Energy Efficient Routing Protocols for Wireless Sensor Networks

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***Abstract*—Sensor networks have become an emerging new tool for habitat monitoring in nature preserves, it monitors and gathering events in hazardous environments, it does the work of buildings surveillance, monitoring the enemy activities in a battlefield environment. Sensor nodes have limited energy resources, less storage capacity and they are energy constrain. Efficient routing protocols are very critical to design in order to prolong the lifetime of the sensor nodes. Sensor networks are mainly designed for monitoring and reporting events though sensor nodes are application dependent, designing a single routing protocol cannot be efficient for sensor networks for all applications. In this paper, we first analyze the requirements, similarities and distinguish between sensors networks and MANETs (Mobile Ad hoc Networks). We look at the existing routing protocols for sensor networks and present a critical analysis of these protocols. The cluster based protocols are energy efficient & prolong the network lifetime when compared to other protocols.**

I. INTRODUCTION

As a result of advances in sensor technology and wireless communication, sensor networks have emerged as an indispensable and important new tool for tracking contamination in hazardous environments, habitat monitoring in the nature preserves, enemy tracking in battlefield environments, traffic monitoring, surveillance of buildings, etc. When compare to the existing network models MANETs (Mobile Ad hoc Networks) have found to be the closest to sensor networks that share many characteristics. For example, the nodes in sensor network are randomly distributed and the network topology is not fixed; there is no electricity supply & battery driven power is a limiting resource. Nodes in the network are connected to each other in wireless fashion via communication links.

MANETs are infra-structure less wireless communication networks where the nodes which are present in MANETs act as both hosts as well as routers. MANETs are collection of wireless mobile hosts which form a temporary network without the aid of any established infrastructure.

Features of MANETs are:

- MANETs have dynamic topology. The network topology in MANETs can change any time because of node mobility and nodes may become disconnected very frequently.
- There is no centralized administrator.
- MANETs nodes have short transmission range. The routes between nodes have one or more hops.
- MANETs nodes act as routers or they depend on others for routing.
- In MANETs the movement of nodes invalidates topology information.

The protocols and techniques which are developed for MANETs cannot be applied to sensor networks because the two networks vary many factors some of them are given below [1].

- Sensor networks are mainly focus on information gathering likewise the MANETs are designed for distributed the information.
- The deployment of sensors is done by one owner, while MANET could be deployed by several unrelated units.
- The magnitude of sensor nodes in sensor networks is higher than that of MANETs [1].
- Each Sensor network nodes will have unique id unlike MANETs nodes which do not have a unique ID [1].
- The nodes in sensor are much cheaper than nodes in a MANETs.
- Sensor nodes are battery operated with cannot be recharged however, nodes in a MANET is recharged somehow.
- The flow of data in sensor networks is either from sink to the nodes or from nodes to the sink while in MANET, the flow of data is irregular.
- The nodes in sensors are deployed once in lifetime, while The nodes in MANET move in an ad hoc manner.
- Sensor nodes have many limitation such as they are energy constrain, limited power supply, limited communication capability than MANETs.

Many researchers have shown interest in sensor networks and they have focused on critical issues to invent new protocol which are energy efficient, low cost, which are power aware, secure, fault tolerant. In this paper, we analyze the issues that are involved in designing efficient routing protocols and compare and contrast the existing routing protocols. This comparison helps in identifying many issues in the area of routing for sensor networks.

II. SENSOR NETWORK ARCHITECTURE AND REQUIREMENTS

First we look how at sensor network architecture and its requirements than we discuss on routing protocols. The deployment of sensor nodes is in the range of hundreds to thousands which are randomly distributed in wide area. The nodes in the network try to communicate with each other directly or with the help of other neighbour nodes. One of the nodes among them will act as a sink. The sink is capable of communicating with the user either directly or through some existing wired networks connection [2].

