

A Survey on Energy Efficient Routing Protocols in Wireless Sensor Network

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Abstract— In WSN, the sensor nodes have limited battery power, limited transmission range as well as their processing and storage capabilities are also limited. Routing protocols for wireless sensor networks are responsible for maintaining the routes in the network under above mentioned limitations. In this paper, I have given a survey of routing protocols for Wireless Sensor Network which works better in the limited resources of sensor nodes

Keywords- *Energy-aware routing; Energy efficient routing; sensor networks;*

I. INTRODUCTION

Recent advances in wireless sensor networks have led researchers to research many protocols which are specially designed for the sensor networks which work under the limited resources available for sensor nodes. Depending on the various approaches, the routing protocols work on the routing protocol can be broadly classified into three main categories, namely data-centric, hierarchical and location-based [1].

A. The data- centric routing protocols

Many sensor network applications use sheer number of sensor nodes, due to which it is difficult to assign global identifiers to each node. Absence of global identification number to each node makes it hard to select the set of sensor node for a particular query. In such condition data is transmitted from each and every sensor node redundancy at the cost of significant amount of energy consumption. To avoid the such unnecessary loss of energy data- centric routing protocol sink queries to certain region and waits for the reply from the sensor nodes in that region. Since data is being requested by sink node through queries, attribute-based naming is used to specify the properties of data. Examples of data-centric routing protocols are SPIN [2], Directed diffusion [3], Rumor routing [4], Shah and Rabaey [5], GBR [6], CADR [7], COUGAR [8] etc.

B. Hierarchical routing protocols

In hierarchical routing, energy consumption of the sensor node is maintained efficiently by using multi-hop communication of sensor nodes within a particular cluster. Data aggregation and fusion is performed in such routing protocols in order to decrease the number of transmitted

messages to the sink. Example of hierarchical routing protocols are LEACH [9], PEGASIS [10], Subramanian and Katz [12], GAF [13] etc.

C. Location- based routing protocols

In most of the routing protocols for sensor networks require node position to calculate the distance between two nodes, so that energy consumption can be estimated in advance. Example of Location- based routing protocols are SPEED [14], Kalpakis et al. [15], GAF [13], GEAR [16] etc.

Following Section lists some of the energy efficient routing protocols for WSN.

II. ENERGY EFFICIENT ROUTING PROTOCOLS

From the discussion in section I , we can say that, most of attention have been given on the energy factor of the sensor node as it is very crucial factor of the sensor node to be in working state. Various works has been done in order to minimize the energy consumption of the sensor node. Routing protocol is one of the factors which can influence the energy consumption rate of the node in various network topologies. Following subsection discusses the energy efficient routing protocols in WSN.

A. LEACH

Low-energy adaptive clustering hierarchy (LEACH) [9] is one of the most popular hierarchical routing protocol for wireless sensor networks. In LEACH , formation of clusters of the sensor nodes are done on the received signal strength. LEACH uses local cluster heads as routers to the sink. The transmission of data is done only through these cluster heads rather than all the sensor nodes in the network. This will save energy as only cluster heads are responsible for transmission of data towards sink. These cluster heads change randomly over time depending on energy dissipation of the sensor nodes. This decision is made by the node choosing a random number between 0 and 1. The node becomes a cluster head for the current round if the number is less than the threshold given below:

$$T(n) = \begin{cases} \frac{p}{1 - p^{*(r \bmod 1/p)}} & \text{if } n \in G, \\ 0 & \text{otherwise.} \end{cases}$$

Where p is the desired percentage of cluster heads (e.g. 0.05), r is the current round, and G is the set of nodes that have not been cluster heads in the last $1/p$ rounds.

LEACH is completely distributed and it does not require global knowledge of network. LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not applicable networks which are deployed in large regions. Furthermore, the idea of dynamic clustering brings extra overhead, e.g. cluster head changes, advertisements etc., which may cause the increase in energy consumption.

B. PEGASIS and Hierarchical-PEGASIS

An improvement over LEACH is proposed in Power-efficient Gathering in Sensor Information Systems (PEGASIS) [10]. PEGASIS forms chains from sensor nodes so that each node transmits and receives from a neighbor and only one node is selected from that chain to transmit to the base station (sink). It minimizes the overhead of forming the multiple cluster heads. Gathered data moves from node to node, aggregated and eventually sent to the base station. The chain construction is performed in a greedy way. As shown in Fig. 1 node n_0 passes its data to node n_1 . Node n_1 aggregates node n_0 's data with its own and then transmits to the leader. After node n_2 passes the token to node n_4 , node n_4 transmits its data to node n_3 . Node n_3 aggregates node n_4 's data with its own and then transmits to the leader. Node n_2 waits to receive data from both neighbor's and then aggregates its data with its neighbor's data. Finally, node n_2 transmits one message to the base station.

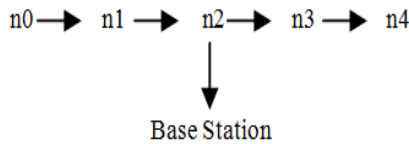


Figure 1. Chaining in PEGASIS

Unlike LEACH, PEGASIS use multi-hop routing by forming chains and selection only one node to transmit to the base station instead of using multiple nodes. However, PEGASIS introduces excessive delay for distant node on the chain. As well as bottleneck can occur in presence of only single leader.

