A COMPARATIVE ANALYSIS: ROUTING PROTOCOLS FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

Recent advances in wireless sensor networks introduce many protocols specially designed for sensor networks. These protocols aim at lower energy consumption. Wireless Sensor Networks (WSNs) consist of small nodes with sensing, computation and wireless communications capabilities. Wireless Sensor Networks have the limitations such as energy source, memory size and processing power. Therefore, developing an energy efficient routing protocol is an interested research work in this field. The usefulness/ effectiveness of any protocol depend on how well its parameters are set for a particular application. The routing protocols in sensor networks could be classified into three categories: flat based, hierarchical based and location based routing. In this paper we present a comparative study of routing protocol that come under this classification for wireless sensor networks. The paper also highlights the advantages and disadvantage of each routing protocol.

***Keywords**: Routing Protocol, Wireless Sensor Networks, flat based, hierarchical based, location based, Optimization Techniques, Flooding and Gossiping.*

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1. INTRODUCTION

A wireless sensor network (WSN) is usually composed of a large collections of small autonomous sensor devices that can sense environmental conditions about the ambient environment. Recent technological advances enables the widespread deployment of WSNs for many different applications, including smart battlefield, healthcare, environment and habitat monitoring, home automation, and traffic control, etc. [6]. The main task of a wireless sensor node is to sense and collect data from a certain domain, process them and transmit it to the sink where the application lies. However, ensuring the direct communication between a sensor and the sink may force nodes to emit their messages with such a high power that their resources could be quickly depleted. Therefore, the collaboration of nodes to ensure that distant nodes communicate with the sink is a requirement. In this way, messages are propagated by intermediate nodes so that a route with multiple links or hops to the sink is established [5]. Communication architecture of wireless sensor networks consists of user, sink, and sensor node shown in Figure 1**.** In the communication architecture, a user connects legacy networks and communicates a sink through a task manager node. A sink instructs sensor nodes to carry out tasks interested by the user, and sensor nodes gather data and forward it to the sink by wireless multi-hop communication manner [7].

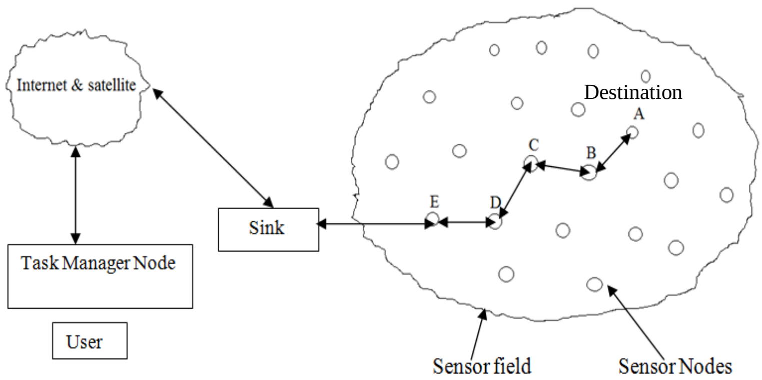

Figure 1: Communication architecture of wireless sensor networks

Sensor network applications require wireless ad hoc networking techniques. Although many protocols and algorithms have been proposed for traditional wireless ad hoc networks, they are not well suited to the unique features and application requirements of sensor networks. To illustrate this point, the differences between sensor networks and ad hoc networks are:

- The number of sensor nodes in a sensor network can be several orders of magnitude higher than the nodes in an ad hoc network.
- Sensor nodes are densely deployed.
- Sensor nodes are prone to failures.

- The topology of a sensor network changes very frequently.
- Sensor nodes mainly use a broadcast communication paradigm, whereas most ad hoc networks are based on point-to-point communications.
- Sensor nodes are limited in power, computational capacities, and memory.
- Sensor nodes may not have global identification (ID) because of the large amount of overhead and large number of sensors.

A sensor node is made up of four basic components, as shown in Figure 2, sensing unit, a processing unit, a transceiver unit, and a power unit. They may also have additional application-dependent components such as a location finding system, power generator, and mobilizer. Sensing units are usually composed of two subunits:

I. Sensors
II. Analog-to-digital converters (ADCs).

The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by the ADC, and then fed into the processing unit. The processing unit, which is generally associated with a small storage unit, manages the procedures that make the sensor node collaborate with the other nodes to carry out the assigned sensing tasks. A transceiver unit connects the node to the network. One of the most important components of a sensor node is the power unit. Power units may be supported by power scavenging units such as solar cells. There are also other subunits that are application-dependent. Most of the sensor network routing techniques and sensing tasks require knowledge of location with high accuracy. Thus, it is common that a sensor node has a location finding system. A mobilizer may sometimes be needed to move sensor nodes when it is required to carry out the assigned tasks.