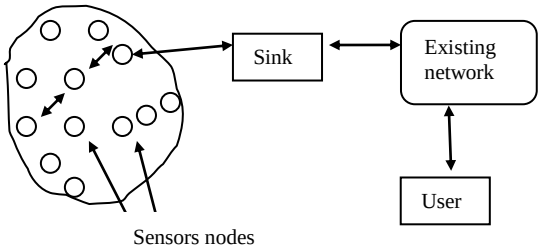

Fig 1. Sensor node architecture

Figure 1 shows the architecture of a sensor network in which sensor nodes are placed randomly which are shown as small circles. The arrow indicated the direction in which data transfers. Each node when it senses the information will aggregate the data and transfer to the neighbour nodes. The neighbour nodes will ultimately help to transfer the data to the sink. If the node is near to the sink then it will transfer the data directly to it. If the node is far from sink then it takes help of other neighbour nodes to transfer the data to the sink. The transfer can be single hop or multi hop depending on how far the node is located from the sink. Once the information is transferred to the sink the user no matter in may be present in any part of the world can access the information sensed by the sensor via existing network connection which can be either wired or wireless connection.

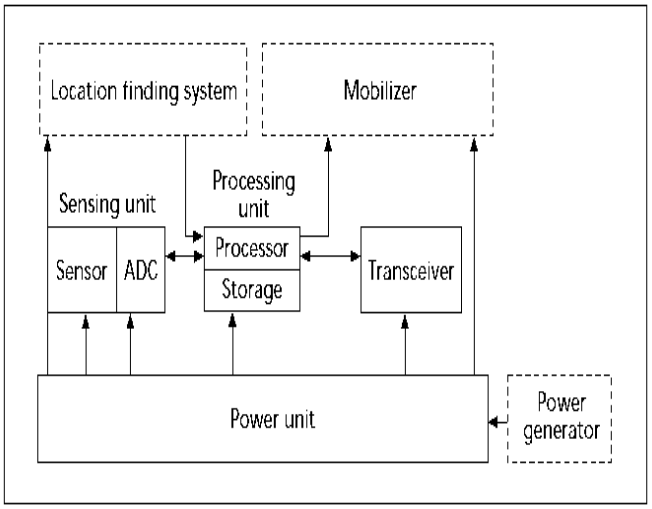

Fig 2. Sensor node components

Each sensor node mainly consists of the five major components which are shown in Figure 2: sensor unit, analog to digital convertor (ADC), central processing unit (CPU), power unit, and communication unit. The sensor unit has two parts one is sensor to sense the data & the other is ADC which is responsible for converting sensed information to digital form. ADC is a translator that informs the CPU what the sensor unit has sensed & informs the sensor unit what to do. Communication unit function is to receive command or the query & transmit the data from CPU to the outside world. CPU is the most important & complex unit. The next unit is the processing unit, the sensed data is processed & the processed data need to be stored in the storage unit. The transceiver unit is the one which connect the node to the network. The power unit will supply power to the node. The power can be supplied by using solar cells. These are the five main components. In some application where we want to find the location of the node in the network than the location finding system is used. In some application where the nodes need to be moved from one place to another than mobilizer is used.

III.WIRELESS SENSOR NETWORKS ROUTING PROTOCOLS

The classification of the routing protocols based on protocol operation & network structure. Based on the classification on how the sender of a message discovers a route to the receiver the routing protocols can be classified into three categories, namely, proactive, reactive & hybrid protocols.

***Proactive protocols*:** In proactive protocols, all routes are computed before they are really needed. It maintains routes between every host pair at all times. Routes are calculated and maintained beforehand. It maintains the routes which may never be used. It is based on periodic updates. It has high routing overhead.

•Example: DSDV (destination sequenced distance vector)

***Reactive protocols*:** It determines the route if and when needed. Routes are calculated on-demand. Source will initiate the route discovery. Lower overhead since routes are determined on demand i.e., when it want to send data. It has significant delay in route determination. It employs flooding (global search). Control traffic may be bursty. It has a better trade-off depends on the traffic and mobility patterns

•Example: DSR (dynamic source routing).

***Hybrid protocols*:** It is adaptive in nature. It uses a combination of these two ideas of proactive and reactive. Since sensor nodes are limited in energy, storage, power and the number of nodes in the network could be very large, sensor nodes cannot afford the storage space for large routing tables. Therefore reactive and hybrid routing protocols are attractive in sensor networks.