To decrease the delay during packet transmission to the base station Hierarchical-PEGASIS [11] proposes a solution to the data gathering problem by considering energy delay metric. A simultaneous transmission of data messages in Hierarchical-PEGASIS reduces the delay in PEGASIS. To

avoid collisions and possible signal interference among the sensors, two approaches have been investigated. The first approach incorporates signal coding, e.g. CDMA. In the second approach only spatially separated nodes are allowed to transmit at the same time.

C. MECN and SMECN

Minimum energy communication network (MECN) [17] maintains a minimum energy network for wireless networks by utilizing low power GPS. Although, the protocol assumes a mobile network, it is best applicable to sensor networks, which are not mobile. A minimum power topology for stationary nodes including a master node is found. MECN considers a master site as the information sink, which is always the case for sensor networks. MECN identifies a relay region for every node which consists of nodes in a surrounding area. Transmitting through those nodes is more energy efficient than direct transmission.

The main idea of MECN is to find a sub-network, which will have less number of nodes and require less power for transmission between any two particular nodes. In this way, global minimum power paths are found without considering all the nodes in the network. This is performed using a localized search for each node considering its relay region.

The MECN works in two phases:

In first phase it takes the positions of a two-dimensional plane and constructs a sparse graph, which consists of all the enclosures of each transmit node in the graph. This construction is done by local computations in the nodes.

The enclosure graph contains globally optimal links in terms of energy consumption. In second phase it finds optimal links on the enclosure graph. It uses distributed Bellman-Ford shortest path algorithm with power consumption as the cost metric. In case of mobility GPS is used for positioning coordinates. Self-reconfiguring nature of MECN can dynamically adapt to node's failure as well as it can dynamically deploy new sensors.

The small minimum energy communication network (SMECN) [18] is an extension to MECN. In MECN, it is assumed that every node can transmit to every other node, which is not possible every time. Unlike MECN, SMECN considers possible obstacles between any pair of nodes. However like MECN, network is still assumed to be fully connected. The sub-network constructed by SMECN for minimum energy relaying is provably smaller (in terms of number of edges) than the one constructed in MECN if broadcasts are able to reach to all nodes in a circular region around the broadcaster. As a result, the number of hops for transmissions will decrease. SMECN uses less energy than MECN and maintenance cost of the links is less. However, finding a sub-network with smaller number of edges introduces more overhead in the algorithm.

D. GAF

Geographic adaptive fidelity (GAF)[13] is an energy-aware location-based routing algorithm. GAF is primarily designed

for mobile ad-hoc networks. But it can also be used for sensor networks. GAF saves energy by turning off unnecessary nodes in the network without affecting the routing quality. It forms a virtual grid for the covered network area. Each node uses its GPS-indicated location to position itself in the virtual grid. Nodes associated with the same point on the grid are considered equivalent in terms of the cost of packet routing. Such equivalence is exploited in keeping some nodes located in a particular grid area in sleeping state in order to save energy. Thus GAF increases the network lifetime as it increases the number of sensor nodes in the network.

E. GEAR

In geographic and energy-aware routing (GEAR) [16], each node has the information about estimated cost and learned cost of reaching the destination through its neighbors. The estimated cost is a combination of residual energy and distance to destination. The learned cost is calculated by refinement of the estimated cost that accounts for routing around.

A hole occurs when a node does not have any closer neighbor to the target region than itself. If there are no holes, the estimated cost is equal to the learned cost. The learned cost is propagated one hop back every time a packet reaches the destination so that route setup for next packet will be adjusted. There are two phases in the GEAR algorithm:

1. Forwarding packets towards the target region:

Upon receiving a packet, a node checks its distance from the target region. It also finds the distance of each of its neighbors from the target region. If there is one neighbor node, which is closer to the target region than itself, the neighbor is selected as next hop. If there is more than one, the nearest neighbor to the target region is selected as the next hop. If they are all further than the node itself, this means there is a hole. In this case, one of the neighbors is picked to forward the packet based on the learning cost function. This choice can then be updated according to the convergence of the learned cost during the delivery of packets.

2. Forwarding the packets within the region:

Once the packet has reached the region, it can be diffused in that region by either recursive geographic forwarding or restricted flooding. Restricted flooding is preferred when the sensors are not densely deployed. In high-density networks, recursive geographic flooding is more energy efficient than restricted flooding. In that case, the region is divided into four sub regions and four copies of the packet are created. This splitting and forwarding process continues until the regions with only one node are left.

F. GPSR

GEAR is compared to a similar non-energy aware routing protocol GPSR [44], which is one of the earlier works in geographic routing that uses planar graphs to solve the problem of holes.

Greedy Perimeter Stateless Routing (GPSP) [19] discovered a novel routing protocol for wireless datagram networks that uses the positions of routers and a packet's destination to make packet forwarding decisions. GPSR makes greedy forwarding decisions using only information about a router's immediate neighbors in the network topology. The algorithm consists of two methods for forwarding packets: greedy forwarding, which is used wherever possible, and perimeter forwarding, which is used in the regions greedy forwarding cannot be.