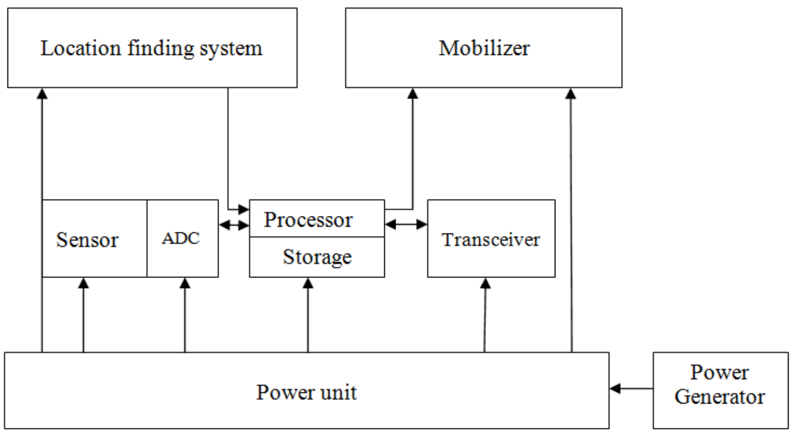

Figure 2: Components of Sensor Node.

Sensor networks are application specific that is design requirements of a sensor network change with application. Position awareness of sensor nodes is important since data collection is normally based on the location. Routing mechanisms consider the inherent features of WSNs and the application and architecture requirements. The task of finding and maintaining routes in WSNs is nontrivial since energy restrictions and sudden changes in node status cause frequent and unpredictable topological changes. To minimize energy consumption, routing techniques proposed in the literature for WSNs employ some well known routing tactics as well as tactics special to WSNs. Classification of almost all of the routing protocols can be according to the network structure as flat, hierarchical, or location based. In flat networks, all nodes play the same role while hierarchical protocols aims at clustering the nodes so that cluster heads can do some aggregation and reduction of data in order to save energy. Location-based protocols utilize the position information to relay the data to the desired regions rather than the whole network. In this paper, flat based, hierarchical based and location based protocols are discussed and classified. The various protocols include SPIN, DD, ACQUIRE, RR, COUGAR, LEACH, TEEN, APTEEN, PEGASIS, GEAR and GAF. SPIN, DD and RR. The characteristics of these protocols along with their advantages and disadvantages are presented in the paper. Finally a comparison is made followed by a conclusion [1]. The advantages and disadvantages of wireless sensor networks can be summarized as follows [10]:

Advantages:

- Network setups can be done without fixed infrastructure.
- Ideal for the non-reachable places such as across the sea, mountains, rural areas or deep forests.
- Flexible if there is ad hoc situation when additional workstation is required.
- Implementation cost is cheap.

Disadvantages:

- Less secure because hackers can enter the access point and get all the information.
- Lower speed compared to a wired network.
- More complex to configure than a wired network.
- Easily affected by surroundings.

2. OPTIMIZATION TECHNIQUES FOR ROUTING IN WSNS

The algorithms in wireless sensor networks usually realize the following specifications:

- Attribute-based

- Energy Efficiency
- Data Aggregation
- Addressing Scheme
- Location-based
- Multipath Communication
- Quality of Service

2.1 Attribute-based: In these algorithms, the sink sends queries to certain regions and waits for the response from the sensors located in this area [14].

***2.2 Energy Efficiency*:** Multiple routes can communicate a node and the sink. The aim of energy-aware algorithms is to select those routes that are expected to maximize the network lifetime. To do so, the routes composed of nodes with higher energy resources are preferred.

***2.3 Data Aggregation*:** Data collected in sensors are derived from common phenomena so nodes in a close area usually share similar information. A way to reduce energy consumption is data aggregation. Aggregation consists of suppressing redundancy in different data messages. When the suppression is achieved by some signal processing techniques, this operation is called data fusion.

2.4 Addressing Scheme: Wireless sensor networks are formed by a significant number of nodes so the manual assignation of unique identifiers is infeasible.

2.5 Location based: When this technique is used, a node decides the transmission route according to the localization of the final destination and the positions of some other nodes in the network.

2.6 Multipath Communication: With this technique, nodes use multiple paths from an origin to a destination in the network. As multipath communications are intended to increase the reliability and the performance of the network, these paths should not share any link. Multipath communications can be accomplished in two ways.