•Example: ZRP (zone routing protocol)

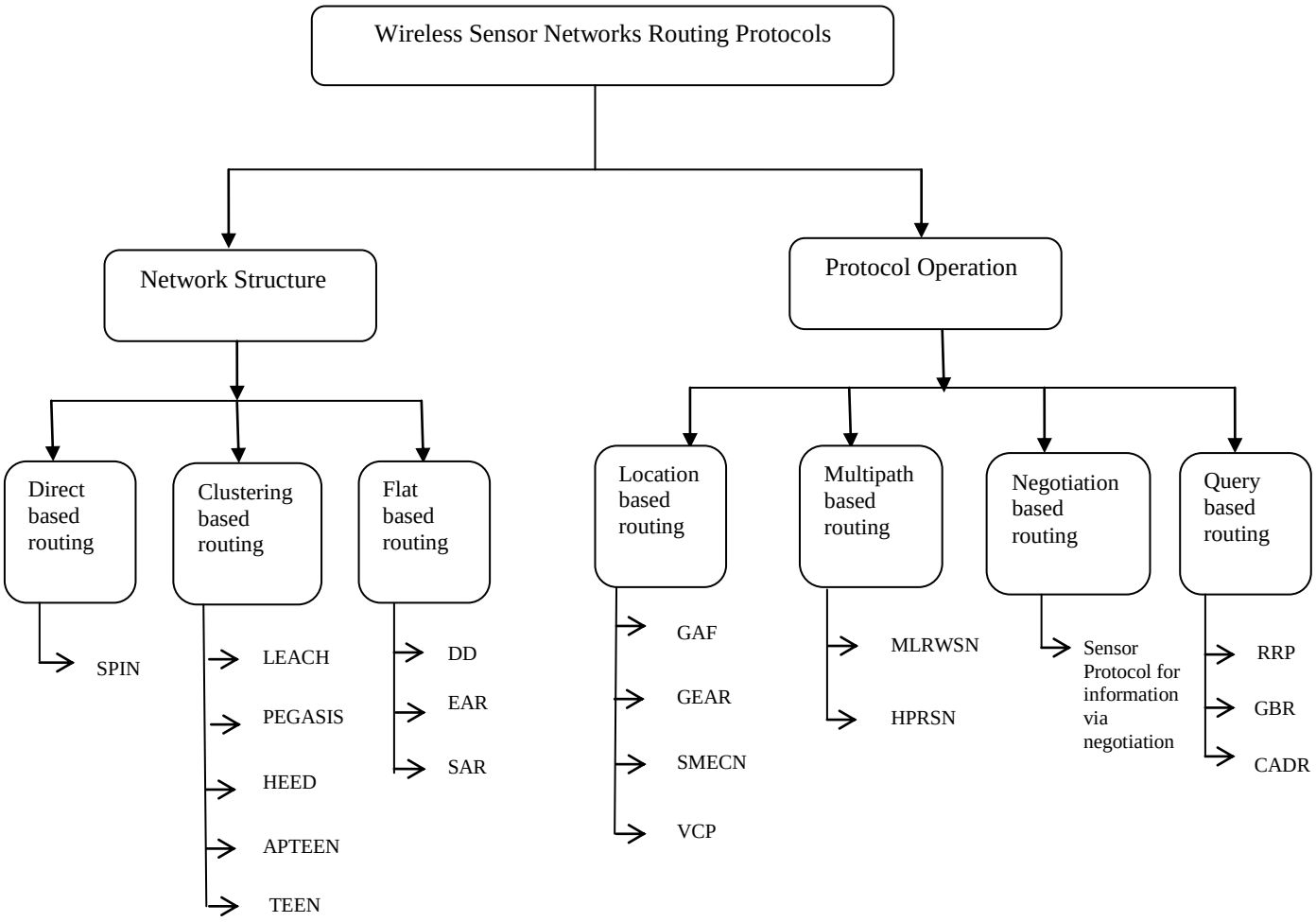

Fig 3. Wireless Sensor Network routing protocols.