In GPSR, packets are marked by their originator with their destinations' locations. As a result, a forwarding node can make a locally optimal, greedy choice in choosing a packet's next hop. Specifically, if a node knows its radio neighbors' positions, the locally optimal choice of next hop is the neighbor geographically closest to the packet's destination. Forwarding in this way is done, until the destination is reached.

Upon receiving a greedy-mode packet for forwarding, a node searches its neighbor table for the neighbor geographically closest to the packet's destination. If this neighbor is closer to the destination, the node forwards the packet to that neighbor. When no neighbor is closer, the node marks the packet into perimeter mode and then perimeter forwarding comes into picture. GPSR forwards perimeter-mode packets using a simple planar graph traversal.

G. EAGR

Energy Aware Greedy Routing (EAGR) [20] scheme greedy routing scheme as defined in GPSR. In EAGR the cost metric of a node depends on the following parameters of a neighboring node: (1) Distance from the destination, (2) Fraction of energy consumed, and (3) Rate of energy consumption.

EAGR algorithm requires each node i to advertise its location (i_x, i_y, i_z), fraction of energy consumption and rate of energy consumption. All this information is filled in EAGR HELLO packet along with the node id. Each node broadcasts HELLO packets to all its neighbors. Each HELLO packet receiving node maintains a neighbor table containing following the information about neighbor (1) Identification number (ID), (2) Geographical location, (3) Fraction of energy consumption and (4) Rate of energy consumption. Each time the node receives the HELLO packet it updates its neighbor table. When there is a request for route finding each node selects the hope which is energy efficient i.e. have maximum remaining energy, which has minimum energy consumption rate and which is nearer to the destination node.

H. SAR

Sequential Assignment Routing (SAR) is the first routing protocol which concentrates more on the energy efficiency and QoS factors. It creates multiple paths from the nodes to the sink to help in achieving a more energy efficient

structure. It also maximizes the fault tolerance of the network.

The SAR protocol creates trees rooted at one-hop neighbors of the sink while considering QoS metric, energy resource on each path and priority level of each packet. These created trees are used to find multiple paths from sink to sensors. While selecting one of the paths among these multiple paths, energy resources and QoS on the path is considered. Routing table consistency between downstream and upstream on each path is enforced for failure recovery.

Any local failure causes an automatic path restoration procedure locally. SAR offers less power consumption than the minimum-energy metric algorithm, which focuses only the energy consumption of each packet without considering its priority. SA ensures fault-tolerance and easy recovery but the protocol suffers from the overhead of maintaining the tables and states at each sensor node especially when the number of nodes is huge.

I. TEEN

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) [21] is a hierarchical protocol which is designed to handle sudden changes in the sensed attributes such as temperature. Handling sudden changes quickly is important for time-critical applications, in which the network operated in a reactive mode. TEEN adapts hierarchical approach along with the use of a data-centric mechanism. In TEEN the sensor network is based on tree like architecture. Architecture follows a hierarchical grouping of closer nodes to form clusters and this process goes on the second level until base station (sink) is reached. After the clusters are formed, the cluster head broadcasts two thresholds i.e hard and soft threshold for sensed attributes towards nodes. Hard threshold is the minimum possible value of an attribute to trigger a sensor node which switches on node's transmitter to transmit sensed attribute towards the cluster head. Thus, the hard threshold allows the nodes to transmit only when the sensed attribute is in the range of interest. Thus it reduce the number of transmissions significantly by minimizing number of transmissions. Once a node senses a value at or beyond the hard threshold, it transmits data only when the value of that sensed attribute changes by an amount equal to or greater than the soft threshold, i.e. soft threshold will further reduce the number of transmissions if there is little or no change in the value of sensed attribute.

However, TEEN is not good for applications where periodic reports are needed for all changes as the user may not get any data at all if the thresholds are not reached.

J. APTEEN

The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) [22] is an extension to TEEN.

It is developed to for capturing periodic data collections and reacting to time critical events. The architecture of APTEEN

is same as in TEEN. When the base station forms the clusters, the cluster heads broadcast the attributes, the threshold values, and the transmission schedule to all nodes. Cluster heads also perform data aggregation in order to save energy. APTEEN supports three different query types: historical, to analyze past data values; one-time, to take a snapshot view of the network; and persistent to monitor an event for a period of time. Simulation of TEEN and APTEEN has shown them to outperform LEACH [9]. TEEN gives the best performance since it decreases the number of transmissions. The main drawbacks of the TEEN and APTEEN approaches are the overhead and complexity of forming clusters in multiple levels, implementing threshold-based functions and dealing with attribute-based naming of queries.

CONCLUSION

In recent years, most of attention has been given on the energy factor of the sensor node as it is very crucial factor of the sensor node. Many researchers have worked on routing protocols for WSN in order to minimize the energy consumption of the sensor node. In this paper I have tried to summarize energy efficient routing protocols in WSN.

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