A Survey- Wireless Sensor Networks Routing Protocols

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Abstract— **Wireless sensor networks are generally battery operated devices and these batteries are non-rechargeable. So it is extremely important to design a reliable and efficient protocol in order to enhance the lifetime of the whole network the lifetime of the entire network is the time until the first node runs out of battery. In this paper a review in wireless sensor networks is carried out which are classified as location based, hierarchical, multipath based, data centric protocols, heterogeneity-based Protocols & Qos- based protocols depending on the structure of the network.**

Index Terms— **Cluster Heads, Nodes, Routing Protocol, Wireless Sensor Networks.**

I. INTRODUCTION

Wireless sensor networks are generally battery operated devices and these batteries are non-rechargeable [1]. Wireless sensor networks is a collection of sensor node having limited resources. Sensor nodes are used to monitor physical or environmental conditions [2]. Such as temperature, pressure, sound etc. sensor node communicate the information gathered through links [2].In wireless sensor networks the sensor nodes have a limited energy resources. Routing protocols for wireless sensor networks are responsible for the routes of the networks and have to make sure a reliable communication path. The ability of a single node is less but the total power of the entire network is enough to perform the user defined tasks. Nodes can easily be deployed in random or deterministic fashion and are normally battery operated. So energy consumption is one of the most important factor [3].In a network there are millions of sensors which are widely and randomly deployed. The source of the energy for sensors is battery and which cannot be recharged after the deployment [4]. But the networks of the sensors is designed in such a way so that they can work up to their last. So efficiency of a network is a big and important issue in a wireless sensor network. Routing consumes a lot of energy, so an efficient and

Reliable routing protocol is also very important. Many protocols have been proposed in order to reduce the energy consumption in the nodes [5]. Routing protocol have an important role in wireless sensor network because micro-sensor node dispersed in real environment field have a limitation of energy capacity, energy-efficient mechanism for wireless communication on each sensor node is so critical[6] so to increase the network life time an energy-efficient routing protocol is also necessary. For maximizing the lifetime of network, the data should be forwarded in such way that energy consumption is balanced among the nodes [7]. Generally wireless sensor networks are made up of thousands or millions of sensor nodes. Each node have processing capabilities (microcontroller, CPUs) and may have several types of memory (data& flash memory), a RF transceiver (single Omni directional antenna) a power source (batteries and solar cells) [3]. In this paper we tried to give a review on the various routing protocols. Which can help in establishing a reliable and efficient routing protocol for the wireless sensor networks.

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II. ROUTING PROTOCOLS FOR WIRELESS SENSOR NETWORKS

Routing in wireless sensor network is different from routing in fixed networks in various ways. Nodes may fail. Links are unreliable, and routing protocols have to meet strict energy saving requirements [8] there are many routing protocols developed for wireless sensor networks. All major routing protocols for wireless sensor networks can be divided into seven types as shown below in table 1.

Sr. No.	Types	Representative Protocol
1	Hierarchical Protocols	LEACH, PEGASIS, TEEN, APTEEN
2	Data-centric Protocols	SPIN, Directed Diffusion, Rumor Routing, Gradient-Based Routing, Energy-aware Routing,
3	Location-based Protocols	MECN, SMECN, GAF, GEAR, TBF,

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4	Multipath-based Protocols	Sensor-Disjoint Multipath, Braided Multipath, N-to-1 Multipath Discovery
5	Heterogeneity-based Protocols	IDSQ, CADR, CHR
6	QoS-based protocols	SAR, SPEED

Table 1: Routing Protocols for Wireless Sensor Networks.

A. Hierarchical Protocols:

A cluster point network can cause the gateway node to become overloaded, particularly as the density of sensor increases. This, in turn, can cause latency in event status delivery. To permit wireless sensor networks to deal with a large population of wireless sensor networks and to cover a large area, multipoint clustering has been proposed. The goal of hierarchical routing is to manage the consumption of energy of wireless sensor network efficiently by establishing the multi-hop communication within a particular cluster, and by performing data aggregation and fusion to decrease the number of transmitted packets [9].