3.1 ROUTING PROTOCOL BASED ON NETWORK STRUCTURE

***3.1.1 DIRECT PROTOCOL*:** In direct communication protocols, sensor node sends the data directly to the sink. In this protocol, the larger the diameter of the sensor nodes, the sooner the power of sensor nodes will be drained off very quickly. Collision will effect when the number of sensor nodes increases that ultimately decreases the data transmission.

1) Sensor Protocols for Information via Negotiation (SPIN) **:** It efficiently disseminates information among all the sensor nodes in an energy constrained way, assuming all of them are potential sinks. The data is named for every node uses high-level data descriptors which is nothing but meta data description. The nodes negotiate to eliminate redundant data transfer throughout the network (duplicate packets). This protocol solves many problems by using data negotiation and resource adaptive algorithms. Data is transferred only when meta data negotiation with the neighbour node is done. The negotiations are done between the nodes by exchanging advertisement and request messages. By this we eliminate duplicate data transfer throughout the network. On the bases of the energy level nodes are selected for data transfer.

3.1.2 CLUSTER PROTOCOL **[3,4] :** This protocol is scalable. It is energy efficient in finding the route to a destination where the routes can be managed easily. In clustering protocol, the sensor nodes are randomly distributed in the sensor network. A node called as cluster-head is elected as the leader which

coordinates & controls all the activities in the sensor network. This node is responsible to transfer the data from the sensor nodes to the base station. Here the network is divided into a number of clusters based on geographical location, or the energy present in the node, or the type of data which they want to send etc. In each cluster a cluster-head is elected based on the clustering algorithm. The cluster-head will control all the activities in the cluster. The nodes in the cluster sense the information & transfer the data to the elected cluster-head. The cluster-head will aggregate all the data & transfer the data to the base station directly if it is nearer to the base station or it transfers via other cluster-heads. By this process the number of nodes participating in the data transfer is deceased. Hence we prolong the network life time.

