Analytical Study of Routing Protocols in WSNs- A Survey

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Abstract—WSNs are networks of sensing devices called sensors (nodes), which are connected without any sought of wires. The main issue is with the power consumption, node consumes a large amount of power for transmission of information. In certain applications recharging or replacement of the batteries at the sensor nodes will be very difficult, like in remote areas or in military applications where humans cannot recharge the battery manually. To overcome this limitation, a perfect algorithm should be designed such way that it should result in an energy efficient network. In this paper, some of the most famous protocols have been explained clearly in an easier way and a qualitative comparison between them for certain parameters are tabulated in a systematic manner.

Keywords—WSN, Routing Protocols, Energy Efficient, LEACH, SPIN, GEAR

I. INTRODUCTION

Wireless Sensor Networks (WSN) are collection of smaller networks of sensing devices called sensors, which is been connected without any sought of wires. The sensed information will be communicated to the BS. WSN’s have wide range of applications, which include military applications, medical applications, smart agriculture, habitat management, environment sensing, forest fire detection, home appliances, etc. The primary units of WSN are nodes, which have the capability of sensing temperature, moisture, pressure etc. based on specific applications. Usually, nodes are made up of basic blocks such as, sensing unit, processing unit, power unit, and the transceiver. The sensed information is to be sent to BS. To have an efficient transmission, the system should communicate data through a secure and reliable path between nodes and the BS. The process of finding the route (path) is known as routing.

There are three different methods of data communication. Namely:

(a) Time driven: In this, nodes will sense and send data to the BS, periodically, even though there is no change occurred. For example: the GPS networks.

(b) Event driven: Communication between node and BS is achieved, only when a sudden change occurs or a rapid variation in conditions. Like, landslide detection, forest fire detection etc.

(c) Query based: In this method, nodes are supposed to send the data to the BS whenever the BS requests for. For example, most of the sensors at military applications are query based.

Along with the above mentioned methods, a combination of two or more of the above mentioned method scan also be considered at a time for better communication.

To make easier classification the routing systems are divided into several protocols as follows:

(a) Hierarchical routing: In this specific routing, large network may be divided into many smaller networks, which may be further subdivided into tiny networks. The communication between nodes to BS, or from BS to node is carried out after passing many stages, thus forms a hierarchy.

(b) Flat routing: The distribution of information between each node which is in turn connected, without formation of any cluster or segments between them. This type of routing allows delivery of data to BS or node through any available path without considering network hierarchy, distribution and composition.
(c) Location based: Location or position-based routing is a routing technique which depends on the position information. In which each node has the capability to determine its own location, as well the location of the BS. By keeping this information, a better path has to be computed and the data can be sent to the BS. Routing is done using different approaches like, single-path, multi-path and flooding. Although, WSN’s are used in many fields, it has its own issues it is facing with. Few such challenges are defined below:

(a) Data Aggregation: When the present sensed data at nodes is similar to the past sensed one i.e. redundant. It requires a large bandwidth to transmit as well as the traffic will be much. This can be cleared by combining the data, the phenomenon of combining the data is said to be as data aggregation, which leads to increase in throughput and an energy efficient system.

(b) Large number of sensors: Sensor networks may contain thousands of nodes. Scalability and managing the massive amount of sensing devices leads to a mandatory issue. One of the best solutions to this problem is dividing the network into several smaller networks called clusters, the process of grouping is said to be as clustering. A group leader is selected to maintain the group, Cluster head (CH).

(c) Power Consumption: The function of a sensor node is to sense the data and to send it to the respective heads or BS, depending on the type of routing. Usually, the energy utilized for the transmission will be comparatively more than sensing the data. More power consumption will lead to reduction in network life time.

(d) Network Life Time: The number of survived nodes points the living nodes with respect to the given time. The time at which the first dead node appears in a network is said to be as the life time of the network.

(e) Nodes Mobility: WSNs can posses the nodes either of mobile or stationary, depending upon the need. But in most of the cases, the nodes will be of fixed type. The kinks in iron out for the WSN are recharging or replacement of the batteries at the sensor nodes, in some cases like in remote areas, or in military applications the humans cannot charge the battery manually. To overcome this limitation, a perfect algorithm should be designed such way that it should be resulting in a most energy efficient and least power consuming network.

The rest of the paper is organized as follows: An insight into some famous routing protocols is done in section II. In section III, a brief qualitative comparison of the protocols has been made and tabulated. Finally section VI gives the concluding remarks.

