hence prolong the total network lifetime. Hence, It is necessary for energy-aware routing protocols to capture this requirement.

III. Routing Protocols in WSNs

In this section, some important routing protocols in wireless sensor network have been discussed. Sensor network holds a lot of applicability in areas where gathering sensing information in a remote location is required. Hence, this necessitates the design of routing protocols for sensor networks that suits the various applications. Due to the challenges and the various constraints of wireless sensor networks, it is not possible to design a routing algorithms performance in all scenarios, thus, according to application requirement a lot of routing algorithms have been proposed and literature survey reveals that the design peace of routing algorithms for WSNs is quite large and we can classify the routing algorithms in many ways. The routing protocols have been classified according to Network

protocols. Figure 1 shows the taxonomy of routing protocols in wireless sensor network.

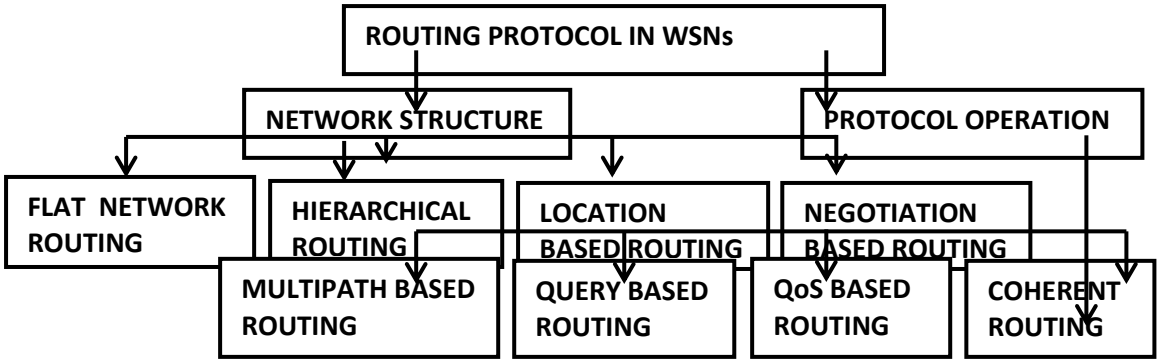

Figure 1. Taxonomy of routing protocol

3.1 Flat Network Routing

In flat networks such as point-to-point networks, every node plays the same role and sensor nodes work together. In flat routing protocols, all nodes play the same important role. Flat based routing is appropriate in the scenarios where the large number of sensor nodes is mandatory. Since, it is not feasible to allocate a global identifier to each node due to a large number of nodes positioned therefore every node plays the same role. Some important routing protocols are below such as SPIN and Direct Diffusion covered under flat based routing. Many flat based routing algorithms are based on these protocols.

3.2 Hierarchical Network Routing

A hierarchical network routing consists of two layer architecture where first layer is
used to select cluster-heads and the second layer is used for routing. Nodes can play distinct roles in the network; in order to save the energy cluster-heads are elected by clustering approach to perform aggregation and reduction of data [7]. The sensing of data is performed by the lower energy nodes while higher energy nodes are responsible for processing and transmission of information. The main objective of hierarchical routing is to effectively and efficiently preserve the energy consumption of sensor nodes by executing multi-hop communication within the clusters, perform data aggregation and fusion in order to reduce the number of transmitting messages to the sink or base station. Hence, to lower the energy consumption within a cluster, Hierarchical routing is an efficient way and it also reduces the number of data packets transmitted to the base station. Routing in wireless sensor networks has various advantages in order to achieve the scalability and efficient communication. Hierarchical routing protocols include LEACH, PEGASIS, TEEN, APTEEN, MECN, SMECN.