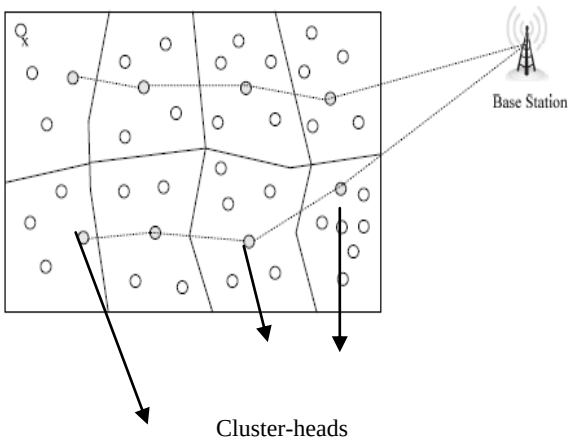

Fig 3.1 Cluster-heads distribution in sensor network

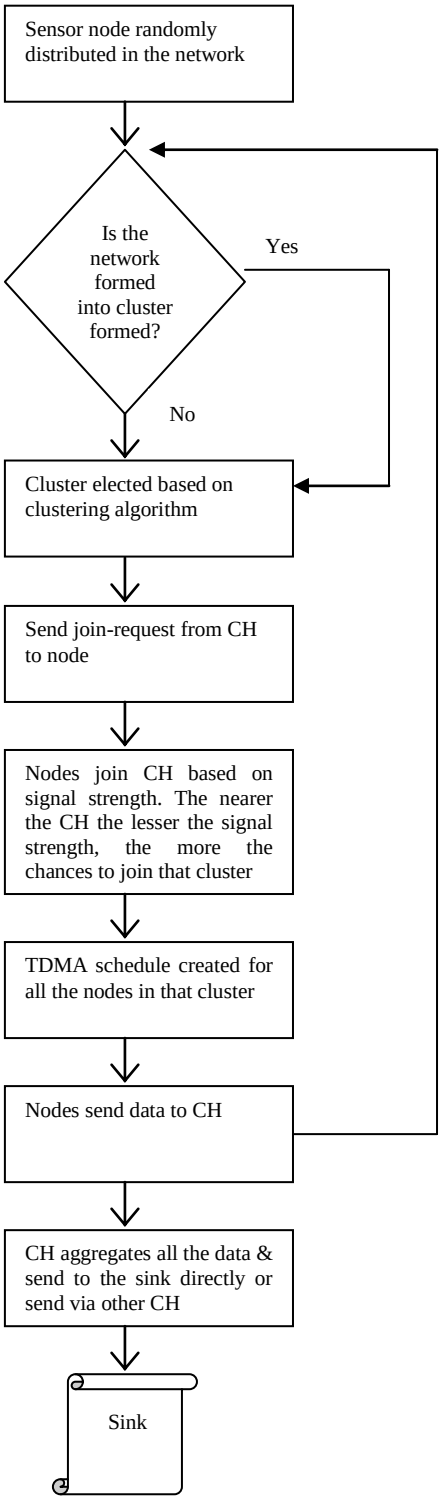

Fig 3.2 Cluster Formation & flow of sending the data

1**) *Low Energy Adaptive Clustering Hierarchy (LEACH*) [5]:** It is a clustering-based protocol with randomized rotation of the cluster-heads to evenly distribute the energy load among the nodes in the network evenly. It is a hierarchical protocol in which most nodes transmit the data to cluster heads. The operation of LEACH mainly consists of two phases: Setup phase & Steady phase.

The Setup Phase: In the setup phase, the clusters will be organized and the cluster heads are will be elected based on the threshold [13]. In every round, a cluster-head will be elected based on the algorithm. If a node is becomes a cluster head in the present round than it cannot become a cluster head again for *P* rounds, where *P* is the number of cluster-head (desired percentage of cluster heads).

The Steady State Phase: In the steady state phase, once the cluster is elected & cluster ate formed the nodes will sense the information to the cluster-head. Cluster-head will send the data is sent to the base station. The duration of the steady state phase is much longer than the duration of the setup phase in order to reduce the overhead. LEACH is a one of the protocol which ends to reduce the energy consumption in a WSN. However, LEACH uses single-hop routing in which each sensor node transmits information either directly to the cluster-head or directly to the sink. Due to this drawback, it is not suitable for networks that are deployed in large regions.

2) *Power-Efficient Gathering in Sensor Information Systems* (PEGASIS) [6]: It is a chain based & an energy efficient protocol, which provides improvements over LEACH protocol. In PEGASIS, in order to send the data each node communicates with nearby neighbor nodes. Once the data is collected the nodes which is nearer to the sink is elected as leader. The other nodes will send the data to the leader node which in turn sends the sensed data to the sink. It takes turns based on the elected leader in order to transmit the information to the base station in this way it reducing the amount of energy spent per round. The nodes are organized in the form a chain which helps to transmit the data to the sink easily. Since each node has global knowledge of the network, the chain can be constructed easily by using some greedy algorithm.

3) *Hybrid Energy Efficient Distributed) protocol* (HEED) [7]: is the clustering protocol. The main feature in HEED is the residual energy than the network topology which consists of nodes degree, nodes distance to the neighbors. These are the two main criteria on which cluster-head is elected to maintain load balance. All the nodes have same initial energy which is called as homogeneous nodes.

4) *AdaPtive Threshold sensitive Energy Efficient sensor Network Protocol* (APTEEN) [8]: The protocol is an extension of TEEN which focuses on both time-critical events and periodic data collections. It has same network architecture like TEEN. After the formation of the cluster's the cluster heads broadcast to the attributes, threshold values, and transmission schedule to all nodes in the cluster. By using the cluster-head concept the data is aggregated & thus energy is saved. Based to the energy dissipation and network lifetime, TEEN has better performance than LEACH and APTEEN because there is a decreased in the number of transmissions. Drawback of TEEN and APTEEN is the overhead and complexity for cluster formation at multi-levels. By the implementation of threshold-based functions and dealing with the attributes based on queries.

