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Energy Efficient Routing Protocols in Wireless Sensor Network

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Abstract

In last few years there has been significant growth in the area of wireless communication. Quality of Service (QoS) has become an important consideration for supporting variety of applications that utilize the network resources. These applications include voice over IP, multimedia services like video streaming, video conferencing etc.. This paper aims on energy efficient routing protocols as implemented by Ad-hoc networks. In real life we use voice call, video streaming which are set up through Wireless Sensor Network. We use many parameters for quality of service and these are: throughput, packet loss, average jitter and average delay. WSN is the part of Adhoc Network in which we don't have intelligent nodes. Wireless Sensor Networks (WSNs) are self-organizing, infrastructure less and multi-hop packet forwarding networks. Energy efficient routing protocols take less energy than other protocols.

Keywords: *Improvement over WSN, Protocols in Ad-hoc Network, Characteristics of WSN, LEACH, GAF, DEED*

1. Introduction

Wireless Sensor Networks (WSNs) are self-organizing, infrastructure less and multi-hop packet forwarding networks. There is no concept of fixed base station. So, each node in the network acts as a router to forward the packets to the next node. Wireless networks are capable of handling of topology changes and malfunctions in nodes. It is fixed through network reconfiguration. For instance, if the node leaves the network and causes link breakages, affected nodes can request new routes and problem will be solved. This will slightly increase the delay, but the network will still be operational. It is the technology aimed to provide broadband wireless data access over long distances. This technology provides basic Internet Protocol (IP) connectivity to the user. The variety of applications used in IP networks has increased tremendously in the recent years. Various multimedia applications along with the common email, file transfer and web browsing applications are becoming increasingly popular. These applications send large audio and video streams with variable bandwidth and delay requirements. On the other hand, remote monitoring of critical services such as E-commerce and banking applications which do not need strict bandwidth guarantees due to the good nature of the data transfer. Instead, these applications require reliable and prompt packet routing. The presence of different kinds of applications in a network, results in heterogeneous traffic load. The traffic from different applications may require certain type of quality of service. In this paper, the energy efficient routing protocols in the Wireless Sensor networks are studied.

In data networks, the main function of network layer is routing. Routing is the process used to determine route for packet traveling from source to destination. Routing is performed by the routers, which updates the routing tables with minimizing cost functions like physical distance, link delay, etc. The metric for optimization can be distance, number of hops or estimated transit time. Protocols are used to implement handshaking activities such as error checking and receiver acknowledgements.

Some of the algorithms used for routing in ad hoc networks are destination-sequenced distance vector routing, wireless routing protocol, ad hoc on-demand distance vector routing and dynamic source routing protocol.

The Energy efficient routing algorithm has the following difference compared to other algorithms:

- All the above algorithms have overhead involved as they have to transfer their routing tables to other nodes over the network. They either transfer them on time-based approach or event based approach. This problem does not exist with an algorithm as there is no need for the transfer of the routing tables.
- Some of the algorithms do not support multiple paths and hence there is no possibility of load balancing, in

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case the optimal path is heavily congested. An algorithm supports generation of multiple paths and hence favors load balancing.

- Above algorithms require special packets for the purpose of route maintenance. Energy efficient based routing algorithm uses data packets for route maintenance.

This paper focuses on the Energy Efficient Routing Protocols in Wireless sensor networks. We have many energy efficient routing protocols like LEACH, DEED, GAF etc.

2. Characteristics of WSN

The following are the characteristics of wireless sensor networks.

