

A Systematic Review of Routing Algorithms for Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Network (WSN) is an emerging technology to monitor physical phenomena and environmental conditions. These networks are composed of large numbers of tiny nodes called sensor nodes. The sensor nodes are capable of sensing environmental conditions such as pressure, temperature, humidity etc., processing the sensed data and transmitting them towards base station through wireless communication. And they are randomly distributed over large field in ad-hoc manner such that they operate in dynamic environment. Because of this, the communication architecture of WSN possesses several challenges such as node deployment, power management, energy constraints, data dissemination etc. To deal with those challenges, various protocols have been introduced and routing algorithm is one of them. Routing algorithms works at network layer and ensures reliable communication for routing the sensor data to base station in limited time period. This paper presents a survey of state-of-the-art on routing algorithms in WSNs. The routing protocols are broadly classified into two categories: routing algorithms based on network structure and routing algorithms based on protocol operation. This survey work has also pointed the advantages and disadvantages of different routing algorithms as well as the performance issues on those routing algorithms.

Keywords:- *Wireless Sensor Network, Sensor Nodes, Ad-hoc, Routing Algorithms*

INTRODUCTION

Recent advances in micro-electro-mechanical systems and low power and highly integrated digital electronics have led to the development Wireless Sensor Network (WSN). Wireless sensor network is a network of sensor nodes that cooperates and communicates with each other by wireless links. It is an emerging technology which is composed of large numbers of tiny nodes called sensor nodes. It is being widely used for monitoring physical phenomena. It allows users to access information and services electronically, regardless of their geographic position or without going into actual environmental observation [1]. They have long term economical potential and have created a great impact on the living

standard of people but they pose many new system-building challenges. That's why; WSN is getting wide range of its application area. In military applications, WSN is being used for intrusion detection, perimeter monitoring, information gathering and smart logistics support in an unknown deployed area. In the field of agriculture, WSN is being used for measuring temperature, pressure, moisture, humidity, acidity etc. Some other applications of WSN include sensor-based personal health monitor, location detection with sensor networks and movement detection [2].

WSN consists of Sensor Nodes and Base Station. It typically contains thousands of sensing nodes with much shorter distance

between adjacent nodes and low application data rate. Sensor nodes in WSN are light weighted, battery operated micro-electro devices that are randomly deployed across large field in ad-hoc manner. They detect unusual conditions in the surrounding, measure them and then transforms them into electric signals that can be processed to achieve interesting patterns about the phenomena located in surroundings around them [3]. A sensor node then performs computation work such as aggregations and then they transmit those data towards Base Station. For this, sensor node has processing unit,

communicating unit, memory, Geo Positioning System, Analog to Digital converter and power source. The base station in WSN acts as a gateway to sensor network. It provides an interface between sensor field and station. In WSN, there can be more than one base station and use of two or more base stations in a sensor network improves the performance of network by decreasing the network delay [15]. Figure 1 shows an illustration of Wireless Sensor Network communication architecture along with sensor node components.

