

Routing Protocols used in Wireless Sensor Network

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Abstract

Objectives: Distinctive routing protocols are designed where energy awareness is considered as essential design issue. The main objective of routing is to enhance the lifetime of the network by selecting appropriate route. **Methods:** The routing protocols are classified into different categories which are location based routing protocols, hierarchical network routing and flat based routing protocols, Area based routing protocols are GAF, GEAR and SPAN. Hierarchical routing protocols are LEACH, PEGASIS, TEEN and APTEEN. Flat routing protocols are SPIN, Directed Diffusion and Rumor Routing. All these protocols have different working and perform different types of operations in order to increase the lifetime of the network. **Findings:** In Wireless Sensor Network, sensor nodes consist of limited storage capacity, transmission range as well as limited energy resources. Also the sensor nodes can process limited amount of data. So in this case we need to have some conventions which can help to reduce the energy consumption of nodes. We found that all routing protocols are performing different operations in order to minimize the energy consumption of the network. Different approaches are used to enhance the lifetime of the network. Some protocols are using hierarchical conventions, some are using flat routing conventions and some are using area based routing conventions. Every one of these conventions is serving the lifetime of system in their own specific manner. **Applications:** The routing protocols are used in all types of Wireless Sensor Networks in order to enhance the lifetime of the network. Routing protocols are mainly used in time-driven, event-driven and query-driven applications.

Keywords: Base Station, Data Dissemination, Data Transmission, Energy Efficiency, Routing Protocols, Wireless Sensor Network

1. Introduction

Deployment of sensor nodes is performed in ad-hoc fashion in Wireless Sensor Networks. The sensor nodes which are deployed into a network automatically organize themselves. The sensors nodes are battery-powered and can operate without any interference for long term of time. Once in a while, if there should arise an occurrence of brutal condition it turns out to be extremely troublesome and illogical to energize the nodes. Thus, in that case proper resources management techniques are required which are routing protocols. In Wireless Sensor Networks routing protocols varies according to the network architecture and application. Routing protocols are divided into three main categories are location-based routing protocols, hierarchical network routing¹ and flat

routing protocols. Moreover, these protocols are also classified into multipath-based, negotiation-based, query-based, QoS-based. Routing in WSNs is very challenging due to inherent characteristics that differentiate these networks from traditional networks such as Mobile and Ad-hoc Network (MANET) and cellular networks. As opposed to conventional correspondence systems, the flow of data in Wireless Sensor Network used to be based upon many-to-one scheme. This will not prevent the flow of data in other form (Eg. multicast, peer to peer). Second, the nodes are constrained in terms of energy, storage capacity and processing. Third, sensors nodes deployed in any area used to be stationary, except few nodes. Also, in case of traditional networks, all sensor nodes used to be mobile which results in frequent topological changes.

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2. Designing Issues and Routing Challenges in case of Wireless Sensor Networks

The architecture of routing protocols in Wireless Sensor Networks is affected by many challenging factors. These factors must be overcome in order to achieve energy-efficient communication^{1,2}.

2.1 Node Deployment

In Wireless Sensor Networks, nodes are deployed in application-specific manner. They can be deployed in random and manual way. In case of manual node deployment, nodes placement in a network takes place in manual fashion and their location can be identified from the predetermined routes. On the other hand, in case of random node deployment, the nodes are deployed randomly creating ad-hoc network structure. If the nodes distribution is not uniform, then in that case clustering become essential in order to establish connection and to enable the energy efficient operations of network. Due to the energy and transmission limitations, inter-node communication takes place between short transmission ranges. So the route consists of multiple wireless hops.

2.2 Restricted Energy Capacity

Sensor nodes have limited energy capacity as they are battery powered. In case of harsh environment it is impossible to recharge the batteries of sensors. Due to which the nodes energy will be depleted after a certain period of time and network will be disturbed.

2.3 Fault Tolerance

Due to the harsh environment and lack of power sensor nodes in network may fail. So in that case failure of some nodes should not affect the whole working of network. There should be some criteria to establish new connection.