Low-energy adaptive clustering hierarchy (LEACH):

LEACH is one of the first hierarchical protocols. When the node in the network fails or its battery stops working then LEACH protocol is used in the network. Leach is self-organizing, adaptive clustering protocol[3] in which nodes will arrange themselves into clusters and cluster members selects cluster head to avoid excessive energy usage and incorporate data aggregation which reduces the amount of message sent to the base station. Each cluster is guided by the selected cluster head. The basic operation of LEACH is organized in two distinct phases, setup phase and steady state phase [2].
Setup phase:

- For organizing the network into clusters
- Advertisement of cluster heads
- Transmission schedule creation.

Steady State phase:

- The data aggregation
- Compression
- Transmission to the sink

It reduces energy consumption by switching close (off) node heads as much as possible in LEACH all node sensors transmits directly to the cluster heads using single hop routing. LEACH is not applicable for the networks which are deployed in large regions. It provides scalability in the network by limiting most of the communication inside various clusters of the network [11].

Power-Efficient Gathering in Sensor Information System (PEGASIS):

PEGASIS is a classical chain-based routing protocol. It saves significant energy compared with the LEACH protocol by improving the cluster configuration and the delivery method of sensing data [12]. PIGASIS is an improved version of LEACH [13]. The objective of the PEGASIS is that all sensor nodes talks to each other in their neighborhood and all nodes have a spin to become cluster head. It selects one cluster-head to communicate to the base station in each round [13]. The basic operation of PEGASIS is divided into two phases:
Phase 1: construction of chain:

Chain can be constructed by using the greedy algorithm staring from the remotest node from the base station.
Phase 2: Data gathering and Transmission to Base Station:

Anyone of the node present in a network can be selected as the cluster-head randomly which communicates with the base-station. When the node is out of battery a new chain is formed bypassing the dead sensor node. The cluster head receives all the data from the other sensors and sends it to the base-station.

Threshold sensitive Energy Efficient sensor Network protocol (TEEN):

This protocol is used in temperature sensing applications based on LEACH. TEEN is the first protocol developed for reactive networks. TEEN splits the cluster heads into the second level and uses hard-threshold and soft-threshold to detect the sudden change in network. In hard-threshold number of transmissions are minimized by allowing the sensor nodes to transmit only when the sensed quality is in its range. The soft-threshold also minimizes the number of transmission by completely removing all the transmission.

In TEEN when we are establishing or implementing the network practically we have to ensure that there are no impact or crash in the sensor node. TEEN cannot be used if we want the data regularly.

Adaptive Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN):

APTEEN is add-on of TEEN the architecture of APTEEN is same as of TEEN. APTEEN focuses only on periodic data gathering and reacting to time critical events. In APTEEN when the cluster-heads are decided in each network. Then the cluster heads transmits the variables to all nodes like schedule threshold etc.

B. Data-centric Protocols:

In data-centric routing protocols base station sends its request to the particular network area in which the network is operating and then base station waits for the data which will be sent by the sensors of that particular area or location. The attributes of a sensor is more important than its address [14]. Some of other important representative data-centric protocols are reviewed below.

SPIN:

SPIN stands for Sensor Protocol for Information via Negotiation (SPIN) [15]. It is a part of adaptive protocol

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which includes SPIN-1 and SPIN-2. SPIN is the very first routing protocol of data-centric protocols for wireless sensor networks. In SPIN in addition to data messages other messages are used to minimize the size of whole transmitted information. When a sensor receive data it sends an advertisement message to all its nearby sensors. Every sensor which requires that data will send a query message to that sensor. When the sensor receive the query message from its nearby sensors it transmits its data to that particular sensor which requested for the data.