II. ENERGY EFFICIENT ROUTING PROTOCOLS

In this section, we define few basic and popular energy efficient protocols. Protocol is nothing but the set of rules, written for a specific function or issue. The protocols explained in this section are designed to overcome the limitations of WSN’s as mentioned in Section I.

Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH is the most popular and important Cluster based Hierarchical routing algorithm, especially designed to get energy efficient system. LEACH works on the concept of grouping the nodes into several groups called clusters and guided by a leader node, i.e. Cluster Head(CH). Nodes that have been CH cannot become CHs for p rounds. Mean, every node will have probability of becoming a CH in every round. At the initial (set-up-phase) state, every node in the network chooses a random number between 0 and 1. If the number chosen is less than a threshold $T(n)$, then the node becomes a CH for that round. The threshold can be found by the expression shown bellow.
Where $p$ being the desirable percentage of CHs, $r$ is the number of the present round, and $G$ is the set of nodes that have not been CH in the last $l/p$ rounds.

Once the CH is formed it broadcasts a message to all the neighboring nodes. Nodes which respond to the message will be added under the CH to form a cluster. The data sensed by every node will be sent to CH, where the CH aggregates the data and sends the combined information to the BS. By doing this, the power consumption at each node in transmission between the node and BS for exchange of information will be completely nil. The drawback of LEACH is, it is not suitable for larger networks, as it uses single-hop routing, where every node should send the data to CH and then to the BS. This algorithm is susceptible for non-mobile nodes. Equal priority is given to nearest and the farthest nodes with respect to the BS, this end up in non-uniformity in energy between nodes.

**Power Efficient Gathering in Sensor Information Systems (PEGASIS)**

PEGASIS is one of the derivatives of LEACH algorithm. In this protocol, every node in the network is in turn connected and communicates with nearest node, by forming a chain. A leader node, which does the data aggregation, will be selected based on the residual energy in the node. The aggregated data at the leader node will be sent to the BS. Resulting in reduce in average power consumption per round, overhead and bandwidth requirement. Node to node communication can be achieved in PEGASIS, i.e. any node in the sensor network can transmit or receive the information to/from other node in the same network.

**Threshold sensitive Energy Efficient sensor Network protocol (TEEN)**

TEEN is a cluster based hierarchal routing protocol, which is also a variant of LEACH algorithm. Like LEACH, the nodes are grouped to form several clusters. Immediately after the formation of cluster, the CH will broadcast two values of thresholds, hard threshold and soft threshold. In which the hard threshold being the least possible value, whereas, the soft threshold can be changed as per the need. Although TEEN performs best due to reduced transmission amount, it lags when a multiple levels are considered leading to complexity in formation of cluster. The node which doesn’t receive the threshold could not transmit its data to the respective CH.

**Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN)**

APTEEN in an improved model of TEEN protocol, designed to overcome the drawbacks of LEACH and TEEN. As in the TEEN, BS will be forming the clusters, immediately after the formation of CHs, the CH broadcast the messages and the threshold values along with the transmission schedule for all the non CH nodes. Once the schedule arrives, the nodes send the data to the CH, where the data aggregation is done, so that to save energy and to minimize data traffic. CH will transmit the aggregated information to the BS periodically. APTEEN transmits data, based on the threshold values unlike LEACH which transmits data at all times.

**Hybrid Energy-Efficient Distributed clustering protocol (HEED)**

HEED is a distributed cluster based hierarchical routing model. In this specific algorithm, before formation of the clusters, the CH is selected periodically, considering the availability of energy at node and the distance to the BS. Later the clusters are formed, and the CH will be collects the information from the non CH nodes and combines the redundant information and transmits the data to the BS. The advantage of HEED protocol over LEACH is, the node with highest residual energy will become the CH resulting in extension of life time of the network.

**Geographical Adaptive Fidelity (GAF)**
GAF being the most popular energy-aware location based routing protocol. The appreciable feature in GAF is, in order to save the energy, the protocols turns off the unnecessary nodes. This action will never affect the remaining nodes in the sensor network. GAF forms virtual grid in the network, where every node’s location with respect to the grid can be found by making use of Global Positioning System (GPS). The nodes belonging to the same location in the grid is treated equally in packet routing. This helps in making the node to achieve sleep-state, in order to save energy. There are three states in GAF, discovery-for determining the neighbors in the grid, active- reflecting participation in routing and sleep when the radio is turned off.

