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A Study on Classification of Energy Efficient Routing Protocols in Wireless Sensor Networks

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Abstract:
The recent advances in integrated circuit technology, microelectro mechanical system technology, Adhoc network routing protocol, distributed signal processing and embedded systems have enabled the development of low cost, low power, network enabled and multifunctional wireless sensor network environment. The most important thing of a routing protocol, in order to be efficient for WSN, is the energy consumption and the extension of networks life time. Wireless sensor networks are initially designed for monitoring and reporting events, nowadays it is used for variety of applications. As every application has distinct requirement single Routing protocol is inefficient. We classify energy efficient routing protocols into three main schemes as data-centric, hierarchical and location based routing. This comparison reveals the important design issues that need to be taken into consideration while designing and evaluating network protocol.

Keywords: *Data-centric protocols, energy efficient protocols, hierarchical protocols, location based protocols, routing protocols, wireless sensor network.*

1. Introduction

WSN is a self-organization wireless network system that incorporates a tiny or huge amount of nodes called sensor nodes. Sensor nodes may vary in size and based on their size, these nodes work in different ways in different fields. Every sensor node can act both as a sensor and a router provided with its computing ability, storage capacity, communication ability and with its limited power supply [1]. A large number of sensor nodes are deployed carefully or randomly over a geographical area.

A WSN node consists of sensor module, Processing module, wireless communication module and power supply module [2]. A sensor module is responsible for collecting information such as humidity, temperature, intensity, pressure, vibration, motion, sound etc. at different locations and returning these data to ADC [11]. A processing module is responsible for carrying out a simple computation over the collected data and handing over them to a communication module. A microcontroller equipped within the processor controls the monitoring process and interprets the query to ADC. A wireless communication module includes a radio transceiver that generates radio waves. It is designed to receive a command or query from and transmit the data from CPU to the outside world. A power supply module provides power to sensor, processing and communication modules. In WSN it is necessary to consider the resource constraints such as low processing power, small memory and limited energy of sensor nodes [5], [6].

Initially WSNs was designed for military and defense industries for sensing intruders, detection of enemy movement. But in current days it has been used in a wide variety of applications and systems with varying requirements [2], [3]. WSN may be used monitoring air pollution, observing biological and artificial systems and for habitual monitoring. These networks may also be used in emergency situations such as during disaster management and hazardous chemical levels and fires. Industrial operations such as factory process control, automation may also benefit from this WSN. Moreover, the use of WSN s on medical field may ease the operations by providing sensors for blood flow, ECG, pulse oxymeter, blood pressure, respiratory rate and fro oxygen measurement. They may also be used in home networks, agriculture, traffic control, water industry for monitoring and controlling.

2. Routing Protocol

The routing strategies are considered as an important issue for the delivery of packets to their destinations. Routing algorithms for WSNs can be classified by many different ways such as node-centric, data centric or location aware and QoS based routing protocol [7].

In node-centric protocols, the destinations are specified based on the numerical addresses or identifiers of nodes. It is the common type of communication adapted in networks but not suitable for WSNs. Routing protocols designed for WSNs may also be data-centric or location aware (geo-centric). In data-centric routing, the sink will make queries to the specified region of the network and waits for collecting data from the sensor nodes of the specified region. As more sensors transmit the data for a single query, there exists a possibility of redundancy. In location aware routing sensor nodes can know where they are in, with in the geographical region. This location information can be used to improve the performance when the queries are made. In QoS based routing certain factors are taken into account such as high data delivery ratio, low latency and low energy consumption.

Routing protocols can also be classified based on whether they are proactive or reactive [2], [10]. In proactive protocols, a path is setup well in advance between all the sensor nodes and maintained in a table. Routes are maintained even there is no demand for the traffic flow at that time. These types of protocols are also termed as table-driven protocols. In reactive routing protocols, the paths are setup only when there is a demand for it. Routing actions are initiated when there is a need for data to be sent or received. As the routes are discovered on demand, these routing protocols are also termed as demand-driven protocols.

Routing protocols can also be classified based on from where it is initiated [3]. In source- initiated protocol, routing paths are set up based on the demand of the source node. Here path starts from the source node. In source-initiated protocol, the source advertises the data when it is available and initiates the data delivery to other sensor nodes. On the other hand, in destination-initiated protocol, the destination initiates the path setup from it.