2.7 Quality of Service: The network application business and its functionalities prompt the need for ensuring a QoS (Quality of Service) in the data exchange. In particular, effective sample rate, delay bounded and temporary precision are often required [9].

3. ROUTING PROTOCOLS IN WSNS

Recent advances in wireless sensor networks have led to many new protocols specifically designed for sensor networks where energy awareness is an essential consideration. In general routing protocols in sensor networks are c1assify into three categories depending on the network structure: [1].

I. Flat Based Routing protocol
II. Hierarchical Based Routing protocol
III. Location Based routing protocol

3.1 Flat based Routing protocol

Routing protocols is the multihop flat routing protocols also known as data centric routing protocols. In flat networks, each sensor node collaborates together to perform the sensing task it is not feasible to assign a global identifier to each node. This consideration has led to flat routing, where the BS sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute-based naming is necessary to specify the properties of data. In data-centric routing, the sink sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute based naming is necessary to specify the properties of data. SPIN [16] is the first data-centric protocol, which considers data negotiation between nodes in order to eliminate redundant data and save energy. Later, Directed Diffusion [18] has been developed and has become a breakthrough in data-centric routing. Then, many other protocols have been proposed either based on Directed Diffusion [15, 4**]** or following a similar concept. In this section, we will describe these protocols in detail and highlight the key ideas.

Flooding and Gossiping: Flooding and gossiping [12] are two classical mechanisms to relay data in sensor networks without the need for any routing algorithms and topology maintenance. In flooding, each sensor receiving a data packet broadcasts it to all of its neighbors and this process continues until the packet arrives at the destination or the maximum number of hops for the packet is reached. On the other hand, gossiping is a slightly enhanced version of flooding where the receiving node sends the packet to a randomly selected neighbor, which picks another random neighbor to forward the packet to and so on.

3.1.1 SPIN (Sensor Protocols for Information via Negotiation)

The idea behind SPIN [4] is to name the data using high level descriptors or meta-data. Before transmission, meta-data are exchanged among sensors via a data advertisement mechanism, which is the key feature of SPIN. Each node upon receiving new data, advertises it to its neighbors and interested neighbors, i.e. those who do not have the data, retrieve the data by sending a request message. SPIN's meta-data negotiation solves the classic problems of flooding such as redundant information passing, overlapping of sensing areas and resource blindness thus, achieving a lot of energy efficiency. There are three messages defined in SPIN to exchange data between nodes. SPIN [8, 2] is a family of adaptive protocols and these protocols uses data negotiation and resource-adaptive algorithms. One of the advantages of SPIN is that topological changes are localized since each node needs to know only its single-hop neighbors. SPIN's data advertisement mechanism cannot guarantee the delivery of data. For instance, if the nodes that are interested in the data are far away from the source node and the nodes between source and destination are not interested in that data, such data will not be delivered to the destination at all. Therefore, SPIN is not a good choice for applications such as intrusion detection, which require reliable delivery of data packets over regular intervals. These are [4] 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. Figure 3 redrawn from [16], summarizes the steps of the SPIN protocol.

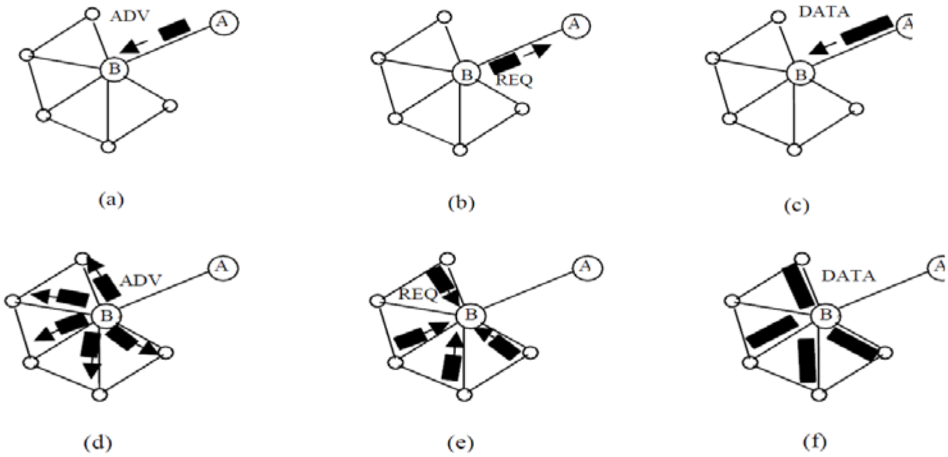

Figure 3: SPIN Protocol

Node A start by advertising its data to node B (a), Node B responds by sending a request to node A (b), After receiving the requested data (c), node B then sends out advertisements to its neighbours (d), who in turn send requests back to B (e-f).

