ARCHITECTURE BASED ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS: A SURVEY

Vivek Pandiya Raj[*], Dr.M.Duraipandian[**], M.Agalya[***]

[*]Assistant Professor, Department of Computer Science and Engineering, Vivekanandha College of Technology for Women, Tiruchengode, Namakkal, Tamil Nadu

[**]Professor, Department of Computer Science and Engineering, Vivekanandha College of Engineering for Women, Tiruchengode, Namakkal, Tamil Nadu

[***]Assistant Professor, Department of Computer Science and Engineering, Vivekanandha College of Technology for Women, Tiruchengode, Namakkal, Tamil Nadu

ABSTRACT- Wireless sensor networks (WSNs) consists of large number of multifunctional sensor nodes. Sensor nodes are battery powered and deployed in harsh environments so it is not always possible to recharge or replace the batteries. Sensor node basically sense data, collects data from other nodes then process that data and then transmit this collected data to the base station. It is proved that node require much power or energy to transmit data rather than sensing thus routing protocols developed for wireless sensor networks must be energy efficient so that the network lifetime can be prolonged. Routing protocols developed for other adhoc networks cannot be applied directly in WSN because of the energy constraint of the sensor nodes. Sensor networks are used in many applications like environment monitoring, health, industrial control units, military applications and in the various computing environments. Since the entire sensor nodes are battery powered devices, energy consumption of nodes during transmission or reception of packets affects the life-time of the entire network. In this paper, a survey on various energy efficient routing protocols based on their architecture has been done indicating their merits and demerits.

Keywords: wireless sensor network, Design challenges, Routing protocol, Data centric, Hierarchical, Location based.

1. INTRODUCTION

Due to recent technological advances, the manufacturing of small and low cost sensors became technically and economically feasible. A Wireless Sensor Network [1] contains hundreds or thousands of these sensor nodes**.** Sensors are tiny devices that sense physical quantities and convert them into electrical signals. The word network signifies that these sensors can communicate among themselves. Wireless denotes that the communication takes place through a wireless medium. Thus wireless sensor network consists of hundreds of sensor nodes that can sense their vicinity and communicate either among themselves or to the external base station (also known as sink) [2]. Originally wireless sensor networks were designed for military applications (which include battlefield surveillance, object protection, intelligent guiding, remote sensing etc.) but nowadays it has wide range of civilian applications also in the areas like environment, health, home, space exploration, chemical processing, disaster relief and other commercial areas.

Figure 1[4], shows the structural view of a sensor network in which sensor nodes are shown as small circles. The primary component of the network is the sensor, essential for monitoring real world physical conditions such as sound, temperature, humidity, intensity, vibration, pressure, motion, pollutants etc. at different locations. The tiny sensor nodes, which consist of sensing, on board processor for data processing, and communicating components, leverage the idea of sensor networks based on collaborative effort of a large number of nodes. Each node typically consists of the four components: sensor unit, central processing unit (CPU), power unit, and communication unit. They are assigned with different tasks. The sensor unit consists of sensor and ADC (Analog to Digital Converter). The sensor unit is responsible for collecting information as the ADC requests, and returning the analog data it sensed. ADC is a translator that tells the CPU what the sensor unit has sensed, and also informs the sensor unit what to do. Communication unit is tasked to receive command or query from and transmit the data from CPU to the outside world. CPU is the most complex unit. It interprets the command or query to ADC, monitors and controls power if necessary, processes received data, computes the next hop to the sink, etc. Power unit supplies power to sensor unit, processing unit and communication unit. Each node may also consist of the two optional components namely Location finding system and Mobilizer. If the user requires the knowledge of location with high accuracy then the node should pusses Location finding system and Mobilizer may be needed to move sensor nodes when it is required to carry out the assigned tasks. Instead of sending the raw data to the nodes responsible for the fusion, sensor nodes use their processing abilities to locally carry out simple computations and transmit only the required and partially processed data.