Routing protocols can also be classified based on the underlying architecture [6]. Normally there are two types of sensor nodes are available in WSN namely homogeneous nodes where all nodes are treated equally and heterogeneous nodes in which it differs in its operation. Routing protocols can also be classified based on whether they are working under a flat topology or hierarchical topology. In former type all nodes in the network are treated equally. But in latter some of the nodes are considered to be more powerful than other nodes. The hierarchy may depend on any factor that is particular for the application. In hierarchical routing protocol, many numbers of nodes may be grouped to form a cluster and the communication between the clusters is through the cluster heads.

Routing protocols may also be classified based on the operation of the protocol such as Query-based routing, Negotiation –based routing, multi-path routing, coherent and non-coherent routing protocols [4], [8]. In query-based routing protocol, a base station or any other sensor node sends queries to find the specific events through the WSN; a node sends the data that matches the query back to the node initiated. Negotiation based routing protocol is an inter domain routing based on dynamic negotiation between the source, intermediate and destination sensor nodes. These protocols use high level data or information descriptors to remove redundant data transmission. In multipath routing protocol, the traffic is spread out from a source node to a destination node over multiple alternative paths throughout the network. The multiple paths computed might be overlapped, edge disjointed or node disjointed with each other. In coherent based routing protocol, data is forwarded to aggregators after processing by applying some functions like max, min, count and duplicate suppression. This aggregation method is implemented to conserve a huge amount of energy when the transmission of data requires more energy compared to the processing. In non-coherent data the nodes can locally process the raw data before sent to other nodes for further processing.

3. Classification of Routing Protocols

3.1. Data centric Routing Protocols

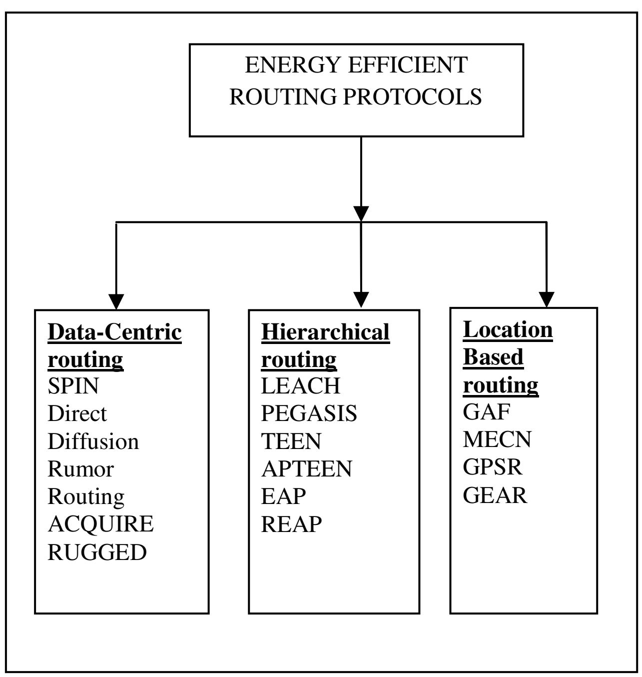

Figure 1: Classification of Routing Protocols

3.1.1. Sensor Protocols for Information via Negotiation (SPIN)

SPIN is a negotiation based information dissemination protocols used in WSN [2],[4],[7]. It rests upon two basic ideas.

1. To work under conserved energy mode, application need to communicate each other about their existing data and required data.
2. To monitor and adapt to the changes to extend the lifetime of the network.

In this protocol, the nodes name their data using high level descriptors called metadata. Metadata is used to negotiate and avoid the transmission of the redundant data.

The transmission of a node is based on both the application specific knowledge of the data and the knowledge of the resources available to them.

Handshaking in SPIN occurs in following three stages.

ADV (Advertise): If a node has some data, it will advertise by sending ADV packet.

REQ (Request): The nodes receiving the ADV packet, if interested then it will send request packet.

DATA (Data): Upon receiving the request packet, the node will send actual data packet.

SPIN provides good scalability as each node needs to know only its single hop neighbors. The main issue with SPIN is that it does not guarantee delivery of data.

SPIN family of protocols include SPIN-PP (SPIN for Point to Point communication), SPIN-EC (SPIN with Energy Conservation), SPIN-BC (SPIN for Broadcast networks) and SPIN-RC (SPIN with Reliability).