5) *Threshold sensitive Energy Efficient Sensor Network protocol (TEEN*) [9]: It is a cluster-based routing protocol based on LEACH protocol. Based on the location, the nodes which are closer form the clusters. The cluster node is responsible to transmit the data to the base station. Once the clusters are formed cluster-heads broadcast two threshold values namely hard threshold & soft threshold. Hard threshold is nothing but the minimum possible value of an attribute to trigger a sensor node. If the event occurs in the range of interest the node will transmit an event. Therefore there is a

significant reduction in the transmission delay happens. Until & unless there is a change in the soft threshold the nodes does not send a new data packets. When soft threshold is employing it prevents from the redundant data transmission. The protocol responds to the sudden changes in the sensed attribute, it is mainly applicable for time-critical applications.

***3.1.3 FLAT PROTOCOLS*:** All the nodes in the network are treated equally. When a node wishes to send data, it will send the data using several hops to the sink. The probability of the nodes participation in the data transmission process is higher for those nodes that are around the sink than those nodes which are far away from the sink. So, the nodes which are around the sink will drain off their power soon. When compared to the nodes far from the sink.

***1) Direct Diffusion (DD)* [10]:** It is a data centric routing algorithm in which all data generated by the sensor nodes are named by attribute value pairs. It basically consists of four elements namely: data messages, gradients, interests & reinforcements. Attribute value pair is used to name the data.
A gradient will specifies the data rate at which data flows & the direction along which the events should be sent. An interest is a list of attribute value pair that describes a task. Reinforcement when there is multiple path we select a single path to transfer a data using reinforcement. In Directed Diffusion, a query is flooded towards nodes which are present in the interested region. As & when query arrives to the interested node which is present in this region it activates its sensors and begins to monitor for events. The data sensed are directed in the reversed path. Based on the data name & attribute value pair the intermediate nodes will aggregate the data. Based on the information gained by localized interactions between nodes the aggregation & propagation is done.

***2) Energy Aware Routing (EAR)* [11]:** It is a reactive protocol. Since it is energy aware it increases the lifetime of the network. The protocol instead on maintaining a single optimal path it maintains a set of multiple paths. Energy consumption is reduce on each path is achieved based on certain probability. Routing table is created for each node based on cost. The destination node performers localized flooding to maintain the paths alive.

***3) Sequential Assignment Routing (SAR)* [12]:** Based on QoS issues for routing this were one of the first protocols proposed for WSNs. The lifetime of the network was increased based on the average weighted QoS metric. Routing decision is based mainly on three factors namely: energy resources, path established based on QoS & packet's traffic managed based on priority. By communicating with the neighbour nodes a multipath approach and localized path is obtained. In multipath tree those nodes whose energy is low is discarded. It creates a multipath table to decrease energy consumption & fault tolerance. Although fault tolerance is managed this protocol suffers from overhead when the routing table for each node need to be maintained & refreshed. Refreshing becomes overhead when there is large number of nodes.

3.2 ROUTING PROTOCOL BASED ON PROTOCOL OPERATION

3.2.1 LOCATION BASED ROUTING: In the protocols, the sensor nodes will be addressed based on their location. The distance between the neighbors is obtained by signal strength or by using GPS receiver.

***1) Geographic Adaptive Fidelity (GAF)* [13]:** It is an energy-aware location based routing designed mainly for MANETs and can is also applicable to sensor networks. The nodes which are unnecessary are turned off by this way energy is reduced. A virtual grid is formed throughout the covered area. Every node uses GPS to locate itself to the grid. Nodes communicate with the neighbor nodes on the same grid assumed to have equivalent. In order to maintain this

equivalence on this nodes which are present on the particular grid area in sleep state to for energy saving. Thus this protocol will increase the network lifetime when the number of nodes increases.

2) Geographic and Energy Aware Routing (GEAR) **[14]:** This protocol uses geographic information while disseminating the queries to the areas of interest. The packet is route in an energy aware manner to the selected neighbor nodes on the bases of geographical information about the node. This protocol will complement directed diffusion protocol by restricting the number of interests sent to a particular area rather than sending to the whole network. Each node maintains a cost estimation to reach the destination through the neighbor nodes.