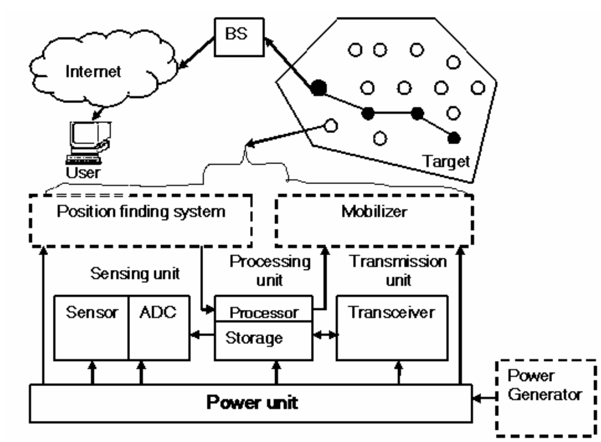

Figure 1: Structural view of sensor network

The design space for routing algorithms for WSNs is quite large and we can classify [5] the routing algorithms for WSNs in many different ways. Routing protocols are classified as node centric, data-centric, or location-aware (geo-centric) and QoS based routing protocols.

Routing protocols can also be classified [5] based on whether they are reactive or proactive. A proactive protocol sets up routing paths and states before there is a demand for routing traffic. Paths are maintained even there is no traffic flow at that time. In reactive routing protocol, routing actions are triggered when there is data to be sent and disseminated to other nodes. Here paths are setup on demand when queries are initiated.

Routing protocols can also be classified [5] based on sensor network architecture. Some WSNs consist of homogenous nodes, whereas some consist of heterogeneous nodes. Based on this concept we can classify the protocols whether they are operating on a flat topology or on a hierarchical topology. In Flat routing [3] protocols all nodes in the network are treated equally. A hierarchical routing protocol is a natural approach to take for heterogeneous networks where some of the nodes are more powerful than the other ones. The hierarchy does not always depend on the power of nodes. In Hierarchical (Clustering) protocols different nodes are grouped to form clusters and data from nodes belonging to a single cluster can be combined (aggregated).The clustering protocols have several advantages like scalable, energy efficient in finding routes and easy to manage.

The rest of the paper is organized as follows. Section 2 provides the overview about wireless sensor network design challenges. Various protocols are listed in section 3. Section 4 contains the comparison of protocol and finally section 5 contains conclusion.

2. WIRELESS SENSOR NETWORK DESIGN CHALLENGES

Depending on the application, different architectures and design goals/constraints have been considered for sensor networks. Since the performance of a routing protocol is closely related to the architectural model, so the design of the routing protocols for WSN is challenging. This section attempts to list down the main aspects involved in the design challenges of sensor networks.

2.1 Limited Energy Capacity

Energy poses a big challenge for the network designers in hostile environments. Since sensor nodes are battery powered, they have limited energy capacity. So when the energy of a sensor reaches a certain threshold, they become faulty and are not able to function properly which affects the overall network performance to great extend. Consequently the routing protocols designed for sensors should be as energy efficient as possible to extend their lifetime, and hence prolong the network lifetime.

2.2 Sensor Location

Managing the locations of the sensors is another challenge that features the design of the routing protocols. Most of the proposed protocols assume that the sensors either are equipped with GPS receivers or use some localization technique to learn about their locations.

2.3 Limited Hardware Resources

Sensors can perform only limited computational functionalities due to their limited processing and storage capacities beside limited energy capacity. These hardware constraints present many challenges in software development and network protocol design for sensor networks.

2.4 Node Deployment

Topological deployment of the sensors in WSNs is application dependent and finally affects the performance of the routing protocol. The deployment is either deterministic or self-organizing. In deterministic situations, the sensors are manually placed and data is routed through pre-determined paths. However in self-organizing systems, the sensor nodes are scattered randomly creating an infrastructure in an ad hoc manner. In that infrastructure, the position of the sink or the cluster-head is also crucial in terms of energy efficiency and performance.

2.5 Network Characteristics and Unreliable Environment

The WSN is consistently prone to frequent topology changes because of extremely vulnerable to node failure, sensors addition, deletion, node damage, link failure, sensor energy exhaustion etc. also susceptible to noise, time consistency and errors due to wireless nature of the network. So the network routing protocol/mechanism be capable of sustain the network topology dynamics, increase network size, energy consumption level, sensor nodes mobility and their related issues like coverage and connectivity to retain specific application requirements.