2.4 Scalability

Numbers of nodes are used to establish a network connection. Depending on application requirement nodes can vary from hundred to thousand. So in that case network should be able to easily adapt the changes. The properties of network should not be affected due to the enhancement of network structure.

2.5 Node/Link Heterogeneity

Node heterogeneity is the big issue in wireless sensor network. Node heterogeneity means all nodes will play same role but some application may require mixture of data so in that case different nodes can play different types of roles. Example is hierarchical protocols in which cluster head perform different role from other nodes and used to be more powerful than other nodes.

2.6 Information Detailing Method

Information detailing is of various sorts, for example, question driven, time-driven and occasion driven or hybrid. Query and event based data reporting is based on sudden changes in the environment. Data is immediately reported to the base station on the generation of any event. These types of data reporting are used in time-critical applications. Time-driven method is used for those applications which require periodic sensing of data. For a periodic time intervals, the sensor node sense the data and send that data to the main station.

3. Routing Protocols in Wireless Sensor Network

3.1 Location-based

In this type of routing, with the help of address over the network sensor nodes are recognized in a network. Information of sensor node location is needed to determine the distance of two nodes from each other due to which consumption of energy can be estimated. The separation between the two specific nodes is calculated with the help of incoming signal strength location of the nodes in a network which can be obtained with the help of GPS. To save energy, if there is no activity to do then that node will go to sleep state which helps in maximize the lifetime of network^{1,2}.

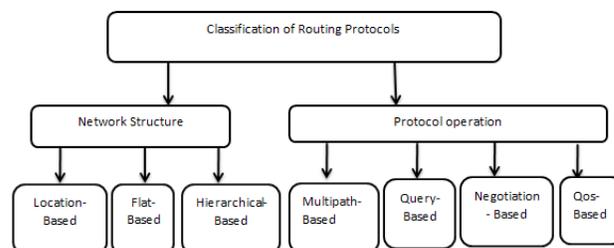


Figure 1. Types of routing protocols.

3.1.1 Geographic Adaptive Fidelity (GAF)

This protocol is an energy-aware routing protocol. GAF is based on the mechanism of turning off the unnecessary sensors if there is no task to do. In GAF, area is divided into fixed zones and forms a grid. Nodes within these grids use their location information, which can be traced with the help of GPS, to come in contact with other nodes in other grids and perform different roles. For example, for a certain period of time one sensor node from all nodes will be selected to stay awake and nodes that are left will go to rest state. The chosen dynamic node will accumulate information from every single other nodes and send that information to the sink. Hence GAF protocol saves energy by switching off unnecessary nodes in a network. GAF consist of three states such as Sleeping, Active and Discovery. Sleeping state consists of nodes which stay in sleeping state and are unnecessary. The second state is active consists of nodes which are performing some task. Each grid has only one active sensor node that is selected based on sensor ranking rules. The ranking of sensor is dependent on their residual energy levels. A sensor with higher rank will be able to handle the corresponding grid. So active sensors have higher rank. Other nodes within same grid except sleeping and active nodes come under discovery state. Figure 2 shows the working of GAF protocol.

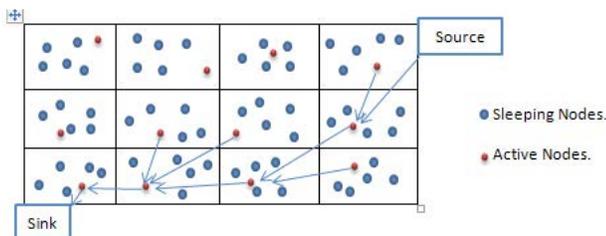


Figure 2. Working of GAF protocol.

3.1.2 Geographic and Energy-aware Routing Protocol (GEAR) Protocol

This protocol is also an energy-efficient routing protocol used to forward queries. In GEAR, sensors are equipped with GPS unit or a localization system so that nodes come to know about their current position in a network. Also, the sensor nodes used to be aware of their own residual energy and neighbouring nodes residual energy. The protocol holds energy-aware heuristics for forwarding data from one location to another in a network. The

energy heuristics that are based on the geographic location are used to select route for forwarding packets across the network^{1,2}.

