A REVIEW ON ENERGY EFFICIENT PROTOCOLS IN WIRELESS SENSOR NETWORKS

Kishan Verma[1], Rajendra Kumar Dwivedi[2]

Abstract

Wireless Sensor networks are a collection of the sensor nodes with inbuilt processor and memory unit. The data collected by each sensor node is communicated through the network to a single processing center that uses all reported data to detect the event. Reliable routing of the packets is the crucial task in the wireless sensor networks. The message passing must be designed to save the energy of the sensor nodes. The routing protocols used in other networks cannot be used in WSN due to its battery powered nodes. This paper give an overview of the different routing approaches used in wireless sensor networks and a brief model of energy efficient protocols in WSN. This paper includes future work in direction to provide better energy efficiency in wireless sensor networks.

Index Terms: Wireless sensor networks, Energy efficiency, Clustering, Security.

I. INTRODUCTION

A wireless sensor networks is consisting of the large number of small sensors with low power transceivers can be the useful tool for gathering data in a variety of environments. The entire nodes are battery powered devices, energy consumption of nodes during transmission or reception of packets affects the whole network. Sensor networks are needed in applications like forest fire detection, medical sectors, military application, industrial control units. To make routing an efficient one number of protocols were developed such as LEACH and PEGASIS etc. This paper describes the existing routing approach in WSN and gives an overview about energy efficient routing protocols like LEACH, GAF, GPSR and PEGASIS etc. This paper brief describes the routing protocols and comparison among them.

II. ROUTING APPROACHES IN WSN

A number of routing approaches have been developed for the WSN till today. Due to its limitation in processing power and limited battery power, the routing protocols for the wired networks cannot be used in WSN. Different routing approaches can be adopted for the different domains based on their requirements. Domains can be time critical or requiring periodic updates, they may require accurate data or long lasting, less precise network, they may continuous flow of data. Routing methods can even be enhanced and adapted for specific application.

Basically, the routing protocol in WSNs can be classified into data-centric, hierarchical, location based routing depending on the network structure as shown in figure 1. In data-centric, the sensor network take the decision based on the data hold by the nodes in the network rather than its destination address or geographical location. In hierarchical approach, some nodes in the network have added a load to reduce the load on the other nodes. In location based, the routing of the data is done by the geographical locations of the nodes it means that nodes are identified by its location only.

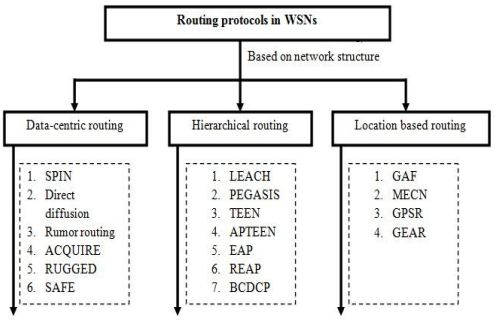

Figure 1. Classification of routing protocols in WSNs

III. DATA-CENTRIC ROUTING TECHNIQUES

A large number of the sensors nodes are deployed over a region making it in comprehensible to assign a global identifier for each node. The sensors nodes in the region aggregate their sensed data and route back to the base station along the reverse path discovered in the previous step. Some of the protocols which follow the data-centric routing are,

- Directed diffusion
- SPIN
- Rumor routing

Directed diffusion: The data generated in the nodes is identified by its attribute-value pair. Here the base station passes its interest all through the network. The issued user interest would be traveling all through the sensor networks and compared with the event record in the concerned node. If the event record matches with the interest the event record is sent to the base station otherwise the interest is passed to the neighboring nodes. Here the use of gradients is an important factor in the direct diffusion technique. When the source node is responding to the base station, it will be receiving the data from multiple routes and again the base station has to select the gradient which is having minimum delay time than others [1].

All sensor nodes in a directed-diffusion based network are application-aware, which enables diffusion to achieve energy savings by selecting better paths and by caching and processing data in the network. Caching can increase the efficiency, robustness, and scalability of coordination between sensor nodes, which is the essence of the data diffusion network.

SPIN: Sensor Protocols for Information Negotiation [2] is the family of protocols based on data centric approach. It is also called as the 3-stage protocol since 3 subsequent steps are involved in data transformation between the nodes. When the node generates information, it is intimated to its 1-hop neighbors using ADV (advertisement) packet and if the neighbor node is in need of the information it will request the data through REQ (request) packet. Finally the original DATA packet will be sent to the neighbor node. Using this protocol redundancy in information is avoided in the sensor networks. The SPIN node will only take the data from its 1-hop neighbor nodes and only forward the best available data to the base station. The main drawback in this method is if a node which is in need of the data can't receive the data when it is not the 1-hop neighbor node to the source node which generates the required data.