3.1.2 DD (Directed Diffusion)

Direct Diffusion [4, 5] is an important milestone in the data-centric routing research of sensor networks. The main reason behind using such a scheme is to get rid of unnecessary operations of network layer routing in order to save energy. A node that demands the data generates a request where an interest is specified according to the attribute-value based scheme defined by the application. The sink usually injects an interest in the network for each application task [10]. The nodes update an internal interest cache with the interest messages received. The nodes also keep a data cache where the recent data messages are stored. This structure helps on determining the data rate. On receiving this message, the nodes establish a reply link to the originator of the interest. This link is called gradient and it is characterized by the data rate, duration and expiration time. Additionally, the node activates its sensors to collect the intended data. The reception of an interest message makes the node establish multiple gradients (or first hop in a route) to the sink. In order to identify the optimum gradient, positive and negative reinforcements are used. There algorithm works with two types of gradients: exploratory and data gradients. Exploratory gradients are intended for route set-up and repair whereas data gradients are used for sending real data.

3.1.3 ACQUIRE

A fairly new data-centric mechanism for querying sensor networks is ACtive Query forwarding in sensor networks (ACQUIRE) [13]. ACQUIRE is the flooding based query techniques. In these techniques, there is a clear distinction between the query dissemination and response gathering stages. As in, the approach views the sensor network as a distributed database and is well suited for complex queries which consist of several sub queries. The querying mechanism works as follows:

The query is forwarded by the sink and each node receiving the query, tries to respond partially by using its pre cached information and forward it to another sensor. If the pre-cached information is not up-to-date, the nodes gather information from its neighbors within a look-ahead of d hops. Once the query is being resolved completely, it is sent back through either the reverse or shortest-path to the sink. One of the main motivations for proposing ACQUIRE is to deal with one-shot, complex queries for data where a response can be provided by many nodes. Since, the data-centric approaches such as Directed Diffusion uses flooding-based query mechanism for continuous and aggregate queries, it would not make sense to use the same mechanism for one shot complex queries due to energy considerations. ACQUIRE mechanism provides efficient querying by adjusting the value of parameter d. Note that if d is equal to network size, then the protocol behaves similar to flooding. On the other hand, the query has to travel more hops if d is too small. A mathematical modelling has been derived for the energy cost of the ACQUIRE approach and been compared to both flooding and ring search, i.e. gradual increase in number of hops. An optimal value of parameter d is calculated for a grid of sensors where each node has 4 immediate neighbors. However, there is no validation of results through simulation and the reception costs have not taken into account during calculations. In ACQUIRE, the next node to forward the query is either picked randomly or the selection is based on maximum potential of query satisfaction [13].

3.1.4 Rumour Routing

Rumour Routing [8] protocol is variation of directed diffusion. It is energy-efficient protocol used when geographic information is not available. It has the following assumptions: [10]

The network is composed of densely distributed nodes.

- Only bi-directional links exits.
- Only short distance transmissions are allowed.
- It has fixed infrastructure.

It uses an events table and an agent. In this protocol the number of events is small and the number of queries is large. The queries are rooted to that particular nodes that are belongs to the interested region. In order to flood events through the network, the rumour routing algorithm employs long-lived packets, called agents. When a node detects an event, it adds such event to its local table known as events table, and generates an agent. Agents travel the network on a random path with related event information. Then they visited nodes form a gradient towards the event. Rumour routing only maintains one path between source and destination.