2.6 Data Aggregation

In WSN the redundancy of data generated from sensor nodes is a key concern. Similar packets from multiple nodes can be aggregated to reduce the extra overhead due to number of the transmissions. Many proposed routing protocols are using data aggregation technique to achieve energy efficiency and data transfer optimization.

2.7 Diverse sensing application requirements

Sensors networks have a wide range of diverse applications. Each application has its own specifications and constraints different from other application. There is no network protocol which can fully meet the criteria of all applications. Therefore the routing protocols designed should compute an optimal path and guarantee the accurate data delivery to the sink on time.

2.8 Scalability

Scalability is very important in WSN as the network size can grow rapidly. So the routing protocols should be designed to work consistently, keeping in consideration that sensors may not necessarily have the same capabilities in terms of energy, processing, sensing, and particularly communication. Furthermore, care should be taken to design routing protocol as there could be asymmetric communication between sensors instead of symmetric (a pair of sensors may not be able to have communication in both directions).

3. ARCHITECTURE BASED ROUTING PROTOCOL

Routing Protocols in wireless sensor networks differs from conventional routing in fixed networks in various ways. There is no infrastructure, wireless links are unreliable, sensor nodes may fail, and routing protocols have to meet strict energy saving requirements. Routing protocols developed for other adhoc networks cannot be applied directly in WSN because of the energy constraint of the sensor nodes. Many routing algorithms were developed for wireless networks in general. All major architecture based routing protocols proposed for WSNs may be divided into three categories as shown in **Figure 2**.

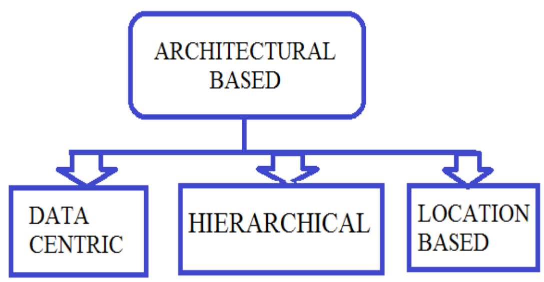

Figure 2: Types of Architectural Based Routing Protocol

3.1 Data-Centric Routing Protocol

In many applications of sensor networks, it is not feasible to assign global identifiers to each node due to the sheer number of nodes deployed. This has led to the development of query based routing techniques known as data-centric routing protocols. In query based, the base station sends a query to a certain region in the network whose data it requires. The query is sent to a random sensor node form the base station, and has to be forwarded to the intended region. In this section, we review some of the data-centric routing protocols for WSNs.

3.1.1 Sensor Protocols for Information via Negotiation (SPIN) [6][7]: SPIN protocol was designed to improve classic flooding protocols and overcome the problems they may cause, for example, implosion and overlap. The SPIN protocols are resource aware and resource adaptive. The sensors running the SPIN protocols are able to compute the energy consumption required to compute, send, and receive data over the network. Thus, they can make informed decisions for efficient use of their own resources. The SPIN protocols are based on two key mechanisms namely **negotiation** and **resource adaptation**. SPIN uses **meta-data** as the descriptors of the data that the sensors want to disseminate. The notion of meta-data avoids the occurrence of overlap given sensors can name the interesting portion of the data they want to get. It may be noted here that the size of the meta-data should definitely be less than that of the corresponding sensor data. This allows the sensors to use their energy and bandwidth efficiently.

There are two protocols in the SPIN family: SPIN-l (or SPIN-PP) and SPIN-2 (or SPIN-EC).While SPIN-l uses a negotiation mechanism to reduce the consumption of the sensors, SPIN-2 uses a resource-aware mechanism for energy savings. Both protocols allow the sensors to exchange information about their sensed data, thus helping them to obtain the data they are interested in.

3.1.2 Directed Diffusion (DD) [8]: Direct diffusion is a data centric query based and application-aware protocol where data aggregation is carried out at each node in the network. The nodes will not advertise the sensed data until a request is made by the BS, and all the data generated by sensor node is named by attribute-value pairs. The gradient specifies data rate and the direction in which to send the events. The node which receives the events information from the source attempts to find a matching entry in its interest cache. All sensor nodes in a directed-diffusion-based network are application-aware, which enables diffusion to achieve energy savings by selecting empirically good 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 paradigm.