- **Dynamic topology**: Due to the node mobility, the topology of wireless sensor networks changes continuously and unpredictably. The link connectivity among the terminals of the network dynamically varies in an arbitrary manner and is based on the proximity of one node to another node. It is also subjected to frequent disconnection during node's mobility. WSNs should adapt to the traffic and propagation conditions as well as to the mobility patterns of the mobile network nodes. The mobile nodes in the network dynamically establish routing among themselves as they move about, forming their own network on the fly. Moreover, a user in the WSNs may not only operate within the network, but may require access to a public fixed network.
- **Bandwidth:** WSNs have significantly lower bandwidth capacity in comparison with fixed networks. The used air interface has higher bit error rates, which aggravates the expected link quality. Current technologies suitable for the realization of WSNs are IEEE 802.11(b,a) with bandwidth up to 54Mbps and Bluetooth providing bandwidth of 1Mbps. The nature of high bit-error rates of wireless connection might be more profound in WSNs. One end-to-end path can be shared by several sessions. The channel over which the terminals communicate is subjected to noise, fading and interference, and has less bandwidth than a wired network. In some scenarios, the path between any pair of users can traverse multiple wireless links and the links themselves can be heterogeneous.
- **Energy:** All mobile devices will get their energy from batteries, which is a scarce resource. Therefore the energy conservation plays an important role in WSNs. This important resource has to be used very efficiently. One of the most important system design criteria for optimization may be energy conservation.
- **Security:** The nodes and the information in WSNs are exposed to the same threats like in other networks. Additionally to these classical threats, in WSNs there are special threats, e.g. denial of service attacks. Also mobility implies higher security risks than static operations because portable devices may be stolen or their traffic may insecurely cross wireless links. Eavesdropping, spoofing and denial of service attacks should be considered.
- **Autonomous:** No centralized administration entity is required to manage the operation of the different mobile nodes. In WSNs, each mobile terminal is an autonomous node, which may function as both a host and a router. So usually endpoints and switches are indistinguishable in WSNs.
- **Distributed Operation**: Since there is no background network for the central control of the network operations, the control and management of the network is distributed among the terminals. The nodes involved in a WSNs should collaborate among themselves and each node acts as a relay as needed, to implement functions e.g. security and routing.
- **Multi-hop Routing:** Basic types of ad hoc routing algorithms can be single-hop and multi-hop, based on different link layer attributes and routing protocols. Single-hop WSNs is simple in comparison with multi-hop WSNs in terms of structures and implementation. When delivering data packets from a source to its destination out of the direct wireless transmission range, the packets should be forwarded via one or more intermediate nodes.
- **Light-Weight Terminals:** In most cases, the WSNs nodes are mobile devices with less CPU processing capability, small memory size and low power storage.
- **Infrastructure less and Self Operated:** A wireless sensor a network includes several advantages over traditional wireless networks, including: ease of deployment, speed of deployment and decreased dependence on a fixed infrastructure. WSN is attractive because it provides an instant network formation without the presence of fixed base stations and system administrators.

3. Energy Efficient Routing Protocols

In the network layer, the choosing of routing relates to the node energy consumption while transmitting data. There are a few paths between two nodes, and of course different routing consumes different energy. We can choose the route which consumes the last energy or the route on which the nodes provides the most energy. And the better choose is to take the two aspects in account, because the rest energy of the nodes on a route which uses the least energy is not the largest and it may cease the transmitting. On the contrary, the one which holds the most energy is not always economical.

At the same time, the multi path routing is benefic which will avoid the premature death of the nodes on the route, and the rest energy of the nodes also should be considered, so it will balance the energy consumption of the nodes. Besides, if routing protocols is combined with the information redundancy, and so on, it will reduce the energy consumption and prolong the lifetime of wireless sensor networks (WSNs).

A LEACH (low-energy adaptive clustering hierarchy)

Routing protocol in uses the idea of dynamic clustering to balance the energy consumption of the whole network. It is to make the nodes which hold more energy to be the clusters header, then to divide the nodes into several clusters, and to transmit the clustering information from the head node to the sink node. The optimized LEACH routing protocol can let the head nodes account for 5 per of all the nodes in the networks.