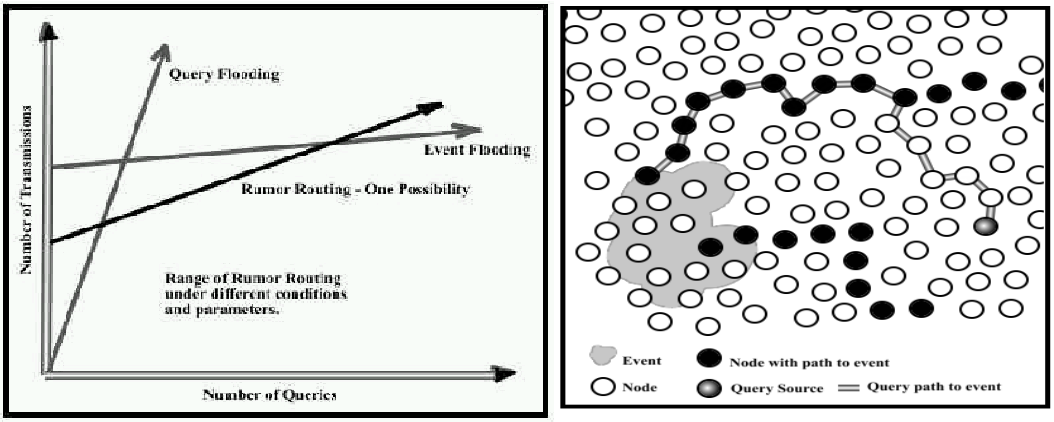

Figure 4: (A) Rumour Routing Range (B) Query's Path

Rumour routing performs well only when the number of events is small. For a large number of events, the cost of maintaining agents and event-tables in cache node becomes infeasible if there is not enough interest in these events from the BS as shown in Figure 4 (A). The gray region shows where a particularly configured instance of rumour routing fits in terms of setup and pre query cost. Obviously the region of interest lies below query and event flooding. Figure 4 (B) shows nodes having observed an event send out agents which leave routing info to the event as state in nodes. Agents attempt to travel in a straight line. If an agent crosses a path to another event, it begins to build the path to both. Agent also optimizes paths if they find shorter ones.

3.1.5 COUGAR

COUGAR [4], [18] a data-centric protocol that views the network as a huge distributed database system is proposed in. The main idea is to use declarative queries in order to abstract query processing from the network layer functions such as selection of relevant sensors etc. and utilize in-network data aggregation to save energy. The abstraction is supported through a new query layer between the network and application layers. COUGAR proposes architecture for the sensor database system where sensor nodes select a leader node to perform aggregation and transmit the data to the gateway (sink). The architecture is depicted in Fig. 5 which is redrawn from [4].

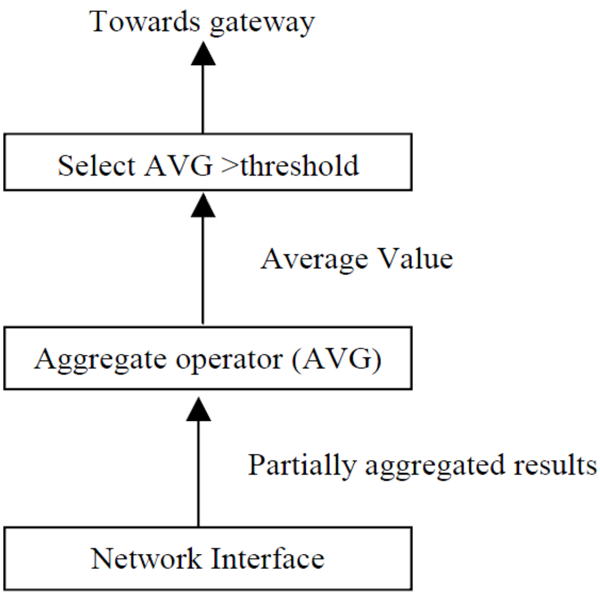

Fig. 5: Query plan at a leader node: The leader node gets all the readings, calculates the average and if it is greater than a threshold sends it to the gateway (sink).

The gateway is responsible for generating a query plan, which specifies the necessary information about the data flow and in-network computation for the incoming query and send it to the relevant nodes. The query plan also describes how to select a leader for the query. The architecture provides in-network computation ability for all the sensor nodes. Such ability ensures energy efficiency especially when the number of sensors generating and sending data to the leader is huge.

Although COUGAR provides a network-layer independent solution for querying the sensors, it has some drawbacks: First of all, introducing additional query layer on each sensor node will bring extra overhead to sensor nodes in terms of energy consumption and storage.

Second, in network data computation from several nodes will require synchronization, i.e. a relaying node should wait every packet from each incoming source, before sending the data to the leader node. Third, the leader nodes should be dynamically maintained to prevent them from failure.

3.2 Hierarchical based Routing protocol

Hierarchical routing protocols also known as cluster-based routing, proposed in wireless networks. They are well-known techniques having special advantages related to scalability and efficient communication.

The concept of hierarchical routing is also utilized to perform energy efficient energy efficient routing in WSNs. In a hierarchical architecture, higher energy nodes can be used to process and send the information while low energy nodes can be used to perform the sensing in the proximity of the target. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption within a cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the BS. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other layer is used for routing. However, most techniques in this category are not about routing, rather on "who and when to send or process/aggregate" the information, channel allocation etc., this can be orthogonal to the multi-hop routing function [17].