3.1.3 Rumor Routing (RR) [9]: Rumor routing is another variation of Directed Diffusion and is mainly intended for contexts in which geographic routing criteria are not applicable. Generally Directed Diffusion floods the query to the entire network when there is no geographic criterion to diffuse tasks. However, in some cases there is only a little amount of data requested from the nodes and thus the use of flooding is unnecessary. An alternative approach is to flood the events if number of events is small and number of queries is large. Rumor routing is between event flooding and query flooding. The idea is to route the queries to the nodes that have observed a particular event rather than flooding the entire network to retrieve information about the occurring events. In order to flood events through the network, the rumor routing algorithm employs long-lived packets, called agents. When a node detects an event, it adds such event to its local table and generates an agent. Agents travel the network in order to propagate information about local events to distant nodes. When a node generates a query for an event, the nodes that know the route, can respond to the query by referring its event table. Hence, the cost of flooding the whole network is avoided. Rumor routing maintains only one path between source and destination as opposed to Directed Diffusion where data can be sent through multiple paths at low rates.

3.1.4 COUGAR [10]: A data-centric protocol that views the network as a huge distributed database system. 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 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.

3.1.5 Active Query Forwarding in Sensor Networks (ACQUIRE) [11]: 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 querier to inject a complex query into the network to be forwarded stepwise through a sequence of sensors.

3.2 Hierarchical Routing Protocol

In hierarchical routing protocols whole network is deviled into multiple clusters. One node in each cluster play leading rule. Cluster-head is the only node that can communicate to Base station in clustering routing protocols. This significantly reduces the routing overhead of normal nodes because normal nodes have to transmit to cluster-head only. We describe some of hierarchical routing protocols here.

3.2.1 Low Energy Adaptive Clustering Hierarchy (LEACH) [12][13]: It is the most popular energy-efficient hierarchical routing algorithm for WSNs to reduce power consumption. In LEACH, direct communication is used by each CH to forward the data to the base station (BS). LEACH divides the network into several clusters. Since energy dissipation of the sensor depends on the distance LEACH attempts to transmit data over short distances and reduce total number of transmission and reception operations.

The key features of LEACH are:

(i) Randomized rotation of the CH and corresponding clusters.

(ii) Local aggregation of data to reduce global communication.

(iii) Localized coordination and control for cluster set-up and operation. In LEACH CH rotation takes place rather than selecting one in static manner, to give an opportunity to each sensor to become a CH and avoid quick dieing of CH by total battery depletion.

Cluster heads (CHs) use CSMA MAC protocol to advertise their status. Thus, all non-cluster head sensors must keep their receivers ON during the setup phase in order to receive the advertisements sent by the CHs. These CHs are selected with some probability by themselves and broadcast their status to the other sensors in the network. The decision for a sensor to become a CH is made independently without any negotiation with the other sensors. Specifically, a sensor decides to become a CH based on the desired percentage P of CHs, the current round r, and the set of sensors that have not become CH in the past 1/P rounds. Nodes which are not selected as the CH in the last 1/P round generate a random number between 0 to 1. If the number is less than T(n), the node becomes a CH for the current round, where T(n) is a threshold given by the following formula:

$$T(n) = \begin{cases} \dfrac{p}{(1 - p\left(r - mod\left(\frac{1}{p}\right)\right))} & , if \;\; n \,\varepsilon\, G \\ 0 & , otherwise \end{cases}$$

Where G is the set of nodes that have been CHs in the last 1/P rounds. Once the network is divided into clusters, a CH computes a TDMA schedule for its sensors specifying when a sensor in the cluster is allowed to send its data. Thus, a sensor will turns its radio ON only when it is authorized to transmit according to the schedule created by its cluster head, therefore significant energy is being saved by switching off the receivers during idle period. Furthermore, LEACH enables data fusion in each cluster by aggregating the data which not only minimizes redundancy but also reduces the total amount of data sent to the sink. The sensors within a cluster transmit their sensed data over short distances, whereas CHs communicate directly with the sink.