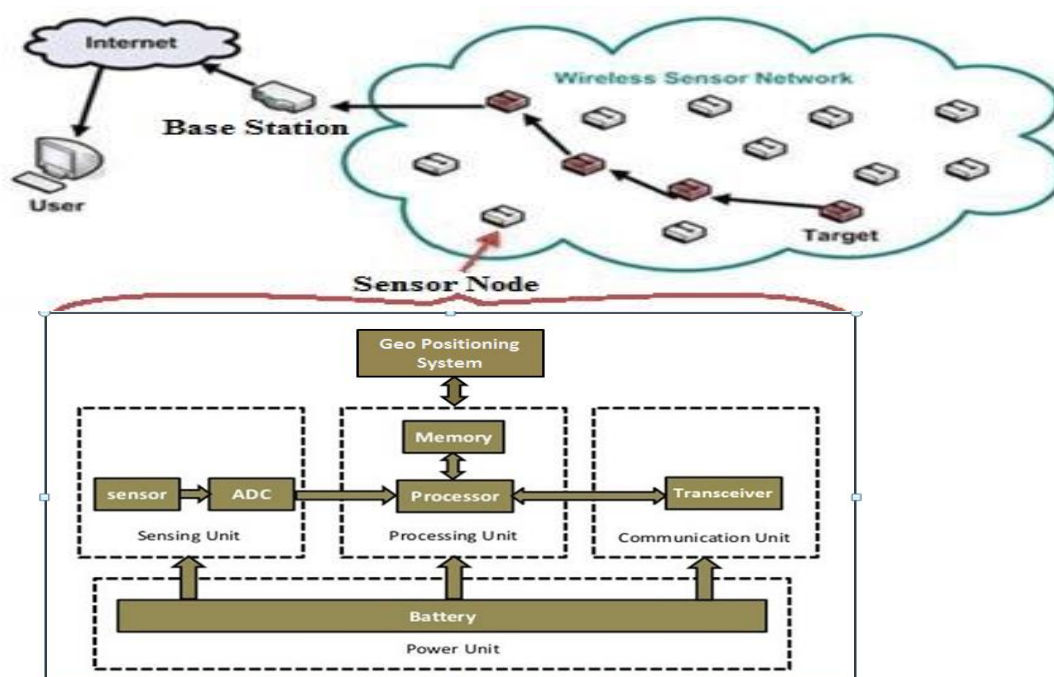


Fig.1:-Illustration of WSN Communication Architecture along with Sensor Node Components

Sensor nodes are constrained in memory size, energy supply and communication bandwidth. The memory size of sensor node is very small (usually in terms of Kbytes) such that it cannot store complex programs like encrypting/decrypting programs in order to make secure communication. Also, the power supply in the sensor node is too low (usually in terms of milliamp) such that the battery life time of the sensor node is very small.

And since all nodes in a WSN communicate with each other via wireless links, the communication cost is much higher than the computational cost. Generally, the energy needed to transmit a message is about twice as great as the energy needed to receive the same message. Thus, innovative techniques to eliminate energy inefficiencies that shorten the lifespan of the network and efficient utilization of the limited bandwidth are

extremely required [15].

In wireless sensor network, routing the data packets is also the most challenging task. It is because IP-based protocols may not be applied to WSN as it needs to maintain routing table for global topology and building a global addressing scheme for WSN is not possible since it contains large number of sensor nodes. And WSN involves flow of data from various sensor nodes to a base station as opposed to traditional communication networks. However, this does not preclude the data flow to be in several forms such as multicast or peer to peer. Also, nodes after deployment in sensor network are usually stationary, but for some cases sensor nodes are required to change their position. Thus, there may occur unpredictable change in the topology of sensor network. Besides this, sensor nodes in WSN involve collecting data based on some event. So, there is a chance of collecting similar data by the sensor nodes. Therefore, to deal with such issues various routing algorithms has been proposed for wireless sensor network. And the routing algorithms used in wireless sensor network must be able to handle such issues with efficient consideration of energy constraints [11].

To solve the problem of routing data, different types of routing protocols has been designed for wireless sensor network. Based on the structure of network, routing protocols are broadly classified as Flat Routing Protocol (Data-Centric Routing Protocol), Hierarchical Routing Protocol and Location Based Routing Protocol according to the network structure. And on the basis of the operation of the protocols, they are classified as multipath-based, query-based, negotiation-based, quality of service (QoS)-based, and coherent-based depending on the protocol operation [3]. In this paper, we have discussed each of these routing protocols in brief along with its

examples. The main focus of this survey work is to investigate various routing algorithms used in WSNs and provide better understanding on them.

The respite of the paper is organized as follows. Section 2 presents the challenges and design issues in WSNs. Section 3 presents a comprehensive survey of various routing algorithms in WSNs along with their advantages and disadvantages. Section 4 discusses the future research directions on routing algorithms in WSN and Section 5 presents conclusion of this work.

ROUTING CHALLENGES AND DESIGN ISSUES IN WIRELESS SENSOR NETWORK

The challenges and issues of wireless sensor network have influences in designing and developing of routing protocols. The routing protocols must deal with those factors in order to achieve efficient communication in WSNs. Some of the challenges and design issues of WSN are discussed as follows:

Dynamic Network Topology

Sensor nodes in most of the WSN applications are assumed to be fixed. However, in some applications both the Base Station or sensor nodes can be mobile. In such case, the network topology remains unstable and routing the messages from or to sensor nodes is becomes difficult [4].

Node Deployment

Deployment of node in WSN is application-dependent. In WSN, nodes can be deployed either deterministic or in randomized manner. In deterministic approach of node deployment, the sensors are placed in predefined location and data is routed through predetermined paths. But in randomized node deployment process, the nodes are distributed in a scattered manner, creating an ad hoc routing

infrastructure. Therefore, optimal clustering is needed in case of randomized node deployment process in order to establish connectivity and enable energy-efficient network operation. Inter-sensor communication is normally within short transmission ranges due to energy and bandwidth limitations [4].