3.1.2. Direct Diffusion

Direct diffusion [2], [4] is a data centric query based and application-aware protocol. Data aggregation is carried out at each node in the network. It implements caching and minimizing the number of transmission and overall energy consumption [2].

DD includes several elements.

Naming: All data generated by sensor nodes are named by attribute –value pair. The interest queries are disseminated throughout the sensor network as an interest for named data. Attributes may be the type of data, interval of transmission data, time duration etc.

Interests and gradient: Every sensor node maintains an interest cache for data matching attributes. A gradient specify data rate and direction state of each node that receives an interest and they are set up within the network.

Data Propagation: Once a sensor node detects a target, it searches the cache for matching interest entry.

Reinforcement: Events obtaining from multiple paths are reinforced into minimal number of paths.

Directed Diffusion has the potential to reduce significant amount of energy and extend the network life time. Caching can increase the efficiency, robustness, and scalability of coordination between sensor nodes, which is the essence of the data diffusion paradigm. But data aggregation in Direct Diffusion is affected by many factors such as position of the source nodes, number of sources and network topology.

3.1.3. Rumor Routing

Rumor routing uses an alternative approach called Flooding. It routes the queries to the events in the network and it offers tradeoff between setup overhead and delivery reliability [2],[4]. An event is an abstraction obtained from a set of sensor readings and a query is a request for information sent by the interested node. A Query may be raised by any node expecting an event. RR algorithm employs agents, long lived packets to flood the events through the network. Agents travel the network to obtain the information about the local events to the distant nodes.

The Number of transmissions in total become N*Q, where N represents the number of nodes and Q represents the Queries. Rumor routing is a logical compromise between flooding queries and flooding event notifications [9]. It is the energy efficient method and guarantees the delivery of data as flooding is employed. The main disadvantage of Rumor Routing is that it is expensive as flooding increase the number of transmissions.

3.1.4. ACtive QUery forwarding in sensoR nEtworks (ACQUIRE)

ACQUIRE [2] considers query as an active query that is routed through the network in search of solution. A query sent from base station node is forwarded by every sensor node receiving the query. At each node, the query is forwarded using the information from all nodes within d hops, which resolves the query partially by its own pre-cached information before forwarding it to another sensor node. If the preached information is not up-to-date, the information is gathered from neighbor to resolve it completely. At the node where the query gets resolved completely, a response is generated and sent back through reverse or shortest path to base station.

ACQUIRE can deal with complex queries by allowing many sensor nodes to take part in resolving the query. It selects the shortest path to minimize the energy consumption. The ACQUIRE protocol is well suited for one shot, complex queries for replicated data. The average latency of ACQUIRE in answering a query is far better than a random walk. But it is not scalable as Directed Diffusion.

3.1.5. Gradient based routing (GBR) – RoUting on finGerprint Gradient in sEnsor Networks (RUGGED)

Every physical event occurring in the environment results in a natural information gradient in the proximity of the phenomenon. Such information is considered as fingerprint of the event caused by the events effect. RUGGED protocol routes the query to the event by effectively utilizing the finger print of the event.

In GBR [4] each node calculates the minimum number of hops namely the height of the node to reach the base station. The main idea is to memorize the number of hops when the interest is diffused through the whole network. It eliminates the overload of preparing and maintaining the gradient information packet is sent with the largest gradient and the techniques data aggregation and traffic spreading are employed. Based on data dissemination technique GBR is classified into three types such as stochastic, energy-based and stream based scheme.

RUGGED uses an environmental model in which the network is divided into two regions -1) Flat region and 2) Gradient region. Gradient region is the space where sensor nodes are able to sense the region and the rest of the space is called a flat region. Initially a query is in a flat region mode and once it finds the sensing the event it automatically changed to gradient region mode.

3.2. Hierarchical routing techniques

In Hierarchical routing protocol nodes are grouped into clusters and every cluster has a cluster head. Clustering not limited to one level, it may be more than two levels having the same concepts of communication mechanism. A hierarchical protocol allows a network administrator to make best use of his fast powerful routers as backbone routers, and the slower, lower powered routers may be used for access purposes.