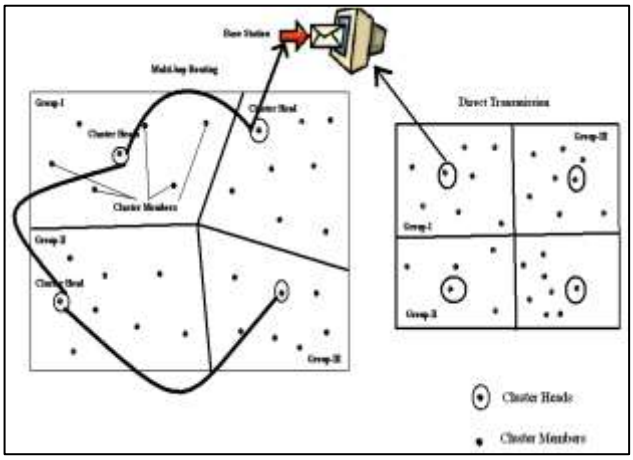
So multiplex routing is only among the head nodes and it saves the energy of the whole networks. LEACH routing protocol prescribes the dynamic some nodes for long time to be the cluster header exhausting the energy consumption of the whole networks is balanced.

The operations that are carried out in the LEACH protocol are divided into two stages, the setup phase and the steady-state phase.

Set-up Phase

In the set up phase, all the sensors within a network group themselves into some cluster regions by communicating with each other through short messages. At a point of time one sensor in the network acts as a cluster head and sends short messages within the network to all the other remaining sensors. The sensors choose to join those groups or regions that are formed by the cluster heads, depending upon the signal strength of the messages sent by the cluster heads. Sensors interested in joining a particular cluster head or region respond back to the cluster heads by sending a response signal indicating their acceptance to join. Thus the set-up phase completes.

The cluster head can decide the optimal number of cluster members it can handle or requires. Before it enters the steady-state phase, certain parameters are considered, such as the network topology and the relative costs of computation versus the communication. A TDMA Schedule is applied to all the members of the cluster group to send messages to the cluster head, and then to the cluster head towards the base station. Figure below shows two phases of a sensor in a LEACH protocol: all the sensors form as cluster members to the cluster heads and in the Real Time Support and Energy Efficiency in WSN. Second phase cluster heads perform the transmission of data to the sink in a multi-hop structure. A direct transmission scheme is also shown below



Steady State Phase

As soon as a cluster head is selected for a region, all the cluster members of that region send the collected or sensed data in their allotted TDMA slots to the cluster head. The cluster head transmits this collected data in a compressed format to the base station which completes the second phase, called the Steady State Phase. Once the steady-state finishes the data transmission to the sink, the whole process comes to an end and a new search for the forming of cluster heads for a region and new cluster-member formation begins. In short, it can be said that a new set/up phase and steady state starts with the end of data transmission done to the sink. This alternative selection of cluster heads within the region, which is carried among the sensors in a self-organized way helps in reducing or lowering the energy that is utilized. There is a possibility that all the sensors might not be too close to the cluster head so the amount of energy that is utilized by the farther sensor is not equal to the amount of energy utilized by the nearest node. In order to minimize this, cluster heads formation or the role of Real Time Support and Energy Efficiency in WSN cluster head is performed by a rotation among all the nodes in the group. LEACH minimizes global energy usage by distributing the load of the network to all the nodes or cluster members at different intervals.

DEED (Distributed Energy Efficient Data Communication Protocol)

It is a completely distributed, high energy-efficient data communication protocol (DEED), and its feature is that the nodes are organized by clustering. The area covered by clustering is limited in a range, and the nodes make the decision independently to be the head or to be a member in a cluster. The cluster headers organized a routing tree according to the weight. In the tree, the root node collects other cluster headers' data and transmits to the sink node.

In DEED protocol, the area covered by the cluster is limited with the radius r, that is to say the nodes can be member of one cluster only when they can be communicated with the cluster header in the distance less than r. r is called the radius of the cluster. In DEED protocol, the communication between member and header or between header and header is free-space based low-power attenuation.