3.2.1 LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH is one of the first hierarchical routing approaches for sensors networks. LEACH [10] is a self-organizing, adaptive clustering protocol. It uses randomization for distributing the energy load among the sensors in the network. The following are the assumptions made in the LEACH protocol:

- All nodes can transmit with enough power to reach the base station.
- Each node has enough computational power to support different MAC protocols.
- Nodes located close to each other have correlated data.

According to this protocol, the base station is fixed and located far from the sensor nodes and the nodes are homogeneous and energy constrained. Here, one node called cluster-head (CH) acts as the local base station. LEACH randomly rotates the high-energy cluster-head so that the activities are equally shared among the sensors and the sensors consume battery power equally. LEACH also performs data fusion, *i.e.* compression of data when data is sent from the clusters to the base station thus reducing energy dissipation and enhancing system lifetime. LEACH divides the total operation into rounds each round consisting of two phases: set-up phase and steady phase. In the set-up phase, clusters are formed and a CH is selected for each cluster. The CH is selected from the sensor nodes at a time with a certain probability. Each node generates a random number from 0 to 1. If this number is lower than the threshold node [T(n)] then this particular node becomes a CH. T(n) is given as follows:

$$T(n) = \frac{p}{1-p}[r \bmod (1/p)], \; n \in G \; = 0, \text{otherwise}$$

Where p is the percentage of nodes that are CHs, r is the current round and G is the set of nodes that have not served as cluster head in the past 1/p rounds. Then the CH allocates time slots to nodes within its cluster. LEACH clustering is shown in Figure 6. In steady state phase, nodes send data to their CH during their allocated time slot using TDMA. When the cluster head gets data from its cluster, it aggregates the data and sends the compressed data to the BS. Since the BS is far away from the CH, it needs high energy for transmitting the data. This affects only the node which are CHs and that's why the selection of a CH depends on the remaining energy of that node.

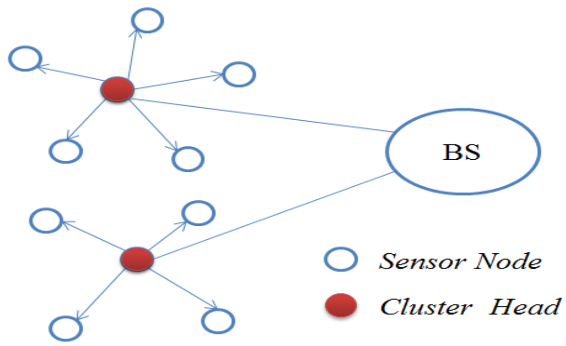

Figure 6: Clustering in LEACH Protocol.

3.2.2 TEEN (Threshold sensitive Energy Efficient sensor Network)

TEEN [3] is a cluster based routing protocol which is based on LEACH. This protocol transfers the data less frequently and senses the medium continuously. The network consists of simple nodes, first-level cluster heads and second-level cluster heads. LEACH strategy used in this protocol for cluster formation. It has two assumptions:

- The BS and the sensor nodes have same initial energy.
- The BS can transmit data to all nodes in the network directly.

First level CHs are formed away from the BS and second level CHS are formed near to the BS. It is targeted at reactive networks and is the first protocol developed for reactive networks. A wireless sensor network is shown in Figure 7.

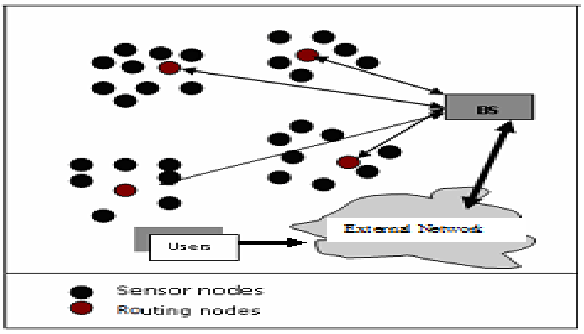

Figure 7: Wireless Sensor Network

Some of the important features of this scheme are as follows:

- It is best suited to time-critical data sensing applications.
- The energy consumption in this scheme can potentially be must less than in the proactive network, because data transmission is done less frequently.
- The soft threshold (change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit) can be varied.
- A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption. Thus, the user can control the trade-off between energy efficiency and accuracy.
- At every cluster time, the attributes are broadcast afresh and so, the user can change them as required.