Energy Constraints

Setting routes in a sensor network is affected by energy consideration. The radio transmission degrades with distance much faster than in free space [4]. Also, each node in a wireless sensor network plays a dual role: one as a data sender and another as a data router. So, malfunctioning of sensor nodes in the network can cause change in network topology which results in reorganizing the network and rerouting of packets [8].

Node/Link Heterogeneity

Sensor nodes deployed on the network may be of different nature. The existence of heterogeneous set of sensor nodes in the sensor network can raise many technical issues related to data roaming. Even reading and reporting from the sensor node may occur at different rates and can follow multiple data reporting models [9].

Scalability

Wireless sensor network involves installing number of sensor nodes over a dense area. Thus, routing protocols used in wireless sensor network must be capable of operating with these large number of sensor nodes. They must be scalable enough for adapting the events around their dynamic surroundings [9].

Fault Tolerance

Some sensor nodes in the sensor network may fail or get blocked due to lacking of power, physical damage, or environmental interference [9]. In such cases, to deduce the energy consumption of the network,

the sensor network requires adjusting powers and signaling rates for transmitting or rerouting the data packets. Routing protocols used in WSN must be able to effectively deal with such issues [10].

Transmission Media

In multi-hop network, since sensor nodes are linked using wireless medium, traditional wireless channel related issues such as high error rate, fading etc. may affect the functioning of the sensor network which is related to designing the MAC. The use of Time-Division Multiple Access (TDMA)-based protocols over contention-based protocols such as Carrier Sense Multiple Access (CSMA) is one of the approaches to MAC design but it not energy efficient [10].

Connectivity

In WSN, the high density of a sensor node prevents them from being totally separated from each other. Thus, sensor nodes are supposed to be strongly linked with each other. This however does not stop the network from getting varied in network size. Furthermore, connectivity relies on random node distribution [11].

Coverage

A sensor node in WSNs can cover a limited physical area as its view of environment is restricted in both reach and precision. Thus, region inclusion is considered as one of the significant plan issue of routing algorithms in WSNs [4].

Data Aggregation

In WSN, sensor nodes may generate redundant data. The redundant data generated by multiple nodes in wireless sensor network can be aggregated for reducing the transmitting energy. And aggregating the data from dissimilar sensor nodes is one of the issues of routing algorithm [11].