3.2.1. Low Energy Adaptive Clustering Hierarchy (LEACH)

Low Energy adaptive clustering hierarchy (LEACH)is known well for energy efficient adaptive clustering algorithm that forms node clusters based on the received signal strength. It is a cluster based protocol that randomly selects the sensor nodes as cluster heads and assigns this role to every sensor node in an evenly manner to distribute the energy load among the network.

The operation of LEACH is divided into many numbers of rounds where each round consists of setup phase, followed by a steady state phase.

In the Setup phase, the clusters are formed and cluster heads are selected. Cluster head collects the data, compress them and forward it to base station. It happens in the following sequence.

1. CH selection: Every round begins with a CH selection. If a node becomes a cluster head, then it cannot be a cluster head for the specified number of rounds.
2. Cluster Formation: Once the CHs have been selected, they advertise themselves to the remaining nodes. Based on the signal strength, the nodes decide which cluster to join.
3. Transmission Schedule Creation: Depending upon the number of nodes in the cluster, the CH allots different time slots for each node using time division multiple access (TDMA) scheduling.

In the steady state phase, the data aggregated from the various sensor nodes are sent to the base station by the cluster heads. The time duration of the steady state phase is longer than set up phase such that the data reaches the base station successfully.

LEACH can be easily configured and it enhances the network lifetime by utilizing the resources efficiently, distributing the load uniformly, aggregating data at the CH, rotating the CH randomly to achieve balanced energy consumption. But it is not recommended for large regions. Variations of LEACH such as LEACH-C (centralized), E-LEACH (enhanced) and MLEACH (multi-hop) can be used depending upon the application.

3.2.2. Power Efficient Gathering in Sensor Information System (PEGASIS)

PEGASIS is a chain based protocol in which each node communicates with their closest neighbor. The nodes are organized to form the chain either by the sensor nodes itself or by a greedy algorithm.BS are assumed to be fixed and it is at a far distance from the sensor nodes. Sensor nodes are homogeneous and energy constraint with uniform energy. The distance between the transmission and reception decides the energy cost. A complete database about the location of the sensor nodes is maintained by every sensor node.

The main advantage of PEGASIS includes increasing the network life time and minimizing the bandwidth usage as it allows only local coordination between the nodes that are close together. It is assumed that each node has global knowledge of the network; it is easy to employ the greedy approach to construct the chain. In PEGASIS there is no consideration of base Stations location and about the energy of the nodes when a sensor node is selected as cluster head.

3.2.3. Threshold sensitive energy efficient protocols (TEEN)

TEEN [2],[7] is a hierarchical protocol designed for checking sudden changes in the sensed attributes that may be given in terms of thresholds. In TEEN sensor nodes are formed into cluster and at every cluster change time, the CH broadcasts the threshold values along with its attributes to its member nodes. TEEN is targeted at the reactive network application where the nodes react immediately to the sudden changes in the sensed data and transmit it to the sink.

Two types of thresholds employed in TEEN are Hard Threshold (HT) and Soft Threshold (ST). Hard threshold is the absolute value of the distribution beyond which, the node sensing the value must switch on its transmitter and report to its CH. The data first transmission of every node depends on the hard threshold. The soft threshold is a small change in the value of the sensed attribute, which triggers the node to switch on its transmitter and transmit.

TEEN mainly focuses on time critical sensing applications. The soft threshold can be varied depending on the criticality of the sensed attribute and the target application. The user can change the threshold values at every cluster change time by broadcasting the new attributes. The message transmission consumes more energy than data sensing. TEEN works well in the environment where sudden changes in the sensed attributes are needed to be observed. There exists a trade-off between energy efficiency and accuracy.

The main drawback of this scheme is that, if the thresholds are not reached, the nodes will not communicate and the user will not get any data from the network at all. Moreover, it consumes more energy in large size networks and when the hierarchy is small.

3.2.4. Adaptive Threshold Sensitive Energy Efficient Protocol (APTEEN)

APTEEN [2],[7] is an improvement over TEEN which can transmit data based on the thresholds. It is applicable in both proactive and reactive networks and it can adapt itself to the application requirements. Once the CH is identified, the CH first broadcasts the attributes, threshold, schedule and count time. Attributes are the set of physical parameters in which the user is interested. Threshold specifies the limit that can be classified into Hard Threshold and Soft Threshold. Schedule is mostly a TDMA for assigning slot to each node and the count time is the maximum time period between two successive reports sent by a sensor node.