3.1.3 Coordination of Power Saving with Routing (SPAN) Protocol

SPAN³ in Wireless Sensor Network is also used to decrease the consumption of energy. It was also previously used in MANET. SPAN uses distributed and randomized algorithms in which node can make local decisions on whether to go in sleep state or not. Each node calculate the estimate of how many node in its neighbours will get benefit from it being awake and also discover the amount of energy obtainable to it. SPAN does not require sensors to know their location information, it uses geographic routing protocols. In SPAN, coordinator or forwarding backbone is joined to sensor nodes that will forward data packets on the behalf of other nodes between source and destination.

Figure 3 shows a connected topology, nodes are connected with solid and dotted lines. Black nodes are coordinator nodes. The solid lines are representing the connections to the coordinators. Data packets between nodes 1 and 5 may struggle for bandwidth between nodes 3 and 4. If 2 act as coordinator then no struggle for bandwidth will occur.

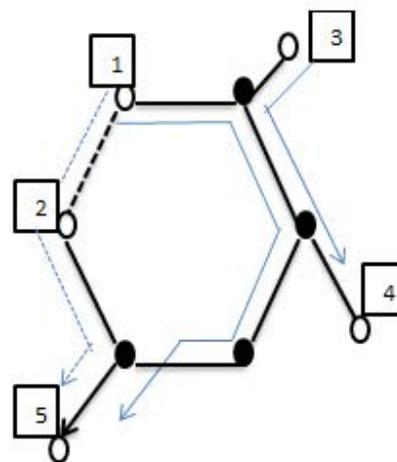


Figure 3. Working of SPAN protocol.

3.2 Flat Routing Protocols

In the event of flat routing, every nodes holds same assignment and mutually with each other (due to a large

number of such nodes, it is not feasible to assign a global identification to each node in a network) which give rises to the data centric approach. In this approach, base station send queries to sensor node deployed in certain area and waits for data from the sensors nodes deployed in that area.

3.2.1 SPIN (Sensor Protocols for Information via Negotiation) Protocol

It is an energy-efficient protocol and is an adaptive routing protocol^{2,4}, spin is modification of flooding. In flooding the information is forwarded over the network due to which the batteries of sensor nodes reduce quickly due to continuous messaging. To overcome this problem SPIN uses metadata of actual data to be transmitted with the help of negotiation. First the node will send metadata of any file and then this data contain the description of message that node wants to send. The transmission of actual data will held only if the nodes want to have the data. SPIN protocol consists of three stages which are ADV, REQUEST and DATA.

ADV: ADV packet is generated by nodes before sending a message, which consist of size, contents and requirement of message.

Request: Once ADV message is received by receiving nodes. Then the nodes check the description of message in order to check whether the message is a duplicate or not. The nodes also check whether the receiver node has enough batteries capacity to transmit data or not. If the node wants to get the data then REQUEST message is send to the sender node.

Data: When sender node receive REQUEST message from receiving nodes then it start sending actual data to receiver nodes. Figures 4, 5 and 6 show the communication process of SPIN protocol.

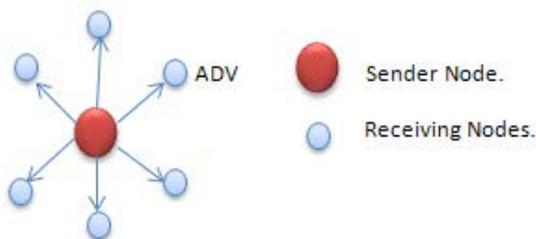


Figure 4. ADV message sending.

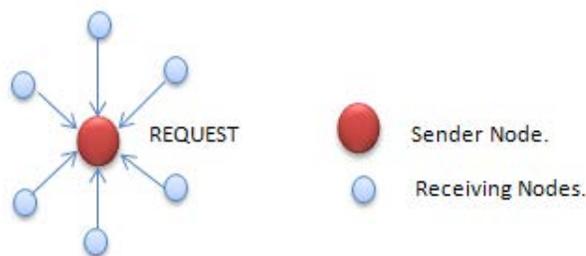


Figure 5. REQUEST message sending.



Figure 6. DATA message sending.