When the nodes turn from sleep state to active and vice-versa will be resulting in balancing the load over the network. All this features help the sensor network to stay alive for more duration as the number of nodes increases the life time of the network also increases.

**Geographic and Energy Aware Routing (GEAR)**

GEAR is a location/geographical based routing protocol, the neighbor selection is done considering the location of the node with respect to the target and the amount of residual energy with it. And sending the data to the destination point should be done time to time. In this protocol, every node will be having two parameters; i.e. estimated cost and learning cost. The estimated cost is a combination of residual energy and distance of node to the destination. The learned cost is enhancement of the estimated cost. A hole occurs when a node does not possess any nearer neighbor to the target region than itself. When there are no holes, then the estimated cost is will be equal to the learned cost. GEAR not only reduces power consumption for the route set up, but also performs better in terms of Packet delivery between node and destination.

**Minimum Energy Communication Network (MECN)**

MECN sets up and maintains a minimum energy network by utilizing low power GPS for wireless network. It is based on two phases. Firstly, it takes the positions of a two dimensional plane and constructs an enclosed (sparse) graph, which consists from all the enclosures in the graph from each transmit nodes. Secondly, finds the optimal links on the enclosure graph. It uses distributive Bellman ford shortest algorithm with power consumption as cost metric.

**Trajectory Based Forwarding (TBF)**

TBF is a routing protocol that requires a sufficiently dense network and the presence of a coordinate system, for example, a GPS, so that the sensors can position themselves and estimate distance to their neighbors. The source specifies the trajectory in a packet, but does not explicitly indicate the path on a hop-by-hop basis. Based on the location information of its neighbors, a forwarding sensor makes a greedy decision to determine the next hop that is the closest to the trajectory fixed by the source sensor. Route maintenance in TBF is unaffected by sensor mobility given that a source route is a trajectory that does not include the names of the forwarding sensors. In order to increase the reliability and capacity of the network, it is also possible to implement multipath routing in TBF where an alternate path is just another trajectory. TBM can be used for implementing networking functions, for example, flooding, discovery, and network management. TBF can also be used for resource discovery. Another interesting application of TBF is securing the perimeter of the network.

**Sensor protocols for information via negotiation (SPIN)**

SPIN is a flat-based, data-centric routing protocol, the backbone of SPIN algorithm lies behind three messages ADV, REQ, and DATA. Using metadata, nodes in the network negotiate with their neighbors before they transmit data, allowing them to avoid unnecessary communications by following some steps as mentioned. A data advertisement is done by the nodes, once the node receives the new data, it starts advertising the same to the neighboring nodes and to the nodes which requests by sending a request message. The function of three message are like ADV message to
allow a sensor to advertise a particular meta-data, REQ message to request the specific data and DATA message that carry the actual data. Meta-data negotiation solves the problems of flooding like: redundant information passing, overlapping of sensing areas and resource blindness, which results in improvement in energy efficiency.

**Rumor Routing**

Rumor routing is a logical compromise between query flooding and event flooding app schemes. Rumor routing is an efficient protocol if the number of queries is between the two intersection points of the curve of rumor routing with those of query flooding and event flooding. Rumor routing is based on the concept of *agent*, which is a long-lived packet that traverses a network and informs each sensor it encounters about the events that it has learned during its network traverse. An agent will travel the network for a certain number of hops and then die. Each sensor, including the agent, maintains an event list that has event-distance pairs, where every entry in the list contains the event and the actual distance in the number of hops to that event from the currently visited sensor. Therefore, when the agent encounters a sensor on its path, it synchronizes its event list with that of the sensor it has encountered. Also, the sensors that hear the agent update their event lists according to that of the agent in order to maintain the shortest paths to the events that occur in the network.

**Active Query Forwarding in Sensor Networks (ACQUIRE)**

ACQUIRE is another data centric querying mechanism used for querying named data. It provides superior query optimization to answer specific types of queries, called one-shot complex queries for replicated data. ACQUIRE query (i.e., interest for named data) consists of several sub-queries for which several simple responses are provided by several relevant sensors. Each sub-query is answered based on the currently stored data at its relevant sensor. ACQUIRE allows a sensor to inject an active query in a network following either a random or a specified trajectory until the query gets answered by some sensors on the path using a localized update mechanism. Unlike other query techniques, ACQUIRE allows the queries to inject a complex query into the network to be forwarded stepwise through a sequence of sensors.