In SPIN, nodes poll their resources before data transmission. Each sensor node has own resource manager that keep track of resource consumption. This allows sensor to cut back energy consumption and bandwidth usage, by being more sagacious in forwarding third party data. SPIN provide high performance at low cost in terms of complexity, energy, computation and communication.

Rumor Routing: In this routing protocol the data collected by the sensor nodes will be sent to its neighboring nodes and it goes on till reaches the interested region or the end node of the network. At the same time the user interest is also sent through the network. When the two regions meet, each other required data are gathered and given to the base station.

Rumor routing [3] routes the queries to the events in the network and it offers tradeoff between setup overhead and delivery reliability. An event is an abstraction obtained from a set of sensor readings that is assumed to be a localized phenomenon occurring in a fixed region in the network. A query is a request for information, sent by the base station to collect data, and once the query arrives at its destination the data can begin to flow back to the queries originator. If there is significant amount of data to be sent, it is advisable to invest in discovering the shortest path from source to sink. There are various methods such as directed diffusion, which are

energy inefficient as they rely only on query flooding until they reach the event location. But method such as rumor routing uses enhanced flooding approach which makes then more energy efficient. Rumor routing is a logical compromise between flooding queries and flooding event notifications. The goal is to create paths leading to each event; while event flooding creates a network wide gradient field [4].

IV. HIERARCHICAL ROUTING TECHNIQUES

Hierarchical routing is the procedure of arranging routers in a hierarchical manner. A hierarchical protocol allows an administrator to make best use of his fast-powerful routers as backbone routers, and the slower, lower powered routers may be used for access purposes. In this way, the access routers form the first tier of the hierarchy, and the backbone routers form the second tier. Hierarchical protocols make an effort to keep local traffic local, that is, they will not forward traffic to the backbone if it is not necessary to reach a destination. The cluster head (CH) aggregates the sensed data from all transmits it to the BS as shown in figure 2. Some of the protocols which follow the hierarchical routing are,

- LEACH
- PEGASIS
- TEEN & APTEEN

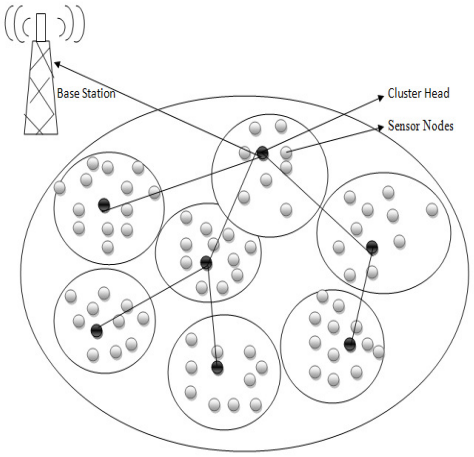

Figure 2. Clusters in WSN

LEACH: Low energy adaptive clustering hierarchy [5] uses the clustering principle to distribute the energy consumption all along its Network. Here, based on data collection, network is divided into Clusters and Cluster heads are elected randomly. The cluster head collects the information from the nodes which are coming under its cluster. Let us see the steps involved in each round in the LEACH protocol.

Advertisement phase: This is the first step in LEACH protocol. The eligible cluster head nodes will be issuing a notification to the nodes coming under its range to become a cluster member in its cluster. The nodes will be accepting the offer based upon the Received Signal Strength (RSS).

Cluster set-up phase: In this step the nodes will be responding to their selected cluster heads.
Schedule creation: After receiving response from the nodes the cluster head have to make a TDMA scheme and send back to its cluster members to intimate them when they have to pass their information to it.

Data transmission: The data collected by the individual sensors will be given to the cluster head during its time interval and on all other time the cluster members radio will be off to reduce it energy consumption.
Here in the LEACH protocol multi cluster interference problem was solved by using unique CDMA codes for each cluster. It helps to prevent energy drain for the same sensor nodes which has been elected as the cluster leader, using randomization for each time cluster head would be changed.
The cluster head is responsible for collecting data from its cluster members and fuse it. Finally, each cluster head will be forwarding the fused data to the base station. When compared with its previous protocols LEACH have shown a considerable Improvement.
LEACH enhances the network lifetime by utilizing the resources efficiently, distributing the load uniformly, aggregating data at the CH to contain only the meaningful information, rotating the CH randomly to achieve balanced energy consumption. Also, the sensors do not need to know the location or distance information. Depending on the applications, the different variations of LEACH such as

LEACH-C (centralized) [6], E-LEACH (enhanced) and MLEACH (multi-hop) can be used.