Directed-Diffusion:

In Data-Centric routing protocols for wireless sensor networks directed-diffusion is one of the important protocol. Directed-Diffusion protocol is designed in such a way that that a when a new request is made the routing will start based on it. Directed-Diffusion works with attribute value pairs of the data and queries the sensor on demand bases however it cannot be applied on all sensor networks [16]. Any sensor which receives the request will store all the parameters in its memory for the next use [14]. Sensors can store data locally on removable media or on an onboard storage device (local storage). In this sensors will store data locally and reduce the amount of sending information. Sensor which receive the request from other sensors of network will send data to its nearby sensors and a gradient is formed. Gradient is a return path by which all nearby sensors have received that request. Various paths will be created between transmitter and receiver by forming or making gradient. Between all these paths only one path will be selected. The choice of path depends on size of receiving information or data.

Energy Aware Routing:

In this protocol the selection of path is same as in directed-diffusion protocol. In directed-diffusion only that path is selected between all other paths which receive the highest level of the total input value. In EAR (Energy Aware Routing) path is selected by possibility option and the possibility option depends upon the energy consumption of the path. Before sending the data to the sink sensor node will must start the route discovery process to create a list of all nearby sensors. Which is nothing but the address of node who are able to transmit data from source to destination [17]. In this process request and reply messages are interchanged between the sensor nodes. The request message contains the source address, sequence number to determine the message origin from the very same source, hop count, required link quality threshold for forwarding the packets, destination address and required energy threshold. Flooding of message to its nearby sensors is not done immediately. Several things are checked by the sensor node before sending the message. The first step in checking process before sending message is to check the available energy of the node. If the energy is less than the energy required for the operation that simply states that the node is not able to perform this kind of tasks anymore then the received request is simply rejected by the sensor node. If the node has sufficient energy to perform the task. Then in next step the link quality of the received signal is measured by the node. The link quality depends upon the distance between the receiver and transmitter. If the receiver is far away from the transmitter then the link quality of received signal should weak. If the request messages are transmitted again from these sensor nodes message collision will takes place to avoid this issue request messages are not to b retransmitted immediately. Back-off scheme is applied to overcome the collisions. At the end of the transmitting message the node has to broadcast the message which is associated with back off timer. Every sensor node compute its back-off delay considering its distance away from the destination Energy Aware Routing provides reliable packet delivery.

Rumor Routing:

Rumor Routing is a wireless sensor network routing algorithm. Whose main aim is to lower the energy consumption. Rumor routing is to create paths leading to each event when the event happens, and later to route queries along these paths [18]. In Rumor Routing agents are used create paths leading to each event when the event happens agents are long lived message traversing in the network. [18]. Afterwards queries are routed on these paths which are generated by the agents. To link the paths queries are sent on unsymmetrical stroll in the network. Every node will maintain the list of its neighboring nodes and an event table (in which all the forwarding information is kept of all the events performed by the node). Expiration time-stamp can be added to the table entries if the events are only required for a definite time or if the volume of the event table is small. The number of events is small and the number of queries is large [19]. Rumor routing is an energy efficient algorithm compared to Gossip based routing, Directed-Diffusion routing. The randomized rumor routing algorithm increases the robustness of rumor routing algorithm [20].

Gradient Based Routing:

The Gradient Based routing protocol is very important and an effective method for wireless sensor networks. Gradient Based Routing protocol (GBR) employ a shortest path principal [21]. To grow efficiency of the entire network mostly all routing protocols uses a shortest way to route data packets. A sink builds a Gradient field fulfilling the network on which it has the lowest Gradient index [22]. Correlated to the wanted sink tis method is known as steepest gradient jumping gradient field build for one Sink may not be acceptable for the multi-sink network when one packet of data travels from source to receiver it should consume very less resources and take the shortest path among all other paths to reach destination. During the network initialization each sensor node learns its gradient through (GRAI) gradient information [23] message transmitted by the sensor node in the network and then it creates a nearby sensor node event table, which will have the information regarding location, distance between the sensor and it's all nearby sensor nodes. In gradient based routing protocols each sensor node defines the gradient as minimum cumulative node cost along the path with will be used to broadcast data towards the receiver [24]. Data packets will only flow from the node towards its nearby nodes having lowest gradient index so that the data will always flow towards the receiver depending on the objective of the routing design node cost can take different forms such as energy consumption or physical distance, hop count [24].