3.2.2 Directed Diffusion

Direct diffusion^{1,5} is very popular data aggregation routing used for Wireless Sensor Network. Direct diffusion combines the data coming from different sources by reducing redundancy and number of transmission which helps to maximize energy of network. The sensors inspect the occasions and deliver gradient of data. The sink request data by broadcasting message (interests). An interest goes hop-by-hop in a network. At the time of interest propagation over the network, the gradient is setup. The gradient is used to match the query of data for the base station. This gradient is set up by every sensor node that gets enthusiasm toward sensor node from which it gets interest. This procedure continuous until the gradient is setup from source to base station. Gradient specifies an attribute value and direction. The gradient strength may be different toward different neighbours, which gives different amount of information flow. Loops are not checked at last stage and are removed. Directed diffusion consists of three steps that are sending request, building gradients, data dissemination. When interest matches with gradient, the path for the information flow from multiple path is formed (best possible path is chosen to prevent flooding). To reduce the communication cost data is assembled on the way. The primary concentration of this protocol is to locate the best accumulation way for

tree that gets the information from the source to sink. Figures 7, 8 and 9 show the working of directed diffusion routing.

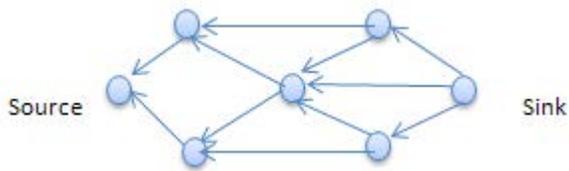


Figure 7. Interest is propagated.

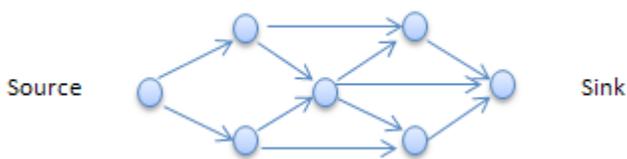


Figure 8. Gradients are set up.

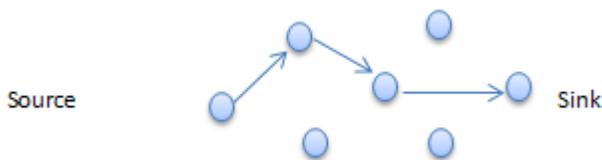


Figure 9. Sends data for path establishment.

3.2.3 Rumor Routing

Rumor routing is used to lower energy consumption. The main motive of rumor routing is to establish paths leading to each event when the event happens. From this path the queries will be routed. The queries are first send on a random wall in order to join the path. Rumor routing varies from directed diffusion because rumor routing is applied on those applications where geographic routing is not considered. In directed diffusion, queries are transmitted with the help of flooding in a network^{2,6}. Be that as it may, under a few conditions there is just slight volume of information is asked for by the nodes, so under these sorts of conditions flooding is not necessary. Therefore, other possible approach in that case is to flood the events if the numbers of events are small and numbers of queries are large. The main idea behind that is to route the queries to the nodes that have encountered the events instead of flooding the whole network. Rumor routing is based on agents. Agents travel through the network

in order to establish shortest path. Whenever event is detected that event is added to the local table of nodes called as event table, and generates agent. Agents go from the system and sends data comparing to the occasions to far off nodes. The node ask query for event, nodes that know the route may respond to the query by inspecting its event table. Hence, there is no need to flood the whole network, which reduces the communication cost. Unlike, directed diffusion in which multiple path are constructed at low rates, rumor routing uses only single path for data transmission between source and destination.

3.3 Hierarchical-based Routing

This type of routing is mainly used to provide scalability and efficient communication. The hubs are parceled into low vitality hub and higher vitality hubs. In this the higher energy nodes are used for processing and sending of the data whereas the low energy nodes are used for sensing.