***PEGASIS*:** PEGASIS [7] is a near optimal chain based protocol. The basic idea is for the nodes to communicate their sensed data to their neighbors and the randomly chosen nodes will take turns in communicating to the BS. It assumes that the BS is fixed at a far distance from the sensor nodes. The sensor nodes are homogeneous and energy constraint with uniform energy. The energy cost for transmitting a packet depends on the distance of transmission. All the nodes maintain a complete database about the location of all other nodes.

This method had been named as Power Efficient Gathering in Sensor Information System [8]. Instead of forwarding the packets from many cluster heads as like in LEACH protocol here in PEGASIS each node will form a chain structure to the base station through which the data would be forwarded to the BS node.

Here in PEGASIS energy efficient is achieved by transmitting the data to only one of its neighbor node. There the collected data is fused and the fused data will be forwarded to its immediate one hop neighbor. Since all the nodes are doing the data fusion at its place there is no rapid depletion of power for the nodes present near the Base station. Also in this method, each node will be getting the chance to forward the gathered data to the base station.

The improvement of PEGASIS, Hierarchical PEGASIS [9], was introduced with the objective of decreasing the delay incurred for packets during transmission to the BS. Energy balancing PEGASIS is the energy efficient chaining algorithm in which a node will consider average distance of formed chain. PEDAP, Power Efficient Data Aggregating Protocol uses spanning tree approach instead of Greedy approach to form the chain resulting in considerable savings energy.

TEEN: Threshold sensitive energy efficient protocol (TEEN) [10] and Adaptive threshold sensitive energy efficient protocol (APTEEN) [11] are the two-threshold sensitive hierarchical routing protocols based on the clustering approach used in LEACH. LEACH is targeted at proactive network applications where as TEEN and APTEEN are targeted at the reactive network applications. In proactive network, the sensed data is sent periodically to the sink which provides the snap shot of relevant parameters at regular intervals. In reactive networks the nodes react immediately to the sudden change in the sensed data and transmit it to the sink. Since they remain in the sleep mode most of the time, the number of transmissions is reduced, thus reducing the energy consumed.

TEEN mainly focuses on time critical sensing applications. The soft threshold can be varied depending on the criticality of the sensed attribute and the target application. The user can change the threshold values at every cluster change time by broadcasting the new attributes. The message transmission consumes more energy than data sensing. So, even though the node senses continuously, the energy consumption in this scheme can be potentially much less than in the proactive network, cause data transmission is done less frequently. A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption. One user can control the trade-off between energy efficiency and accuracy.

APTEEN: APTEEN is an improvement over TEEN which can transmit data based on the thresholds and also periodically. It is applicable in both proactive and reactive networks and it can adapt itself to the application requirements. Once the CH are decided in each cluster period, the CH first broadcasts a set of parameters, attributes (the set of physical parameters of the environment in which the user is interested), thresholds (this parameter consists of the hard and soft thresholds), schedule (this is a TDMA schedule for assigning a slot to each node), (Tc) Count Time (it is the maximum time period between two successive reports sent by a node. It can be a multiple of the TDMA schedule length and it accounts for the proactive component).

V. LOCATION BASED ROUTING TECHNIQUES

Routing algorithms which is using geographical location is an important research subject in wireless sensor network. The routing of data to the nodes are identified by its location of the nodes. They use location information to guide routing discovery and maintenance as well as

packet forwarding, thus enabling the best routing to be selected, reducing energy consumption and optimizing the whole network. The location information of the nodes is obtained by the low power GPS receivers embedded in the nodes. Some of the most important protocols coming under the Location Based Routing strategy are,

- GAF
- GPSR
- GEAR

GEOGRAPHIC ADAPTIVE FIDELITY: GAF [12] is a location based routing protocol for WSN. It is also an energy aware routing protocol. GAF works in such a way that, it turns off unnecessary nodes in the network without affecting the level of routing fidelity, this conserves energy. A virtual grid for the area that is to be covered is formed. The cost of packet routing is considered equivalent for nodes associated with the same point on the virtual grid. Such equivalence is exploited in keeping some nodes located in a particular grid area in sleeping state in order to save energy. By doing this the network lifetime is increased as the number of nodes increases. There are three states in this protocol and they are discovery, for determining the neighbors in the grid, active tells that the nodes are participating in routing and sleep when the radio is turned off. The load is balanced when nodes change states from sleeping to active in turns. GAF keeps the network connected, by keeping a representative node always in active node for each region on its virtual grid. Although GAF is a location based protocol, it can be considered as a hierarchical protocol, where the clusters are based on geographic location.