3) Small Minimum Energy Communication Network (SMECN) **[15]:** This protocol uses low power GPS to minimize the energy of the nodes in wireless sensor network. This protocol assumes a mobile network but it is best applicable to sensor networks which are not mobile.

4) Virtual Cord Protocol (VCP) **[16]:** It is a routing protocol for sensor networks that provides different methods for data management. It offers efficient routing mechanism by maintaining a distributed hash table, besides on this hash table function. The geographical vicinity of the neighbor nodes will reduces the communication load. It needs only the information about those nodes which are directly its neighbors for routing. The implemented of this protocol will be easy on top of MAC layer.

3.2.2 MULTIPATH BASED ROUTING: This protocol has at least one alternate path from source to sink to avoid fault tolerant & ultimately decrease energy consumption. Path will be kept alive by sending periodic messages.

1) Maximum Lifetime Routing in Wireless Sensor Networks (MLRWSN) **[17]:** In this protocol, a path is created on those node whose residual energy is high & data is sent via this path. This path is used until the energy is reduced below the minimum energy. There is a switch in the path when a better path is discovered. Using this approach the nodes in earlier path will not depleted their energy resources through continuously using of the same path. In this way we increase the lifetime.

2) Hierarchical Power-aware Routing in Sensor Networks (HPRSN) **[18]:** By using multipath routing it enhances the reliability of WSNs. This protocol is useful for delivering data in an unreliable environment. The main idea is to define multiple paths from source to sink & send the sub packets through them. By this way traffic will increase significantly not the energy, but it will increasing the reliability of the network. The original data packets will be divided into sub packets & transferred to the selected path. Even if the sub packets are lost during transfer of data the original packets can be reconstructed & original packets can be obtained.

3.2.3 QUERY BASED ROUTING: In these protocols, when a node senses the data it will send a query to the nodes in the network. The destination nodes will send a data query from the node through the network. Finally the nodes which contain the data will send it to the node which initiated the query.

1) Rumor routing protocol (RRP) **[19]:** It is one of the routing protocols which are used in event notification. When an event occurs it does not flood the information in the network. Few paths are set in the network by sending out one or more agents. Whenever the agent visits each node it installs the route information about the event in each node. Whenever a shortest path is discovered from the optimal path, the shortest path is updated in the routing table accordingly. Each node will create an agent in a probabilistic fashion.

***2) Gradient-Based Routing (GBR)*:** When the interest is diffused throughout the nodes in the network, it keeps track of number of hops. Each node will calculate the minimum number of hops to reach the base station. This is the height of the node. Gradient is nothing but the link difference between the nodes height & its neighbor. Packet will be forwarded to the nodes with highest gradient. To order to balance the load over the network it uses techniques such as data fusion & traffic spreading. Relay nodes will aggregate the data when many paths exist.

***3) Constrained anisotropic dif- fusion routing (CADR)*:** It is a query based sensors that route data in the network in order to maximize the information gain while minimizing bandwidth & latency. It uses queries by using which a set of information criteria to choose sensors that can get the data. Only those sensors that are closer to particular event are chosen. The main difference of CADR from direct diffusion is that it takes into account both information gain and communication cost. Each node evaluates the cost to forward data based on the local information. Model information utility measure was used to estimate the cost.

IV. CONCLUSION

Sensor nodes will remain resource poor when compared to MANETs. Energy efficiency is one of the main challenges in designing a routing protocol for WSNs due to the inadequate energy resources. The main objective in designing any routing protocol for WSNs is to prolong the life time of the network. In this paper, we have reviewed a study on routing protocols which were mainly based on clustering. Although many routing protocols have been proposed based on many factor but the main constrain is energy conservation. By clustering the number of nodes participating in the transfer of data is reduced. The number of transmission is also reduced. If less number of nodes is participating the energy of the non-participating node is conserved. These nodes can be used to do different tasks. Clustering algorithm is used to ultimately reduce the energy consumption & prolong the network life time. The study reveals that it is not possible to design a routing algorithm which will have better performance for all applications under all scenarios. Based on the application different routing protocols can be used.

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