ROUTING ALGORITHMS OF WIRELESS SENSOR NETWORK

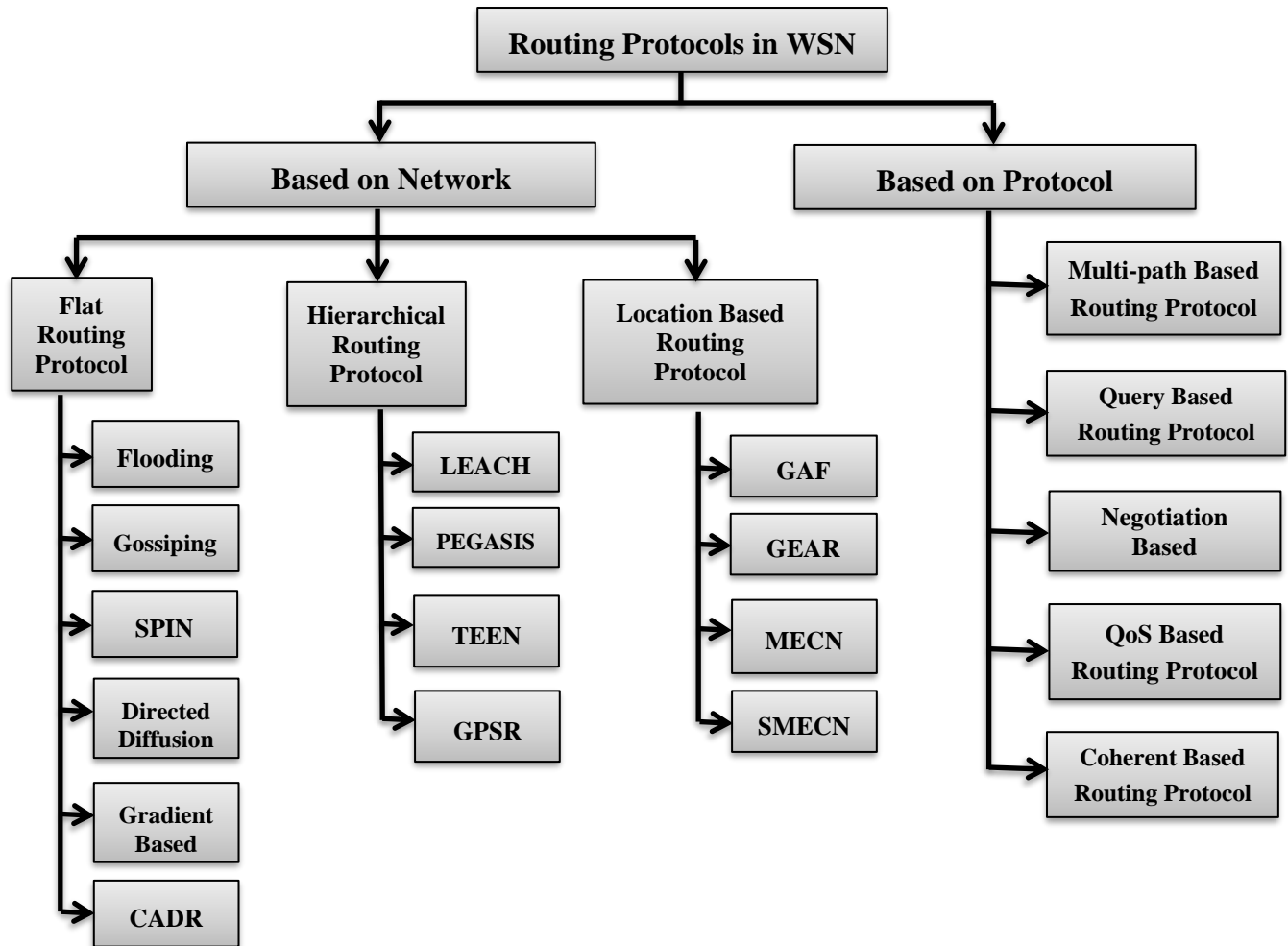


Fig.2:-Taxonomy of the Routing algorithms

Routing algorithms in wireless sensor networks differs from routing algorithms in conventional fixed networks. In wireless sensor network, routing algorithms especially deals with improving energy efficiency of the network and bandwidth utilization. Thus, routing algorithms in wireless sensor network are broadly classified into two categories: routing algorithms based on network structure and routing algorithms based on protocol operation. Routing algorithms based on network structure are further classified into three types: Flat Routing Protocol, Hierarchical Routing Protocol and Location Based Routing Protocol.

Similarly routing algorithms according to

protocol operation are classified as: multipath-based, query-based, negotiation-based, QoS-based and coherent-based routing [10]. Figure 3.1 shows taxonomy of the routing algorithms.

NETWORK STRUCTURE BASED PROTOCOLS

In wireless sensor network, the underlying structure of network can play a vital role in routing the data packets from source node to base station. So, various types of routing algorithms have been derived based on the structure of sensor network. Those routing protocols are broadly classified as Flat routing protocol, Hierarchical routing protocol and Location based routing

protocol [3]. This section presents discussion on these routing protocols.

Flat Routing Protocol

Flat routing protocols are also called Data-centric routing protocol. These are query based routing protocol that depends on the naming of data of interest, which could help in eliminating redundant data. With this routing protocol, each node in the sensor network cooperates with each other and they exhibit similar role. It is not feasible to assign a global identifier to each sensor node in the network since they are large in number. This resulted in implementing Flat routing protocol in which queries are made by base station requesting data from certain region and waits until they get data from source node. Since queries are made by base station for collecting data, attribute-based naming property should be used for specifying the characteristics of data [5]. Examples of flat routing protocols are discussed as follows:

Flooding

Flooding is simple routing protocol which is very easy to implement. It does not require complex topology maintenance. In flooding, a node broadcasts the data packets to its entire neighbor unless maximum no. of hops is reached. If the maximum hop count is not achieved then each node that receives a packet must broadcast it [6].

Advantages: As it has the highest rate of message transmission, it is quickest

approach and is also efficient. Without no or minimum delay, the flooding converges first.

Disadvantages: Flooding has got the problems of Implosion, Overlapping and Resource Binding

Gossiping

An alternative approach to Flooding process is Gossiping which is a data centric routing protocol. In Gossiping, instead of broadcasting, the sensor data are transferred to randomly selected sensor node [6].

Advantages: Solves the problem of implosion.

Disadvantages: Delay in propagation of data among sensor nodes and it does not guarantee that all nodes will receive the data packets.