The important features of APTEEN include the combination of both reactive and proactive networks [9]. It behaves as proactive by transmitting periodic data, thereby giving a snapshot of the network to the user. It also responds to the drastic changes thus making it responsive to the time critical applications. Thus the network and it is energy consumption can be controlled by setting the count time and threshold values according to the application. But TEEN requires an additional overhead to implement threshold functions and count time.

3.2.5. Energy Aware Routing Protocol (EAP)

EAP takes into consideration the power level of each node and avoids using the nodes with the low energy. So that energy consumption of nodes is balanced to increase the lifetime of the network.

EAP is a hierarchical cluster based protocol implementing TDMA approach. The operation is divided into several rounds. As in LEACH, EAP initially selects the cluster head, forms the cluster, aggregate the data and the data is sent to the sink node using the two phases called set up phase followed by the working phase. The CH role is rotated evenly to all the sensor nodes as CH consumes more energy than member nodes. Every node in EAP maintains a neighborhood table to store the information about its neighbors. Initially each node broadcast the E-message with in its radio range. The nodes that receive the E-message are said to be in its cluster range and added to the neighborhood table.

EAP achieves a good performance in terms of lifetime by minimizing energy consumption for in-network communication and balancing energy load among all nodes.

3.2.6. Ring based Energy Adaptive Protocol (REAP)

In REAP the nodes self-organize in virtual ring bands centered from BS. BS gets the data packets from the nodes in the decreasing ring band number. The workload among neighboring nodes within the same ring band is balanced.

BS initiates the ring band formation process across the sensor nodes that are within its transmission range with the hop distance 1. These nodes are said to be belonged to ring band 1. The multiple ring bands are formed recursively by the nodes present in the previous ring band. Thus the i^{th} ring band is formed by the nodes present in ring band i-1, provided that the node does not belongs to the any one of the i-1 ring bands.

Once the ring band formation process is completed, the data is forwarded from outer ring bands to inner ring bands and finally to the base station. REAP uses power aware strategy in which the forwarding decision is made up by considering the residual energy and the number of attempts to forward the packet. If a node has sufficient energy to forward the packet, then it can do so otherwise the data packet is dropped. The dropped packet may be forwarded by some other sensor node that has the power enough to transmit towards the inner ring band. Thus the load is distributed among the neighboring nodes.

The confirmation is provided as the neighboring node overhears the transmission of data packets towards the inner ring band or to the Base Station. Hence an extra packet need not be sent in the form of ACK. Thus it avoids the collision and redundancy of packets.

REAP saves significant amount of energy by limiting the use of flooding. It is robust against node failures because it does not create and maintain the routing tables. Instead of routing table sensor nodes maintain the ring band number to which they belong to. REAP is scalable and the ring bands may be formed automatically when there exists failure of the nodes.

3.3. Location Based Routing

Location Based Routing algorithms are based on the geographical location. Here location information is used to guide route discovery and for route maintenance.LBR reduces the energy consumption and optimize the network by selecting the best path and by forwarding the packets through the path. The entire region is partitioned virtually and best routing scheme is employed based on the location.

3.3.1. Geographic Adaptive Fidelity (GAF)

GAF [7] is a location based routing protocol as well as an energy aware routing protocol. GAF conserves the energy by turning off the unnecessary nodes in the network that does not affect the level of routing. It forms a virtual grid for the entire region to be covered. The cost of routing is considered equal for all the nodes in the same point of virtual grid. By doing so, network lifetime can be increased. Three operations involved in this protocol includes discovery, determining neighbors in the grid and representing the active nodes that participate in routing and the sleeping nodes in which the radio is turned off.

GAF keeps the network alive for longer period of time as it switches off the transceiver of some sensor nodes that do not take part in packet forwarding process. It keeps a representative node always in active mode for each region on its virtual grid. Once the number of active nodes starts diminishing, it wakes up the sleeping nodes thereby balancing the energy of the network. As clusters are based on the geographical location, it can also be considered as a hierarchical protocol.

3.3.2. Minimum Energy Communication Network (MECN)

MECN [7] is a location based routing protocol that first identifies a relay region that consists of the sensor nodes in a surrounding area where transmission through those nodes is more energy efficient than directly transmitting the packet. It has two phases namely construction of a sparse graph and optimization of links. In first phase, it constructs a sparse graph or enclosure graph by taking positions of a two dimensional plane requiring local computation. The enclosure graph is a graph that contains globally optimal links in terms of energy consumption. Next phase includes finding an optimal links on the graph using Belmann Ford algorithm.