3.3.1 Low Energy Adaptive Clustering Hierarchy (LEACH) Protocol

The first energy-efficient protocol is leach protocol in Wireless Sensor Network. Leach protocol is hierarchical protocol in which cluster heads are used for the assembling of data from nodes and forward that data to the sink. Cluster head is responsible for the creation of TDMA (Time Division Multiple Access) schedule all the other nodes of a cluster are member nodes of that cluster^{1,2}. TDMA slots are assigned to member nodes which can be used to exchange data between the cluster head and the member nodes. The information is transmitted to base station by cluster head through direct correspondence. The sink used to be far away from the cluster head due to which cluster head require great energy for transmission. To transmit data to the cluster head is much cheaper than to transmit it directly to the sink by the member nodes Cluster head needs large amount of energy because it is always switched on and is responsible for long range of transmission. So cluster head is utilized to amplify the lifetime of the system. In leach convention the network is separated into number of groups not to reduce the amount of data to be transmitted but also to make the data dissemination and routing more adaptable and vigorous. The node that is not a group head from long time is chosen as a cluster head and other member nodes communicate with cluster according to TDMA. The nodes which are

not cluster head pick their cluster head according to the coming signal strength. The protocol is organised in round. These round are further divided into two phase that is setup phase and steady phase. The setup is used to organize the network, to transmit advertisement of cluster head and also used to create network schedule. The setup phase starts with the self election of nodes to cluster head. By generating advertisement, the cluster head advise with advertisement packet to their neighbourhood. The nodes which are non-bunch get the advertisement packet and send CSMA protocol to inform the cluster head. Due to which the cluster head come to know about their member nodes. On the other hand, steady phase is responsible for the aggregation, transmission and compression of data to the sink. Due to collisions of large number of advertisement packets, the protocol does not assure that each non-cluster head node belongs to cluster. But it can only guarantee that nodes belong to atleast one cluster. The cluster head remains switched on during the whole process and member nodes remain switched off during setup phase and sometimes in case of steady phase. Figure 10 shows the working of leach protocol.

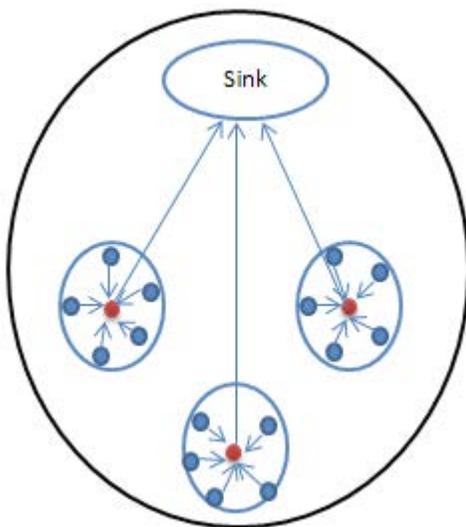


Figure 10. LEACH protocol.

3.3.2 Power-efficient Gathering in Sensor Information Systems (PEGASIS) Protocol

PEGASIS is chain based convention and is improvement of LEACH protocol. PEGASIS overcome the shortcomings of LEACH protocol. In this protocol chain is formed so that each node can communicate with its neighbours.

From that chain one node is selected to transmit data to the sink. The data is collected and flow from node-to-node and send to sink. The PEGASIS does not form clusters like LEACH protocol. Instead of it uses chain and chooses one node from that chain for the transmission of data to the sink. PEGASIS mainly aims to increase the lifetime of network by communicating to nodes which are in neighbourhood. Due to which the bandwidth used for the communication will be reduced. The neighbour nodes are selected according to the signal strength and then signal strength is adjusted so that only one node that is used for communication to the sink can get it. The chain consists of only those nodes which are close to each other and to the sink. The chain formation is based on greedy approach. In case of node failure, the new nodes are also selected according to greedy approach. The node is randomly chosen from chain for sending data to the sink which reduces the energy consumption per round. The overheads in case of LEACH are high due to cluster formation and on the other hand PEGASIS consist of small amount of energy consumption than the LEACH protocol because PEGASIS does not support cluster formation^{1,2}. Figure 11 shows the formation of chain in PEGASIS.