Drawback of LEACH – The algorithm possesses clustering approach and if implemented properly it can lead to energy efficient routing in WSNs. But still it has some shortcomings as described below:

(i) It uses single-hop routing where each node can transmit directly to the cluster-head and the sink. So it is applicable only for small network and not suitable to networks deployed in large regions.

(ii) Dynamic clustering brings extra overhead, e.g. rotation of cluster head, advertisements, re-clustering etc., which may diminish the gain in energy consumption.

(iii) LEACH provides time slots for each node in the TDMA schedule generated by CHs in the network. Sensor nodes are supposed to send their data in its own time slot but this method wastes bandwidth because some nodes might not have data to transmit.

(iv)Though LEACH helps the sensors within their cluster dissipate their energy slowly, a larger amount of energy is consumed by the CHs when they are located farther away from the sink.

(v) LEACH clustering terminates in a finite number of iterations, but does not guarantee good CH distribution. There is no mechanism to ensure that the elected CHs will be uniformly distributed over the network. So all cluster heads may be concentrated only in one part of the network. That's why uniform energy consumption for CHs is not practical.

3.2.2 LEACH-Centralized (LEACH-C) [14][15]: It is a centralized clustering algorithm based on LEACH. This algorithm is proposed mainly to solve the global coordination problem of LEACH. In this the sensor nodes sends their location and remaining energy information to the base station. On the basis of this information the base station form clusters, select cluster heads and non cluster head nodes in the cluster. In this way the setup phase is completed. The steady phase is same as that of LEACH. It is less reliable due to single point of failure and can cause hotspot problem. It is advancement over **LEACH**.

3.2.3 Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [16]: PEGASIS forms chains rather than clusters for data transmission. This protocol is proposed as an improvement over LEACH. The chains are formed using the greedy approach either by the sensor nodes themselves or by the base station. Data is transferred node by node until it reaches the base station. Each node fuses its own data with the data received from the previous node and sends it to the next neighbor which is closer to base station than itself. It starts from the farthest node to ensure that the nodes away from sink have close neighbors. When a node dies, the chain is formed by using the same greedy approach by bypassing the dead nodes. Simulation results illustrated that PEGASIS increases network lifetime to twice as compared to LEACH.

3.2.4 Hybrid, Energy-Efficient Distributed Clustering (HEED) [17]: HEED is proposed as an improvement over LEACH. The enhancement is done in cluster head selection method. In HEED cluster head selection is not random. It chooses cluster head by considering two main parameters- residual energy and node degree. In HEED each sensor node sets the probability C_{prob} of becoming a cluster head as follows

$$CH_{prob} = C_{prob} \cdot \frac{E_{residuai}}{E_{\max}}$$

Where C_{prob} is initial percentage of cluster heads required in the network, $E_{residual}$ is the current residual energy of the node and E_{max} is the maximum energy corresponding to the fully charged battery. HEED is a fully distributed routing technique and achieves load balancing and uniform cluster head distribution. Disadvantages of HEED include more cluster heads are generated than expected and it is not aware of heterogeneity.

3.2.5 Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN) [18]: TEEN is a hierarchical clustering protocol, which groups sensors into clusters with each led by a CH. After the formation of clusters, the cluster heads broadcast two threshold values to ordinary sensor nodes known as hard threshold (Ht) and soft threshold (St). Hard threshold denotes the minimum value for an attribute beyond which the node should turn on its transmitter and send data to cluster head. Soft threshold refers to the small change in value of attribute for which the node should turn its transmitter on and transmit the sensed value to the cluster head. This protocol significantly reduced the number of transmissions between ordinary sensor nodes and the cluster head, thus saving a huge amount of energy. TEEN is useful for applications where the users can control a trade-off between energy efficiency, data accuracy, and response time dynamically. TEEN uses a data-centric method with hierarchical approach. Important features of TEEN include its suitability for time critical sensing applications. Also, since message transmission consumes more energy than data sensing, so the energy consumption in this scheme is less than the proactive networks. However, TEEN is not suitable for sensing applications where periodic reports are needed since the user may not get any data at all if the thresholds are not reached.