MECN maintains a minimum energy network for wireless networks by utilizing low power GPS. This protocol can be used for mobile networks as well as for sensor networks. A master node is included to a minimum power topology for stationary nodes. MECN assumes a master-site as the information sink, which is always the case for sensor networks. MECN is self-organizing and dynamically adapts to nodes failure or the deployment of new sensor nodes. Small Minimum Energy Communication Network (SMECN) is an extension of MECN in which possible obstacles between any pair of nodes are considered.

3.3.3. Greedy Perimeter Stateless Routing (GPSR)

The Greedy Perimeter Stateless Routing (GPSR) is a responsive, efficient location based routing protocol based on the position of routers and packets destination to make a forwarding decision. GPSR exploits the correspondence between geographic position and connectivity in WSN, by using the positions of the nodes to make forwarding decision. The packets are forwarded using Greedy approach. It makes the decision based on the information about a router’s immediate neighbors in the network topology. In GPSR initially packets are try to be forwarded using greedy approach. If a packet cannot be forwarded using greedy approach, then it takes an alternative method called perimeter routing where routing around the perimeter of the region. 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. As the network topology changes frequently, it identifies a new route using the local topology information. In GPSR sensor nodes use beacons to know their neighbor nodes. If a beacon is not received for a specified period of time, then the node is considered as failed and it is removed from the neighborhood table. The beacons time interval should be in such a way that it recognizes whether a sensor node is in or out of the range and to update the table according to that.

GPSR routing algorithm is robust in delivering the packets on densely deployed networks. It generates a traffic that is independent of the length of the routes through the network. GPSR benefits from geographic routings as it only immediate-neighbor information in forwarding decisions.

3.3.4. Geographic and Energy Aware Routing (GEAR)

Geographic and Energy Aware Routing algorithm is a Location based routing protocol as well as energy efficient one [4],[7]. It uses the energy aware neighbor selection to route a packet towards a target region. It uses recursive geographic forwarding algorithm or restricted flooding algorithm. Here the packet forwarding process in a target region depends upon two characteristics.

If a neighbor node is closer to the destination node, GEAR chooses a next –hop node among all neighbors that are closer to the destination.

If all neighbors are far away, then there is a presence of hole to which it chooses a next hop node which minimizes the cost value of the neighbor.

The next step is to disseminate the packets inside the target region. Simply flooding with duplicate suppression may also be used, but flooding is expensive in terms of energy consumption in highly densed network.

GEAR enables longer network lifetime than non-energy aware routing algorithm particularly with non-uniform traffic distribution. It is very much sensitive to the location error. GEAR selects different path every time to make the network alive. But when GEAR uses recursive forwarding, the algorithm does not terminate in an empty target region.

4. Design Issues

Initially WSNs was mainly motivated by military applications. Later on the civilian application domain of wireless sensor networks have been considered, such as environmental and species monitoring, production and healthcare, smart home etc. These WSNs may consist of heterogeneous and mobile sensor nodes, the network topology may be as simple as a star topology; the scale and density of a network varies depending on the application. To meet this general trend towards diversification, the following important design issues of the sensor network have to be considered [2],[8].

4.1 Fault Tolerance

Sensor nodes are subjected to fail or to be blocked due to physical damage, power constraints and environmental interference. The failure of sensor nodes should not affect the overall task of the sensor network. This is termed as reliability or fault tolerance issue. Fault tolerance is the ability to sustain sensor network functionalities without any interruption because of sensor node failures.

4.2 Scalability

Scalability is an important factor in designing an efficient routing protocol for WSN.A WSN can consist of hundreds, thousands or more number of sensor nodes and routing schemes must be scalable enough to respond to events. A good routing protocol has to be scalable and adaptive to the changes in the network topology. It must perform well when the network grows larger or as the workload increases.

4.3 Production Costs

The number of sensor nodes in WSN may be in the order of hundreds and thousands. The cost of a single sensor node plays a vital role, as it will justify the overall cost of the networks. So the cost of each sensor node is expected to be low.