Sensor Protocol for Information via Negotiation (SPIN):

SPIN works on the mechanism of negotiation and resource adaptation to address the deficiency of flooding. In this, Meta data is transmitted instead of raw data. It specifies exchanging of collected data via advertisement mechanism so that node can distribute data which other do not pose. SPIN has three types of messages: ADV (advertisement for metadata), REQ (Request for actual data) and DATA (Actual Data). Figure 3 illustrated the basic operation of SPIN [6].

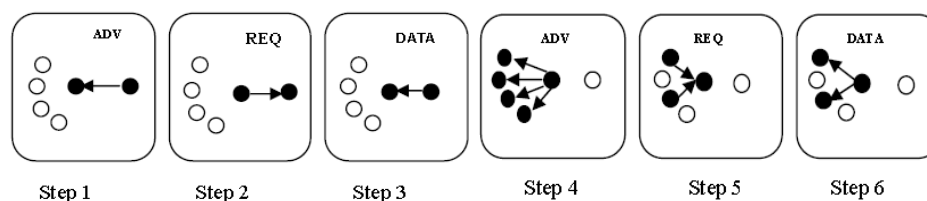


Fig.3:-Illustrated the basic operation of SPIN

SPIN has got its two types: SPIN-1 and SPIN-2. SPIN-1 does not deal with energy

efficiency whereas SPIN-2 is energy aware. Also, SPIN has got its family and

they are:

SPIN-PP: It is hop-by-hop routing specially designed for a point-to-point communication.

SPIN-EC: It behaves like SPIN-PP, but adds energy conservation heuristic added.

SPIN-BC: It is optimized for channels that broadcast.

SPIN-RL: SPIN-RL is used in case of lossy channel where adjustments are should be added.

Advantages: Solves the problem of implosion, resource blindness and overlapping.

Disadvantages: Takes long time to send data from source node to sink node and consumes more energy.

Directed Diffusion

It is a type of data-centric routing algorithm in which the property of attribute-value pairs is used for naming the data generated by the sensor nodes. The basic principle used in this routing protocol is to merge the data from various nodes with a view to eliminate duplicate

data such that the effort for transmitting data from source node to sink node gets minimized which in turn preserves network resources and increases the network lifetime. In directed diffusion, data are demanded by base station by propagating interest over the network. Thus, Interests are distributed over the network hop-to-hop. After getting the interest, from base station, each sensor nodes setup's the gradients for transferring the data to the sink node. Once the gradients are set up, data propagation process starts. In data propagation process, Sensor which has data matching an interest sends the data down to its neighbors. When data is received, base station now sends reinforcement interest with increased data rates. If the neighbor node has reinforced rate higher than the gradients then interest is sent to neighbor node to down convert the neighbor node into gradient. In this way the path for transmitting sensor data is established [6]. Figure 4 illustrated the working mechanism of Directed Diffusion protocol.

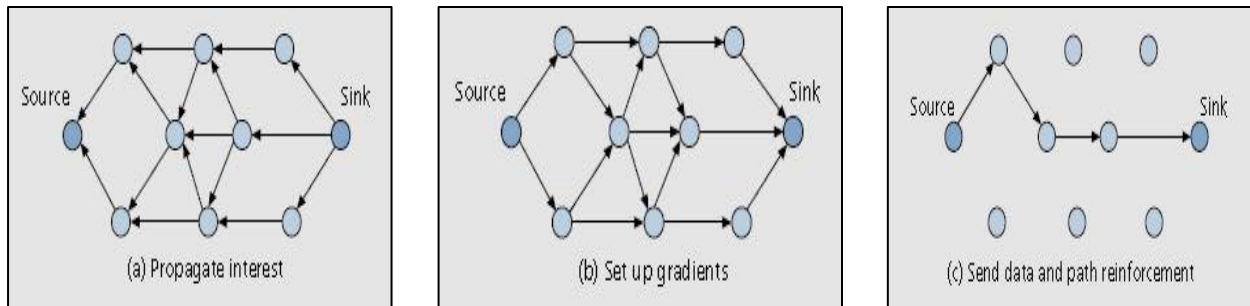


Fig.4:- Working Mechanism of Directed Diffusion

Advantages: It is energy efficient routing protocol which provides flexibility in network topology change. Data aggregation property and negative reinforcement drastically improves efficiency. Reliable data delivery under node failures, additions and removals. Increase in the number of sensors does not adversely affect performance.

Disadvantages: Insufficient knowledge of one node about its neighbors. It does not

know which neighbor can aggregate the data more efficiently. It does not know which neighbor can distribute its data to different sinks more efficiently.