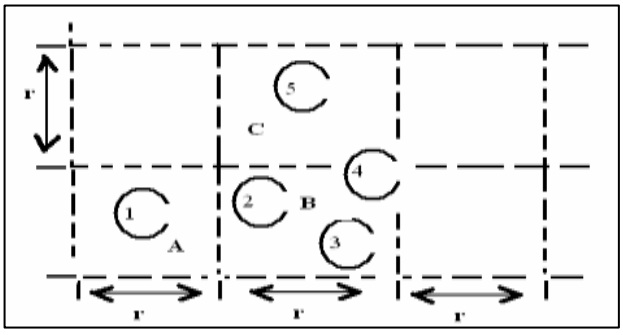
Compared with LEACH, DEED protocol consumes less energy, since the cluster is limited in the area whose radius is r, and the nodes in the cluster work on free-space transmission mode.

GAF (Geographic Adaptive Fidelity Protocol)

Routing protocols is a kind of energy sensing routing protocol based on the position information. And its basic idea is that to reduce the energy consumption and prolong the lifetime of the networks by closing the unnecessary nodes . GAF routing protocol assumes that every node can get the self-location by GPS, and the covered area is divided into virtual grids. It's considered equation to transmit data if the nodes are in the same grid. Consequently, it's unnecessary to let all the nodes in the same grid work at the same time, and it can save energy.
In GAF protocol divided the grid is to find the redundant nodes and adjust the nodes' work time. Also the alternate usage of the nodes in a grid will balance the energy consumption in wireless sensor networks (WSNs). The simulation experiment show that GAF protocol leads low delay and prolongs the life time of wireless sensor networks. Almost all protocols are efficient in routing packets and in saving a lot of energy by forming clusters or organizing a random coordinator to do the functional job, but they all lack in few things which are almost unavoidable, such as overhearing on the medium or network, protocol like PAMAS. Every time a packet is forwarded, all the nodes have to check whether the packet is destined for them or if they have to forward it to some other neighboring node so that it reaches the correct destination.

We have seen that nodes consume a vast amount of energy while sending or receiving data, it is stated that nodes uses some physical amount of energy when they are in the idle or listening state. Energy dissipation during the idle state cannot be ignored, as it is statistically proven that the energy consumed by a node in idle-receive-transmit is in the ratio of 1:1.2:1.7.The ratio shows that the amount of energy that is wasted when the node is in idle state is less that that compared to receiving data from other nodes and transmitting data to the neighbor nodes or to the sink.

The energy that is wasted when the nodes are in the idle state can be saved by turning off the radios when they are not in use, because energy cannot be saved only by reducing the number of transmissions or receptions of data packets or even by reducing the functions at the sensing nodes. One advantage of turning off the radios is that we can save not only the energy that is wasted during the idle state, but also conserve energy that is wasted by all the nodes in the region by overhearing the same data packet. Switching off the intermediate nodes in an order can make us achieve connectivity within the network while there are multiple paths existing between nodes. This can be illustrated using an example which implements this theory. Figure below redrawn from shows the virtual grid formation using the nodes in the network for GAF. There are 5 nodes in the network and node 1 can communicate with nodes2, 3, and 4 and these three nodes in turn communicate with node 5. If node 1 wants to communicate with node 5, it has to pass through any of the 2, 3 and 4 nodes. If we assume that all these nodes 2, 3 and 4 are equal in all functionalities, we can make one node active and let the other two nodes 2 and 3 go to sleep so that we can conserve the energy that is wasted by only making them active for overhearing the traffic that is passing through one of these nodes to reach node 5. This is known as routing fidelity where both nodes 1 and 5 are communicating by making intermediate nodes go into sleep mode and using only one efficient node as their routing partner.