3.2.6 Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN) [19]: APTEEN is an improvement to TEEN to overcome its shortcomings and aims at both capturing periodic data collections (LEACH) and reacting to time-critical events (TEEN). Thus, APTEEN is a hybrid clustering-based routing protocol that allows the sensor to send their sensed data periodically and react to any sudden change in the value of the sensed attribute by reporting the corresponding values to their CHs. The architecture of APTEEN is same as in TEEN, which uses the concept hierarchical clustering for energy efficient communication between source sensors and the sink. APTEEN supports three different query types namely,

(i) Historical query, to analyze past data values.

(ii) One-time query, to take a snapshot view of the network.

(iii) Persistent queries, to monitor an event for a period of time.

APTEEN guarantees lower energy dissipation and a larger number of sensors alive.

3.2.7 Energy Efficient Inter Cluster Coordination Protocol (EEICCP) [20]: In existing routing protocols cluster heads send data directly to the base station, it is found that direct transmission by the CHs is not an optimal solution and dissipates a lot of energy, so a new novel EEICCP protocol has been proposed which evenly distributes the energy load among the sensor nodes and use the multi hop approach for the CHs .Energy consumption in conventional protocols increases due to multi path fading channel which affects the network life time. In EEICCP an attempt has been made to reduce this power loss. The arrangements of the nodes has been done in this way that one cluster always, is very close to the base station i.e. in line of sight propagation and that cluster will have head nodes sufficient for all the below clusters which will forward the data of all those clusters. Layers of clusters have been formed so there is always one cluster coordinator for every lowest cluster. The division of clusters is done from top to bottom. EEICCP protocol works by starting the election phase in which the cluster heads are elected according to the distance based on the received signal strength (RSS). Number of clusters is fixed so as the cluster heads and the cluster coordinators. After election of cluster coordinators by the CHs, a cluster id is assigned to each cluster head and the cluster coordinator. This id is transmitted by each cluster to their nodes by the advertisement message. After that the transmission phase begins in which data is transferred to the cluster head and that data is passed to the base station with the help of the cluster coordinators (CCOs). In first round the data is collected by the CH of that cluster which has data to send, then in the other iterations the data is passed to the base station with the help of cluster co-coordinators. The path is set for the data transmission with the help of the cluster coordinators ids. EEICCP has shown remarkable improvement over already existing LEACH and HCR protocols in terms of reliability and stability.

3.3 Location-based Routing protocols

Routing algorithms based on geographical location is an important research subject in the WSN. 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. To save energy, some location based schemes demand that nodes should go to sleep if there is no activity. More energy savings can be obtained by having as many sleeping nodes in the network as possible. In this section, we review most of the location or geographic based routing protocols.

3.3.1 Geographic Adaptive Fidelity (GAF) [21]: GAF is an energy-aware location-based routing algorithm designed primarily for mobile ad hoc networks, but may be applicable to sensor networks as well. The network area is first divided into fixed zones and forms a virtual grid. Inside each zone, nodes collaborate with each other to play different roles. For example, nodes will elect one sensor node to stay awake for a certain period of time and then they go to sleep. This node is responsible for monitoring and reporting data to the BS on behalf of the nodes in the zone. Hence, GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. 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. Such equivalence is exploited in keeping some nodes located in a particular grid area in sleeping state in order to save energy. Thus, GAF can substantially increase the network lifetime as the number of nodes increases. There are three states defined in GAF. These states are **discovery**, for determining the neighbors in the grid, **active** reflecting participation in routing and **sleep** when the radio is turned off. In order to handle the mobility, each node in the grid estimates it's leaving time of grid and sends this to its neighbors. The sleeping neighbors adjust their sleeping time accordingly in order to keep the routing fidelity. Before the leaving time of the active node expires, sleeping nodes wake up and one of them becomes active. GAF is implemented both for non-mobility (GAF- basic) and mobility (GAF-mobility adaptation) of nodes.

3.3.2 Greedy Perimeter Stateless Routing (GPSR) [22]: GPSR 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. GPSR benefits all stem from geographic routings use of only immediate-neighbor information in forwarding decisions.