GREEDY PERIMETER STATELESS ROUTING: The modified version of greedy-face-greedy algorithm is the Greedy perimeter stateless routing [13]. Here the combination of greedy and perimeter approach is taken. Initially the data is forwarded by using greedy approach and if the packet gets stuck at any point, perimeter approach comes to rescue of the situation. But this perimeter approach is followed till a node closer to the destination was found than the node at which the packet got stuck. It ensures the guaranteed delivery of packets to the destination.

The Greedy Perimeter Stateless Routing (GPSR) [14,15], is a routing protocol based on the position of routers and packets destination to make a forwarding decision for WSN. GPSR makes the forwarding decision which is actually transferring the packet from one node to another destination node using the minimum shortest path possible. Hence the routing protocol is associated with the term “greedy”. The greedy forwarding decision for a packet is made using the information about a router’s immediate neighbors in the network topology. If a packet reaches a region where greedy forwarding is not possible, then an alternative step is taken by routing around the perimeter of the region. Even though there are frequent changes made to the topology due to mobility, the GPSR protocol uses the local topology information to find correct new routes quickly. The scalability of GPSR routing protocol depends on two major factors like the rate of change of topology and the number of routers existing in the routing domain. Scalability is aimed at increasing number of nodes in the network and increasing the mobility rate.

GEOGRAPHIC AND ENERGY AWARE ROUTING: Geographic and Energy Aware Routing algorithm or simply known as GEAR [16] is a location based routing protocol for WSN. GEAR is an energy efficient protocol which uses the energy aware neighbor selection to route a packet towards a particular geographical region and then use either the recursive geographic forwarding or restricted flooding algorithms to disseminate the packet inside the destination region. GEAR shows considerably longer network lifetime than most non-energy aware geographic routing algorithms especially for non-uniform traffic distribution when compared to uniform traffic distribution. This protocol is used by considering the least cost path to route the packets to the destination node which is identified by its location information.

GEAR protocol is very sensitive to location error which is caused due to imprecise measurement from the GPS system. GEAR achieves energy balancing by taking a different path or an alternative path, therefore the energy balancing strategy increases the path length by 25% to 45% overall packets delivered.

VI. COMPARISION OF ROUTING PROTOCOLS

In this paper, we compared the following routing protocols according to their design characteristics. Table 1 represents Classification and Comparison of routing protocols in WSNs.

Table1: Classification and Comparison of routing protocols in WSNs.

Routing Protocols	Classification	Power Usage	Data Aggregation	Scalability
Directed Diffusion	Flat/ Data-centric/ Dst-initiated	Limited	Yes	Limited
SPIN	Flat/ Src-initiated/ Data-centric	Limited	Yes	Limited
Rumor Routing	Flat	Low	Yes	Good
LEACH	Hierarchical/ Dst-initiated/ Node-centric	High	Yes	Good
PEGASIS	Hierarchical	Max	No	Good
TEEN & APTEEN	Hierarchical	High	Yes	Good
GAF	Hierarchical/ Location	Limited	No	Good
GPSR	Location	Limited	No	Good
GEAR	Location	Limited	No	Limited

The continuous growth in the wireless sensor network and increasing interest in advance electronics and wireless communication technologies have encourage some previous efforts for reviewing the characteristics, application and communication protocols in the technical area. In this paper, we highlight the features that differentiate our review and hint the difference in scope. The goal is to make a comprehensive survey of working of protocols proposed in the network layer and possible applications of sensor networks are also mentioned. This survey is a good introduction for readers interested in this widespread field. In this paper, we classify sensor networks based on network architecture and dynamics. Such classification is helpful for a designer to select the appropriate infrastructure for his/her application. We study the advantages and disadvantages that are existing in all the wireless sensor networks. Our work is a dedicated study of network layer, describing and categorizing the different approaches for data routing.

VII. CONCLUSION

In this paper a brief description about some of the secure data dissemination protocols used in wireless sensor networks was given and they were compared. The wireless sensor network is growing day by day and widely used in major-critical applications (i.e. military, fire detection, hospitality etc.). In this paper, we classify the routing protocols in WSNs into data-centric, hierarchical and location based depending on the network structure. Data-centric protocols use the metadata structure to transmit the sensed information to the BS. Naming the data helps to construct a query which requests for only certain attributes of the data, thus known as data-centric routing techniques. Regardless, the sensor nodes can also be grouped for efficient data dissemination to the sink. Hierarchical routing protocols adopt the clustering approach by grouping sensor nodes. This approach is highly scalable and thus used in a number of applications. Location based protocols use the information of position of sensor nodes intelligently to route data. Future work may concentrate on achieving better energy efficiency in wireless sensor networks.

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