The main drawback of this scheme is that, if the thresholds are not reached, the nodes will never communicate the user will not get any data from the network at all and will not come to know even if all the nodes die. Thus, this protocol is not well suited for applications where the user needs to get data on a regular basis. Other problem that arises is practical implementation would have to ensure that there are no collisions in the cluster.

3.2.3 APTEEN (Adaptive Threshold TEEN)

APTEEN **[**3] is the improved version of the TEEN which enables reliable monitoring and analysis of the environment. In this once the CHs are decided, in each cluster period, the CH first broadcasts the following parameters:

- Attributes
- Thresholds
- Schedule
- Count Time

If a node does not send data for a time period equal to the count time, it is forced to sense and retransmit the data thus maintaining energy consumption. Since it is a hybrid protocol, it can emulate a proactive network or a reactive network depending on the count time and threshold value.

The main features of this protocol include:

- It combines both proactive and reactive policies by giving complete picture of the network and also responds immediately to drastic changes.
- It offers a flexibility of allowing the user to set the time interval and the threshold values for the attributes. Energy consumption can be controlled by the count time and the threshold values.
- The hybrid network can emulate a proactive network or a reactive network, by suitably setting the count time and the threshold values.

One of the limitations of this protocol is that in order to implement the threshold function and count time additional complexity is required.

3.2.4 PEGASIS (Power efficient Gathering Sensor Information System)

In PEGASIS [19] each node communicates only with a close neighbor and takes turns transmitting to the base station, thus reducing the amount of energy spent per round. This approach will distribute the energy load evenly among the sensor nodes in the network. Nodes will be organized to form a chain, which can either be accomplished by the sensor nodes themselves using a greedy algorithm starting from some node. Alternatively, the BS can compute this chain and broadcast it to all the sensor nodes. For gathering data in each round, each node receives data from one neighbor, fuses with its own data, and transmits to the other neighbor on the chain. PEGASIS performs data fusion at every node except the end nodes in the chain. Each node will use its neighbor's data with its own to generate a single packet of the same length and then transmit that to its other neighbor (if it has two neighbors). Thus, in PEGASIS each node will receive and transmit one packet in each round and be the leader once every 100 rounds.

The performance of this protocol can be improved by:

- Using Greedy algorithm for chain construction.
- Not allowing nodes which dissipate more energy to become the leader.
- Applying a threshold adaptive to the remaining energy levels in nodes.

This protocol saves energy at various stages. First, in the local gathering, the distances that most of the nodes transmit are much less compared to transmitting to a cluster-head in LEACH. Second, the amount of data for the leader to receive is at most two messages instead of 20 (20 nodes per cluster in LEACH for a 100-node network). Finally, only one node transmits to the BS in each round of communication.

3.3 Location Based routing protocol

Location based protocols in which sensor nodes are addressed by means of their locations. The incoming signal strengths can estimate the distance between neighbouring nodes. Relative coordinates of neighbouring nodes can be obtained by exchanging such information between neighbours. An alternate for this is that the location of nodes may be available directly by communicating with a satellite, using GPS (Global Positioning System), if nodes are equipped with a small low power GPS receiver. Some location based schemes demand that nodes should go to sleep if there is no activity, to save energy. More the number of sleeping nodes more is the energy saving obtained in the network. The problem of designing sleep period schedules for each node in a localized manner was addressed.

3.3.1. GEAR (Geographic and Energy-Aware Routing)

Yu et al. [20**]** suggested the use of geographic information to appropriate regions as the data queries often includes geographic attributes. GEAR uses the GIS (Geographical Information System) for finding location of sensor nodes in the network. GEAR limits the number of interests in Directed Diffusion by considering only a certain region rather than sending the interests to the whole network. The key idea to restrict the number of interests in directed diffusion by only considering a certain region rather than sending the interests to the whole network. GEAR thus complements Directed Diffusion and conserves more energy. In this protocol, each node each node keeps an estimated cost and a learning cost of reaching the destination through its neighbours. In case when node doesn't find any neighbour close to target region a hole occurs. If there are no holes, the estimated cost is equal to the learned cost. Two phrases occur in the algorithm of this protocol:

Phrase I: Forwarding packets towards the target region. As packet is received by target node it searches for the neighbour that is close to the target region. This is then selected as the next hop.

Phrase II: Forwarding the packets within the region. The packet within region is diffused by either recursive geographic forwarding or restricted flooding.