3.3.3 SPAN [23][24]: Another position based algorithm called SPAN selects some nodes as coordinators based on their positions. The coordinators form a network backbone that is used to forward messages. A node should become a coordinator if two neighbors of a non-coordinator node cannot reach each other directly or via one or two coordinators (3 hop reachability). New and existing coordinators are not necessarily neighbors in which in effect, makes the design less energy efficient because of the need to maintain the positions of two or three hop neighbors in the complicated SPAN algorithm.

3.3.4 Geographic and Energy Aware Routing (GEAR)[25]: Geographic and Energy Aware Routing algorithm or simply known as GEAR 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.

3.3.5 The Greedy Other Adaptive Face Routing (GOAFR) [26]: A geometric ad-hoc routing algorithm combining greedy and face routing was proposed. We will now briefly review the key points of GOAFR in this section. The greedy algorithm of GOAFR always picks the neighbor closest to a node to be next node for routing. However, it can be easily stuck at some local minimum, i.e. no neighbor is closer to a node than the current node. Other Face Routing (OFR) is a variant of Face Routing (FR). The Face Routing (FR) algorithm is the first one that guarantees success if the source and the destination are connected. However, the worst-case cost of FR is proportional to the size of the network in terms of number of nodes. The first algorithm that can compete with the best route in the worst-case is the Adaptive Face Routing (AFR) algorithm. Moreover, by a lower bound argument, AFR is shown to be asymptotically worst-case optimal. But AFR is not average-case efficient. OFR utilizes the face structure of planar graphs such that the message is routed from node s to node t by traversing a series of face boundaries. The aim is to find the best node on the boundary, i.e., the closest node to the destination t by using geometric planes. When finished, the algorithm returns to s the best node on the boundary. It was shown that GOAFR algorithm can achieve both worst-case optimality and average case efficiency. It is shown that GOAFR outperforms other prominent algorithms, such as GPSR or AF

4. COMPARISSION OF ROUTING PROTOCOLS

ROUTING PROTOCOLS	CLASSIFICATION	MOBILITY	POWER USAGE	DATA AGGREGATIO N	SCALABILITY	MULTIPATH
SPIN	FLAT	POSSIBLE	LIMITED	YES	LIMITED	YES
DD	FLAT	LIMITED	LIMITED	YES	LIMITED	YES
RR	FLAT	VERY LIMITED	N/A	YES	GOOD	NO
COUGAR	FLAT	NO	LIMITED	YES	LIMITED	NO
ACQUIRE	FLAT	LIMITED	N/A	YES	LIMITED	NO
LEACH	HIERARCHICAL	FIXED BS	MAX.	YES	LIMITED	NO
LEACH-C	HIERARCHICAL	FIXED BS	LIMITED	YES	LIMITED	NO
PEGASIS	HIERARCHICAL	FIXED BS	MAX.	NO	GOOD	NO
HEED	HIERARCHICAL	FIXED BS	LIMITED	YES	LIMITED	YES
TEEN	HIERARCHICAL	FIXED BS	MAX.	YES	GOOD	NO
APTEEN	HIERARCHICAL	FIXED BS	MAX.	YES	GOOD	NO
EEICCP	HIERARCHICAL	FIXED BS	LIMITED	YES	LIMITED	POSSIBLE
GAF	LOCATION	LIMITED	LIMITED	NO	GOOD	NO
GPSR	LOCATION	LIMITED	MAX.	NO	LIMITED	YES
GEAR	LOCATION	LIMITED	N/A	NO	LIMITED	NO
SPAN	LOCATION	LIMITED	N/A	NO	LIMITED	NO
GOAFR	LOCATION	NO	N/A	NO	GOOD	NO

Table 1: Classification and comparison of routing protocols in wireless sensor networks

5. CONCLUSION

Routing in sensor networks is a new area of research, with a limited, but rapidly growing set of research results. In this paper, we presented a comprehensive survey of routing techniques in wireless sensor networks which have been presented in the literature. They have the common objective of trying to extend the lifetime of the sensor network, while not compromising data delivery. Overall, the routing techniques are classified based on the network structure into three categories: flat, hierarchical, and location based routing protocols. Although many of these routing techniques look promising, there are still many challenges that need to be solved in the sensor networks. We highlighted those challenges and pinpoint future research directions in this regard.

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