GAF Algorithm

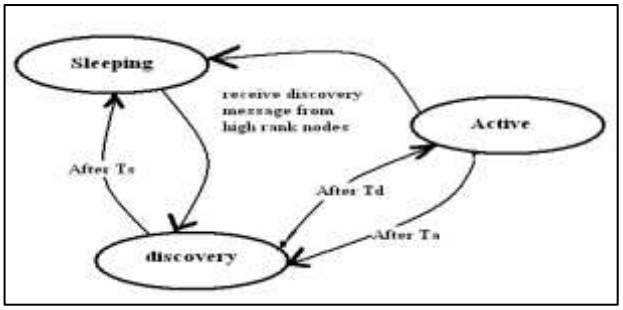
The name Geographic Adaptive Fidelity states that it locates nodes in the network and makes the best use of them to have a better fidelity. All the nodes use a location-identification technique to locate itself within the network along with its nearest neighbor by using location-information systems like GPS. In GAF, all the nodes arrange themselves according to grids also called virtual grids. All the nodes in the network divide themselves in virtual grids and all those nodes which are under a same grid coordinate among themselves to see who will go into sleep state and for how long. Load balancing is performed and a single node will not get drained with extraneous work. It can also be very simple to define virtual grids as all the nodes which are in grid A can communicate with all the nodes in grid B that are

adjacent. The time for sleeping is decided or depends on the application and system information.

GAF has three state transitions, namely discovery, active and sleeping. Initially Every node starts with the discovery state. In this state the node turns on its radio and starts sending discovery messages to find the adjacent nodes in the same grid. Every discovery message is a combination of certain parameters, such as:

Node State: - Discovery, Active or Sleeping
Node ID: - The node itself or its current location
Grid ID: - Every node in the network uses its location information from GPS and its grid size in order to determine its grid id***(enat):-*** Estimated node active time, this value can be set equal to node lifetime, which means that the nodes keeps on using the energy until it dies or drains out of energy.

Using these parameters as a node enters a discovery state, it sets its time Td (Discovery time) and sends discovery messages to all the nearest neighbors in its own grid. After broadcasting this discovery message it enters the active state. A node can fall into sleep state if there are other nodes in the grid which are equivalent in handling the fidelity before falling into the active state. In the active state the node sets a timeout value Ta which shows the remaining amount of time for which a node is intended to stay in active state. During its active state anode re-broadcasts its discovery message for given time intervals Td and goes into the sleep state if it finds another node which is equivalent or has an node with higher node rank that can handle communication or routing process. All these three types of state processing can be seen in the Figure given below, which shows node performance during the discovery, active and sleep state. A node enters into sleeping state either from the discovery state or the active state. Before it goes into the sleeping state it cancels all the timers like Ta and Td and power down the radio. In order to get back or wake up into the discovery state, the node has to complete the sleep time Ts, which is decided by the application or system. In order to maintain a constant communication medium or routing path between the nodes, GAF has to follow some load-balancing scheme so as to make all the nodes work efficiently and see that the nodes lifetime increases. This can be achieved by assuming that all the nodes in the region are equal, and no node is used fully or depleted till it dies. If the nodes that are inactive state for the time interval Ta are brought back to the discovery state, a chance is give into all those nodes which are in the discovery state to handle the further process, among those which strive to become active node members, there might be some nodes with more energy resources, or higher-rank nodes. These nodes set the timer Ta equal to enat and start advertising their discovery messages. The nodes which are in sleeping state set their timers equal to enat, i.e. the sleeping time.



From the analytical analysis shown it is clear that the overhead issue in GAF is very low, while there are certain drawbacks like packet loss and route latency. The network lifetime depends upon the density of nodes if there are many nodes in the virtual grid there is maximum scope of high network lifetime because at least one node will stay awake in the grid while all the other are in sleep state handling the route fidelity. If the node density is low there are a lot of chances that the nodes keep on moving so at times if there are no active nodes in the grid the communication path is lost.

Conclusion

In this paper, the characteristics of wireless sensor networks were studied. We have concentrated here on different energy efficient routing protocols like LEACH (low-energy adaptive clustering hierarchy), *DEED* (Distributed Energy Efficient Data Communication Protocol) and GAF (Geographic Adaptive fidelity protocols).

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