4.4 Operating Environment

Based on the application, the operating environment of the sensor nodes may vary. Sensor network may be set up with in a battle field, inside of the large machines, at the oceans, in the forest for habitat monitoring, in a residential area, in a chemical field, in automotive machineries, in a biologically contaminated field, attached to a vehicle even attached with a person for tracking and monitoring.

4.5 Power Consumption

The transmission power required for the wireless radio is directionally proportional to the square of the distance between the transmitter and the receiver. It may be even higher in the presence of obstacles. So multi-hop routing may be opted to consume less energy than direct communication. But it is associated with the overhead for topology management and medium access control.

4.6 Data Delivery Models

The models that decide when the data collected has to be delivered are named as data delivery models. There are variety of data delivery model depends upon the application such as Continuous, Event driven, Query-driven and Hybrid. In the continuous delivery model, each sensor sends data periodically. In event-driven models, the transmission of data is triggered when an event occurs. In query driven models, the transmission of data is triggered when query is generated by the sink. Some networks apply a hybrid model using a combination of continuous, event-driven and query driven data delivery.

4.7 Data Aggregation/Fusion

Data aggregation is the process of combining the data from different sources by using certain functions such as minimum, maximum, count, average or even certain user defined functions [8]. It may also be a suppression that eliminates redundant data. As similar packets from multiple nodes can be aggregated, the number of transmissions would be reduced. As computation would be less energy consuming than

Routing protocol	Classification	Power usage	Data Aggregation	Scalability	Query Based	Overhead	Data delivery model	QoS
SPIN	Flat/Source initiated/Data centric	Limited	Yes	Limited	Yes	Low	Even driven	No
DD	Flat/Destination initiated/Data Centric	Limited	Yes	Limited	Yes	Low	Demand driven	No
RR	Flat	Low	Yes	Good	Yes	Low	Demand driven	No
ACQUIRE	Flat/Data centric	Low	Yes	Limited	Yes	Low	Complex query	No
RUGGED/ GBR	Flat	Low	Yes	Limited	Yes	Low	Hybrid	No
LEACH	Hierarchical/ Destination initiated/Node centric	High	Yes	Good	No	High	Cluster head	No
PEGASIS	Hierarchical	Max	No	Good	No	Low	Chain based	No
TEEN	Hierarchical	High	Yes	Good	No	High	Active threshold	No
APTEEN	Hierarchical	High	Yes	Good	No	High	Active threshold	No
EAP	Hierarchical	Low	Yes	Limited	No	Moderate	Cluster head	No
REAP	Hierarchical	Low	No	Good	No	High	Virtual ring band	No
GAF	Hierarchical /Location	Limited	No	Good	No	Moderate	Virtual grid	No
MECN	Location	Low	Yes	Good	Yes	High	Master node	No
GPSR	Location	Limited	No	Limited	No	Moderate	Greedy	No
GEAR	Location	Low	No	Limited	yes	Moderate	Demand driven	No

Table 1: Routing protocols with their design issues communication, substantial energy savings can be obtained through data aggregation. This technique has been used to achieve energy efficiency and traffic optimization in a number of routing protocols.

4.8. Quality of Service

The quality of service is the measure of expected service required by the application. It could be the throughput, network life time; the data transfer rate, data packet transmission rate, the data reliable, energy efficiency, location-awareness, collaborative-processing and load parameters. These factors will affect the selection of routing protocols for a particular application.

4.9. Data latency and Overhead

Data latency and several overheads play a vital role in designing the routing protocol. Data aggregation and multi-hop routing may cause data latency, some routing protocols create excessive overheads to implement their algorithms, which are not suitable for serious energy constrained networks.

4.10. Node deployment

Deploying the sensor nodes in an environment is purely application dependent. There are two methods of deployment namely deterministic and self- organizing. In deterministic, the nodes are manually placed and data is routed through the pre-determined path. But in self organizing, the nodes are scattered randomly. Whatever may the deployment model, the position of cluster head is significant to decide the entire network performance and energy, so cluster head should be optimally positioned.

5. Conclusion

In this paper, we presented the strengths and weaknesses of each protocol by providing a classification and comparison by considering the important design issues. As sensor networks are designed for the specific applications, there may be different requirements of QoS. From this study, it is clear that it is impossible to design a routing algorithm that may give high performance for all applications under all scenarios. But while designing the routing algorithm, these design issues may be considered to obtain comparatively better performance.

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