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C. Location-based Protocols:

In routing protocols mostly all routing protocols requires information regarding location of the sensor nodes in wireless sensor networks. The location information is required to calculate the gap or space between the two sensor nodes. It is also used in routing data in such a way so that energy efficiency of a network is increase when the addressing scheme for network is unknown.

Minimum Energy Communication Network (MECN) [25]:

It is based on location-based protocol to attain minimum energy in any case deployed ad-hoc network. MECN attempts to maintain or to structure a minimum energy network with mobile sensors. Minimum energy communication network is a self-reconfiguring protocol which keeps the network connectivity. MECN distinguish a relay region for every sensor node. The relay region contains sensor node in its neighborhood. Through which transmission is more energy efficient then the direct transmission. The relay region for node pair (i, r) in figure 1. Redrawn from [26].

The enclosure of a node is then created by taking the union of all relay regions that node i can reach. The main purpose of the MECN is to find a network within the network so that by using lesser number of sensor node the power required between the two sensors is also less in this way energy consumption of a network is also reduced without considering all sensors of the network. In this way global minimum power paths are found. The small minimum energy communication network (SMECN) [26] is an extension to MECN. In MECN it is assumed that every sensor can transmit to each and every other sensor in the network which is not possible sometimes. In SMECN every possible difficulty between any two pairs of sensor are considered but network is still assumed to be connected as in MECN. The subnetwork constricted by SMECN for minimum energy usage is may be smaller than as constructed in MECN if the transmissions are able to reach to all possible node in a specific region around the transmitter as a result number of hops for transmission will be decreased. There is less energy consumption in SMECN as compared to MECN and maintenance cost of links is also low.

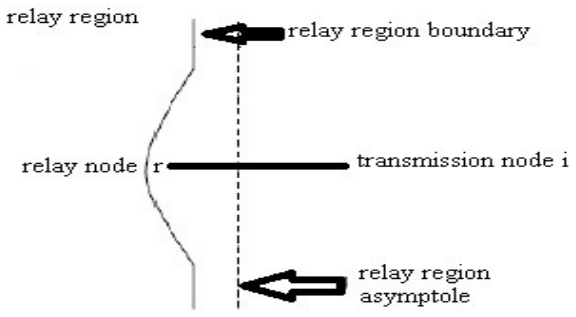

Figure 1.

Geographic Adaptive Fidelity (GAF) [27]:

It is an energy aware location based routing protocol basically designed for mobile ad-hoc networks, however it may can be implemented or may be applicable to wireless sensor networks also. In GAF energy consumption is reduced by turning off or switching off unwanted sensors without affecting the routing fidelity of the network. It forms an essential grid for the observed area every node uses its location indicated with the help of GPS to relate itself with the virtual grid. Sensor nodes related with the same point on the grid are taken as equal in terms of cost of packet routing. Such equivalence is utilized in keeping some nodes in particular grid area in sleeping state to save energy of the network. If number of nodes are increased in GAF the lifetime of a network is also increased. An example is shown in figure 2 which is redrawn from [28]. In figure node 1 can reach any of 2, 3 or 4 and node 2, 3 and 4 can reach 5 therefore node 2, 3 and 4 are equal so any two of them can sleep. Node can change their state from sleeping to active mode in order to balance the load in the entire network. There are three states in GAF discovery, sleep and active. In discovery node determines the neighbors in the grid. Active nodes take parts in routing process. When the radio is off the node are in sleep state. The three states are shown in figure 3 in which the time of sleeping of a node is application dependent and the related parameters are changed accordingly during the routing process. Each node in the grid estimates it's leaving time and send this to its neighbors in order to keep the routing fidelity the sleeping nodes adjust their sleeping time. Before leaving time of the grid the active sensor dies and sleeping nodes wave up and one of them become active node.