3.3. Location Based Routing

Most of the routing protocols for sensor networks necessitate the location information for sensor nodes. In most of the cases location information is required in order to calculate the distance between two meticulous sensor nodes in order to estimate the energy consumption.
In location-based routing, also known as geographic routing, sensor nodes are identified by means of their positions [8]. This is based on two principal assumptions: first of all, that every node has knowledge about its own and its network neighbor's location; secondly, that the source of the message is conversant about the location of the destination. The distance between neighbor nodes is calculated by means of three ways; based on relative coordinate information exchanged between neighboring nodes, satellite communications if nodes are equipped with a small low-power GPS receiver and incoming signal strength. In order to save the save energy, some location-based schemes require that some nodes sleep if there is no activity. Since sensor nodes are spatially deployed over a region and there is no addressing scheme, location information can be utilized in order to routing data in an energy efficient way. For example, by using the location information of sensor nodes, the region to be sensed can be identified so that the query can be diffused over that particular region, which in result eliminates the number of transmission significantly. Some of the protocols discussed in this section consider the mobility of nodes and designed primarily for mobile ad hoc networks[9].However, these routing protocols are well applicable to wireless sensor networks also, where there is very less or no mobility. But, many of these location based routing protocols are not applicable to sensor networks since they are not energy aware like Cartesian and trajectory-based routing.
In a localized manner, the matter of designing sleeping period schedules is addressed in SPAN and GAF[10]. Some famous location-based routing

protocols consist of SPAN, GEAR, MFR, GEDIR, and GAF.

3.4 Negotiation Based Routing

In order to eliminate the redundant data transmission through negotiation, negotiation based routing consider high-level data descriptors. The SPIN protocols are examples of negotiation-based routing protocol. This class of protocols takes intellectual decisions for communication and some other action on the basis of availability of resources. These protocols utilize the highest level data descriptors to eliminate redundant data transmission through negotiation. Negotiation based routing protocols are Sensor Protocols for Information via Negotiation (SPAN), Sequential Assignment Routing (SAR), Directed Diffusion (DD).

3.5 Multipath Based Routing Protocols

The multipath routing technique is efficiently used to find alternate paths between sources and sink and verified its competence to improve the performance of wireless sensor network. This approach is considered as one of the existing solutions to cope with the limitations of routing. In multipath routing the main aim is to provide path resilience against the node or link failures and reliable data transmission. Whenever a sensor node cannot transmit its data packets towards the base station, it can benefit from the availability of alternative paths to retrieve its data packets from node or link failures. Since backup routes are identified during route discovery, multipath routing provides the minimum delay. Effective bandwidth aggregation is possible in Multipath routing, since data to the same destination has been split into multiple stream while everyone is routed through a different path.

3.6 Query Based Routing Protocols

Literature survey shows that a number of query-based routing protocols have been proposed for wireless sensor networks (WSNs). In this perspective routing protocol can be classified into two categories, energy balancers and energy savers. Energy saving protocols designed with an aim to decrease the overall energy consumed by a WSN, whereas energy balancing protocols designed with an aim to efficiently and effectively distribute the depletion of energy within the network. In general terms, the energy saving protocol is not necessarily good at balancing energy and vice versa. An Energy-aware Query-based Routing protocol for WSNs (EQR), proposes a worthy trade-off between the traditional energy balancing and energy saving objectives.

3.7 Qos Based Routing Protocols

QoS-aware schemes consider end-to-end delay requirements while setting up the paths in the sensor network. In QoS-based routing protocols (SAR, SPEED, MERR, AMERR etc), the network has to balance between energy consumption and data quality, and to satisfy certain QoS metrics (such as energy, bandwidth and delay) when delivering data to the base station.

3.8 Coherent Based Routing Protocols

Coherent data-processing routing is applied when energy efficient routing is mandatory. In this routing format, minimum processing (typically, time-stamping, suppression, etc.) has been performed over the raw data locally by the sensor nodes before transmitting it for further processing to other nodes. Then it is sent to other nodes called an aggregator for further processing known as aggregation. Data processing in non-coherent processing involves three phases. In the first phase, target detection, its data collection, and preprocessing of its data takes place. Then, for the cooperative function, the node needs to enter into phase two where it shows its intention to neighboring nodes. Here all neighboring nodes must be aware of the local network topology. Finally, in phase three a center node is selected for further refined information processing. Therefore the central node must have enough energy resources and computation abilities .

IV. Conclusion

Recent developments and research in wireless sensor networks have led to many new protocols specifically designed for sensor networks where energy awareness is an essential consideration. Most of the consideration however has been given to the routing protocols since they might differ depending on network architecture and the application. Routing in sensor networks is very challenging due to several characteristics that distinguish them from contemporary communication and wireless ad-hoc networks. These routing protocols have considered the characteristics of sensor nodes along with the application and architecture requirements. Almost all of the routing protocols can be classified as data-centric, hierarchical or location-based, although there are few distinct ones based on network flow or QoS awareness.

In this paper, recent research has been summarized and a comprehensive survey of routing techniques in wireless sensor networks has been discussed.

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