3.3.2. GAF (Geographic Adaptive Fidelity)

This is a protocol designed for mobile ad hoc networks and is energy-aware location based routing protocol [**11].** GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. It forms a virtual grid for the covered area. Each node uses its GPS-indicated location to associate itself with a point in the virtual grid. Nodes associated with the same point on the grid are considered equivalent in terms of the cost of packet routing. In order to balance the load balance the nodes change their states. The states mention in this protocol are *Discovery*, in order to find neighbor in the grid, *Active* reflects node participation in routing and *Sleep* when radio is turned off. The states transitions are shown in Figure 8. GAF is implemented for both mobility and non mobility of nodes.

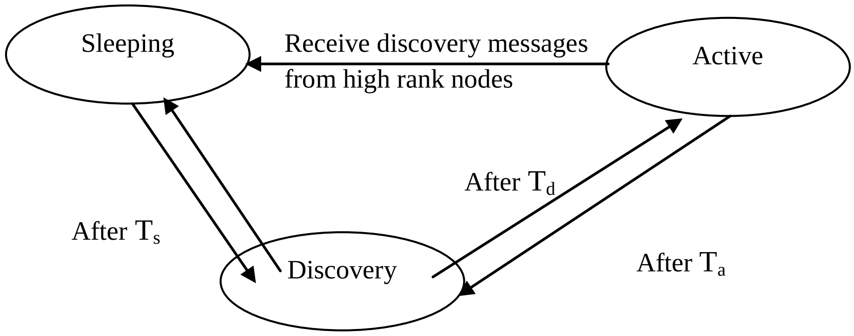

Figure 8: State Transitions in GAF [4]

4. COMPARATIVE ANALYSIS OF ROUTING PROTOCOLS OF WSNS

The routing protocols mentioned in the above sections are developed for different applications. Here a comparative analysis of all these protocols is been sited according to their performance based on different parameters. This comparison is presented in Table 1.

Routing Protocol	Classifica -tion	Data Delivery Model	Data Aggregation	Power Usages	Scalability	QoS	Query Based	Overhead	Network Life Time	Resource Awareness	Mobility
SPIN	Flat	Event driven	Yes	Ltd	Ltd	No	Yes	Low	Good	Yes	Supported
DD	Flat	Demand driven	Yes	Ltd	Ltd	No	Yes	Low	Good	Yes	Limited
ACQUIRE	Flat	Complex query	Yes	Low	Ltd	No	Yes	Low	Good	Yes	Fixed BS
RR	Flat	Demand driven	Yes	Low	Good	No	Yes	Low	Very good	Yes	Limited
COUGAR	Flat	Query driven	Yes	Ltd	Ltd	No	Yes	High	Very good	Yes	Supported
LEACH	Hierarchical	Cluster-head	Yes	High	Good	No	No	High	Very good	Yes	Fixed BS
TEEN	Hierarchical	Active threshold	Yes	High	Good	No	No	High	Very good	Yes	Fixed BS
APTEEN	Hierarchical	Active threshold	Yes	High	Good	No	No	High	Very good	Yes	Fixed BS
PEGASIS	Hierarchical	Chains based	No	Max	Chains based	No	No	Low	Very good	Yes	Fixed BS
GEAR	Location	Demand driven	No	Ltd	Ltd	No	No	Mod	Good	Yes	Limited
GAF	Hierarchical / Location	Virtual grid	No	Ltd	Good	No	No	Mod	Good	Yes	Limited

Table 1: A Comparative Analysis of routing protocols of wireless sensor networks

CONCLUSION

Sensors have made the wireless sensor network popular and routing in the sensor network is the new area of research. Based on different applications sensor networks are designed accordingly. This paper presents a categorisation of routing protocol in the sensor network which includes flat based, hierarchical based and location based protocols. Each category further discusses the protocols that come under each of these categories. The discussed protocols are SPIN, DD, ACQUIRE, RR, COUGAR, LEACH, TEEN, APTEEN, PEGASIS, GEAR and GAF. SPIN, DD, ACQUIRE, RR and COUGAR protocols come under flat based routing protocol which is data centric protocol. It distributes the information as needed to any router that can be reached or receive information. LEACH, TEEN, APTEEN and PEGASIS are mentioned under hierarchical based routing protocol. This often group routers together by function into a hierarchy. While GEAR and GAF are discussed as location based routing protocol. Based on this categorisation a comparative analysis of the protocol is presented. This comparison is based on the various parameters of the protocol. Each of this protocol is designed for a particular application as results some protocols work for one situation while other for other situations.

Hence for future perspective of this work may be well focused on modifying any of the above routing protocols such that the modified protocol could minimize more energy for the entire network.

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