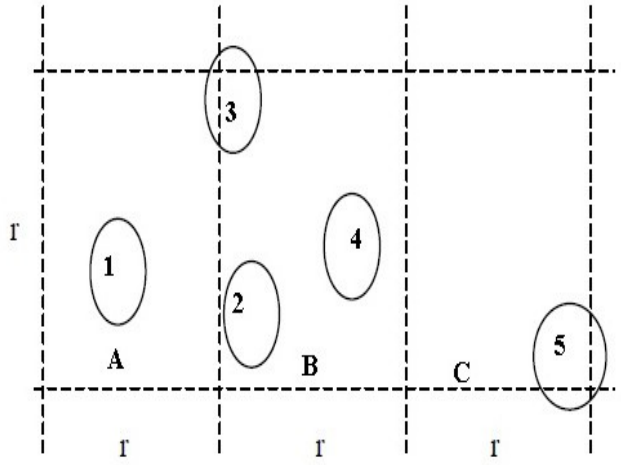

Figure 2

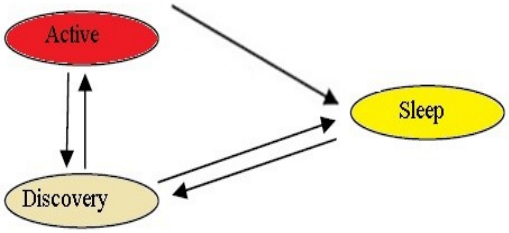

Figure 3: state transition diagram of GAF

Geographic and Energy Aware Routing (GEAR) [28]:

In GEAR the sensors are generally assumed to have localization hardware equipped for example a localization system or GPS unit [29]. This helps sensors to know their current location moreover the sensors are aware of their residual energy as well as the location and

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the residual energy of each of the nearby sensors. GEAR uses energy aware heuristics that are based on geographical information for the selection of route of a data packets towards the receiver side. The gear uses a recursive geographic forwarding algorithm to disseminate the packet inside the target region.

Trajectory Based Forwarding (TBF):

TBF is a routing protocol which requires a sufficient dense network and the presence of localization system so that sensor can know their current position and judge the gap, space or distance between them and their nearby sensors. The sensor specifies the trajectory in packet but does not indicate specifically the path on hop by hop basis. Based on the location information of its nearby sensors route maintenance in TBF is not affected by sensor mobility. To increase the capacity and reliability of the network implementation of multipath routing in TBF is possible. TBF can be used flooding, discovery and network management.

D. Multipath Based protocols:

Transmission of data from source to destination can be done in two ways that is single path routing and multipath routing. In single path routing each sensor sends its data towards sink through shortest path whereas is multipath routing each sensor having any data firstly finds the shortest path towards sink and then divides its load among these paths.

Sensor-Disjoint Multipath Routing [30]:

It helps in finding a smaller number of alternate paths that have no sensors in common with primary path. Alternate paths have longer latency and due to this are less desirable. The primary path is best available path for the Sensor-Disjoint Multipath routing. So if it fails it stays local and does not affect any of these alternate path. The sink can distinguish that which of its nearby sensor can provide the finest quality data by the shortest delay and lowest loss once the network is flooded with some low-rate sample. Although disjoint paths are more resilient to sensor failures, they can be potentially longer than the primary path and thus less energy efficient.

Braided Multipath [30]:

Braided multipath is a partially disjoint path from primary one after relaxing the disjointedness constraint. To make a braided multipath firstly primary path is calculated. Then it is calculated for each sensor node. Thus best path from source to sink is calculated the braided multipath can also be created in a localized manner in which case the sink sends out a primary path reinforcement to its first preferred neighbor and alternate path reinforcement to its second preferred nearby sensor.

N-to-1 Multipath Discovery:

Aim of most multipath routing protocols is to find multiple disjoint or partially disjoint paths between a single source destination [31]. N-to-1 multipath discovery is based on the simple flooding starting from sink. N-to-1 multipath consist of two phases. In phase 1 branch aware flooding and phase 2 is multipath extension of flooding. Both the two phases uses same routing message type.