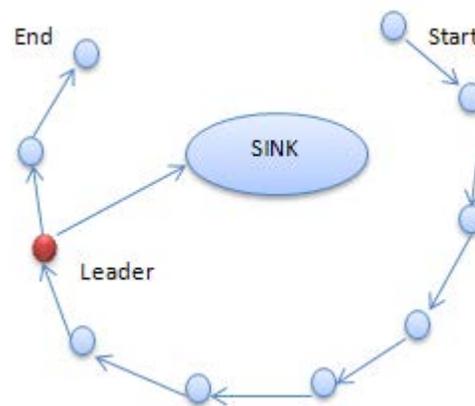


Figure 11. Chain formation in greedy fashion.

3.3.3 Threshold-sensitive Energy Efficient (TEEN) Protocol

TEEN protocol is used for time sensitive applications. Transmission of data is not frequent but data is sensed continuously from the medium. Cluster head nodes send two different types threshold (edges) to its members

that are hard edge and soft edge. Hard edge stores the information about value of attribute that is detected by nodes. On the other hand, soft edge conveys the moment change in the estimation of value of attribute that is detected. By which node is pushed to the level where it starts transmitting. If the sensed attribute is within the range of interest only then the nodes are allowed to transmit and therefore in this way hard threshold helps in reducing the number of transmissions. Apart from this, small changes may also occur in the attribute being sensed which generated number of transmissions and these transmissions are further reduced by the soft threshold. The small value in case of soft threshold may also help to generate more accurate overview of network. Therefore, this helps in controlling the problem of accuracy of data and energy-efficiency. Thresholds are the essential part of this protocol because if nodes do not get threshold value then they will not be able to communicate with other nodes in a system and subsequently there will be no information broadcasting in a system.

3.3.4 Adaptive Period Threshold-sensitive Energy Efficient Protocol (APTEEN)

In case of APTEEN, threshold value and periodicity used by TEEN are changed as per the needs of user and type of application used^{1,2}. The APTEEN protocol not only supports the time-critical applications like TEEN. But also, in addition to that it gives an overview of network at certain intervals of time. User can query about past, present and future through this type of network protocol. APTEEN contains three types of queries that are historical queries, one-time queries and persistent queries. Historical queries are those which are used for identification of historical data placed in base station. One-time queries are used to get present information and picture of network. Persistent queries are used to get the network information according to some defined parameters for certain period of time.

3.4 Routing Protocols that are based on Operation

3.4.1 Multipath Routing Protocol

The routing protocol uses multiple paths for routing in place of single path to increase the network lifetime. In

multipath routing protocols, if one path fails then in place of that other path can also be used for sending data between source and destination. With the help of periodic messaging these alternate nodes are kept alive. Directed diffusion is an example of multipath routing protocol in which multipath path are used due to which energy failure can be recovered^{1,2}.

3.4.2 Query-based Routing Protocol

This type of routing is completely based on queries. These queries can be in any language. The queries can be in high level language or natural language. Directed diffusion routing is based on query in which base node sends the query for interest. The interest is then propagated through network and the gradient is setup from source back to base station. When source has data that matches the interest, the source node send that data through the gradient path.

3.4.3 Negotiation-based Routing Protocol

The fundamental concentration of this convention is to dispose of the copy content by arrangement and furthermore to keep this information being transmit to principle station before the transmission of genuine information begins. To assemble the data from energy-constraint network via negotiation, SPIN protocol of this category is also introduced. To reduce the duplicate data high level descriptors for data are used.

3.4.4 QoS-based Routing Protocol

This class of routing is utilized for the guaranteeing of QoS parameters while conveying information to the base station. Delay, energy and bandwidth are the three parameters of QoS. Sequential Assignment Routing (SAR) is example of QoS-based routing. Decisions of routing in SAR mainly focus on level of priority of each packet, resources of energy and each path QoS. Multipath routing is used in order to reduce single connection disappointment amongst source and goal. With the making of tree various courses are created amongst source and goal. By avoiding the nodes with low energy and QoS guarantees, routes of tree are constructed. To minimize the average weighted QoS metric throughout the network is the main aim of SAR protocol.

4. Conclusion

The essential objective of the routing protocols is to keep the sensor functioning as far as might be feasible. This paper is introducing a writing review on routing protocols of various classes. The fundamental classes in which protocols are divided are area-based; flat routing protocols and hierarchical routing protocols.

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6. References

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