**Energy-Aware Data-Centric Routing (EAD)**

EAD is a novel distributed routing protocol, which builds a virtual backbone composed of active sensors that are responsible for in-network data processing and traffic relaying. In this protocol, a network is represented by a broadcast tree spanning all sensors in the network and rooted at the gateway, in which all leaf nodes’ radios are turned off while all other nodes correspond to active sensors forming the backbone and thus their radios are turned on. Specifically, EAD attempts to construct a broadcast tree that approximates an optimal spanning tree with a minimum number of leaves, thus reducing the size of the backbone formed by active sensors. EAD approach is energy aware and helps extend the network lifetime. The gateway plays the role of a data sink or event sink, whereas each sensor acts as a data source or event source.

### III. COMPARISON

This sections ends with the qualitative compression of the above mentioned energy efficient routing protocols i.e. section II, by considering several network parameters. **Classification** points the type of routing in the specific protocol, like Hierarchical, Location based. **Cluster**, shows whether any formation of groups or clusters takes place. **Data aggregation** shows the occurrence of combining of sensed information. **Multi-hop** indicates the type of hop in the algorithm. **Query based** designates whether the nodes send the information with them to the BS on demand. **Location based** spot the condition to which the algorithm is either of geographical based or not. At last, **Mobility of nodes** defines the property of node’s motion, either mobile or fixed to a point.
From the comparisons we tabulated, among all these protocols LEACH, TEEN, APTEEN, PEGASIS, HEED are of hierarchical type routing, whereas GAF, GEAR, MECN, TBF and BVGF being location based type and the SPIN, Rumor routing, ACQUIRE and EAD belongs to Data centric routing type.

**TABLE.1 COMPARISISSION OF SOME ROUTING PROTOCOLS**

<table>
<thead>
<tr>
<th>Protocol Type</th>
<th>Classification</th>
<th>Cluster Data Aggregation</th>
<th>Multi-Hop</th>
<th>Query based</th>
<th>Data centric</th>
<th>Location Based</th>
<th>Mobility of nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEACH</td>
<td>Hierarchical</td>
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<td>√</td>
<td></td>
<td></td>
<td>Fixed</td>
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<tr>
<td>PEGASIS</td>
<td>Hierarchical</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td>Fixed</td>
<td></td>
</tr>
<tr>
<td>TEEN</td>
<td>Hierarchical</td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
<td>Fixed</td>
<td></td>
</tr>
<tr>
<td>APTEEN</td>
<td>Hierarchical</td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
<td>Fixed</td>
<td></td>
</tr>
<tr>
<td>HEED</td>
<td>Hierarchical</td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
<td>Fixed</td>
<td></td>
</tr>
<tr>
<td>GAF</td>
<td>Location Based</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
<td>Depends</td>
<td></td>
</tr>
<tr>
<td>GEAR</td>
<td>Location Based</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
<td>Depends</td>
<td></td>
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<tr>
<td>MECN</td>
<td>Location Based</td>
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<td></td>
<td>√</td>
<td></td>
<td>Depends</td>
<td></td>
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<tr>
<td>TBF</td>
<td>Location Based</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
<td>Depends</td>
<td></td>
</tr>
<tr>
<td>BVGF</td>
<td>Location Based</td>
<td></td>
<td></td>
<td>√</td>
<td></td>
<td>Depends</td>
<td></td>
</tr>
<tr>
<td>SPIN</td>
<td>Data centric</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
<td>Fixed and Mobile</td>
<td></td>
</tr>
<tr>
<td>Rumor Routing</td>
<td>Data centric</td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
<td>Fixed and Mobile</td>
<td></td>
</tr>
<tr>
<td>ACQUIRE</td>
<td>Data centric</td>
<td>√</td>
<td></td>
<td>√</td>
<td></td>
<td>Fixed and Mobile</td>
<td></td>
</tr>
<tr>
<td>EAD</td>
<td>Data centric</td>
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<td></td>
<td>√</td>
<td></td>
<td>Fixed and Mobile</td>
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</tbody>
</table>

**IV. CONCLUSION**

WSN plays a vital role in development of a nation providing a secured environment. Energy constraint is being one of the major issues of the system. To find the cause for the energy inefficiency of the system, we studied some famous routing protocols and we did a qualitative comparison between all those protocols with respect to some common parameters. As per our analysis, we found that improving all these protocols by designing a specific algorithm for each protocol will yield an energy efficient system, with increased in network life time and reduced power consumption.

**REFERENCES**