E. Heterogeneity-Based Protocol:

In heterogeneity sensor networks there are two types of sensors. With Limited lifetime the battery powered sensors and line powered sensors which have no-energy limitation. It uses its energy efficiently by minimizing the data computation and communication

IDSQ:

IDSQ addresses the problem that is how to dynamically query sensors and route data in a network so that information gain is maximized while latency and bandwidth consumption is minimized [32] for target localization and tracking. To increase the tracking accuracy and lessen the detection latency communication between sensors is compulsory and consumes significant energy. In order to save energy only some of the sensors in the network needs to be active when there is something to transmit in the network. In IDSQ protocol the very first step is selection of any sensor as cluster head from the group of sensors. This cluster head is responsible for selecting best sensor on the basis of some information utility measure.

Cluster Head Relay Routing (CHR):

It uses two types of sensors from heterogeneous network with single sink a large number of sensors L-sensors (low-end sensors) and a small number of powerful sensors also called as H-sensors (high-end sensors). By the use of some location service like GPS both of these sensors are aware of their location information. Both sensors are static and both these sensors are uniformly and randomly spread in the field of sensors. The CHR protocol divides the network into group of clusters. Each one of these sensors is created of L-sensor and guided by H-sensors with in a group of sensors. L-sensor manages sensing and forwarding of data packets which is generated by other L-sensors towards cluster heads in multi-hop fashion. Whereas on the other hand H-sensor are incharge for data fusion within their own group of sensor network and forwarding data packets towards sink originated by the other cluster heads in a multi-hop fashion using only cluster heads. The L-sensor uses short range data transmission to their nearby H-sensors with in the same group of sensors on the other hand H-sensor do long range data communication to all nearby H-sensor and the sink.

F. QoS-Based Protocol:

In addition to energy consumption quality of service (QoS) is also very important in terms of delay, fault tolerance and reliability of routing process in wireless sensor networks.

Sequential Assignment Routing (SAR) [33]:

Routing in Sequential Assignment Routing depends on three factors quality of service on each path, priority level of each packet and energy

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resources [34]. SAR is the first protocol providing QoS supports for wireless sensor network. This protocol is a table driven multipath routing protocol and it tries to get both fault tolerance and energy efficiency [35]. The SAR creates a tree of nodes rooted at one hop of neighbors of the sink node. By taking QoS metrics, energy resources in each path and priority of each packet into consideration with the use of created tree multiple path are selected on the basis of energy resources and QoS on each path failure recovery is done by enforcing routing table consistency on each path between downstream and upstream node. SAR provides fault recovery and tolerance. The aim of the SAR algorithm is to decrease the average weighted QoS metrics throughout the lifetime of the network due to node failure topology changes a path re-computation is needed.

SPEED:

SPEED is also a QoS routing protocol for wireless sensor network. It is a real-time routing protocol [36]. The demand of this protocol is that each node keeps information about its neighbor sensors. It uses geographic location information for its routing decisions. SPEED does not uses routing tables it provides congestion avoidance when the network is congested. Usage of memory is minimum in SPEED as it is called stateless and does not uses routing tables [37]. The module used for routing in SPPED is called stateless non-deterministic geographic forwarding (SNGF). The beacon exchange mechanism collects information and provides the geographic location of the neighbor. Delay estimation at each node is calculated by calculating elapsed time when acknowledgment is received from neighbors which helps SNGF to select a node meeting speed requirement. If failure occurs the relay ratio of the node is checked, relay ratio can be calculated by looking at the miss ration of neighbors of the node and then fed to the SNGF. SPEED performs better in terms of end-to-end delay and miss ratio as compared to Dynamic Source Routing [38] and Ad-hoc on-demand vector routing. The total transmission energy is less due to its simplicity.

III. CONCLUSION

Energy efficiency is the major challenge in the field of wireless sensor networks. The common idea behind all routing protocols is to increase the life time of sensors so that they can operate as long as possible. Energy of sensors is utilized by the data transmission and reception. So routing protocol should be energy efficient. In this paper, we have surveyed routing protocols which are classified as location based, hierarchical, multipath based, data centric protocols, heterogeneity-based Protocols & Qos- based protocols depending on the structure of the network.

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