Rumor Routing

Rumor routing is also a type of data centric routing protocol that is mainly intended for applications where geographic routing is not feasible. In this routing protocol, data from sensor nodes observing an event are routed to a particular node instead of

flooding into entire network. It employs agent i.e., long-lived data packets to flood events across the network. In this, an event table is maintained to record the events whenever the sensor node senses the event. As sensor node senses the event, agents are generated and they are propagated to distinct node to inform about event recorded by sensor nodes. When a base station generates a query for an event, the source node provides response to that query through the path that it discovers by inspecting its event table. Thus, Rumor routing reduces the expenses of connectivity since only one route is established between source node and sink node [6].

Advantages: It can handle failure of nodes and exhibits significant improve on saving the energy constraints of the network.

Disadvantages: Applicable when events to be recorded are small in number. Becomes infeasible when events are in large number as there evolves difficulty in maintaining event table and generating agents.

Gradient Based Routing

Gradient-based routing (GBR) is another data centric routing protocol variant of directed diffusion. In this routing protocol, the nodes in the sensor network are partitioned into number of clusters of uneven size and each of the sensor nodes keeps record of minimum hop count in order to reach to base station which is defined as gradient value. The size of the cluster in this protocol is calculated by using gradient value. Packets of data are dispatched on a connection having prominent gradient value. Some of subsidiary approaches like data aggregation can be used by GBR to ensure a consistent distribution of traffic over the network. In GBR, there are three data dissemination techniques, namely, stochastic scheme, energy-based scheme and stream-based scheme. The motive of these schemes is to ensure a fair flow of traffic across the network [6].

Advantages: GBR does not implement the concept of broadcast for transmitting sensor data. Instead, sensor node sends data in point-to-point fashion. Thus, it increases the lifespan of the sensor network.

Disadvantages: In GBR, the sensor node close to base station is over used. So, they die quickly as compared to other nodes. Thus, network failure occurs quickly.

Constrained Anisotropic Diffusion Routing (CADR)

CADR is one of the data centric, energy efficient routing protocols for routing sensor data in ad-hoc network. It involves querying the data and routing the data by optimizing information gain, bandwidth and latency. In this, the sensor node near to a particular event gets activated. Thus, CADR adjust the routes dynamically. And it uses greedy approach for adjusting the route. In CADR, sensor nodes in the network are categorized into two types: Line powered Sensor Nodes and Battery Powered Sensor Nodes [6].

Advantages: This technique can minimize the energy needed to route the query to its destination by choosing the shortest path. It can also maximize the information gain by taking an irregular walk with more steps.

Disadvantages: This routing scheme is complemented by the technique information-driven sensor querying (IDSQ) that it will not specifically define how data and the queries are routed between sensors and the base stations.

Hierarchical Routing Protocol

Hierarchical routing protocols are the most efficient routing algorithms used in wireless sensor network. In this protocol, sensor nodes with higher energy rate called cluster head are used for transmitting sensor data to Base station. This routing protocol operates in two layers: One layer involves forming cluster heads and other layer involves routing the data from source

node to sink node via cluster head. This routing protocol provides feature of data aggregation and network scalability for reducing data transmission cost and improving network performances [12]. Examples of hierarchical routing protocols are as follows:

Low-Energy Adaptive Clustering Hierarchy (LEACH)

It is one of the popular energy-efficient routing algorithms which provide conception of round. It was introduced with a motive to minimize energy consumption in the sensor network [7]. The main idea of LEACH is to form cluster of nodes based on received signal strength and use local cluster heads as routers to sink. Initially cluster heads are selected randomly and are changed over time to spread load and balance energy dispersion of nodes. And cluster-heads are chosen stochastically as [13]:

$$T(n) = \frac{P}{1 - P * (r \bmod P^{-1})} \quad \forall n \in G$$

$$T(n) = 0 \quad \forall n \notin G$$

Where, n is a random number between 0 and 1, P is the cluster head probability and G is the set of nodes that weren't cluster heads in the previous rounds.

Cluster head collects the proactive data from other nodes, aggregates and compresses and then sends to sink. For reducing reduce inter-cluster and intra-cluster collisions, LEACH uses TDMA/CDMA MAC. The operation of LEACH is divided into rounds having two phases: one is setup phase which involves organizing the network into clusters, choosing Cluster Head, scheduling transmission and another one is steady state phase which involves transmitting aggregated data to the base station [13]. Figure 5 illustrates the concept of LEACH algorithm.

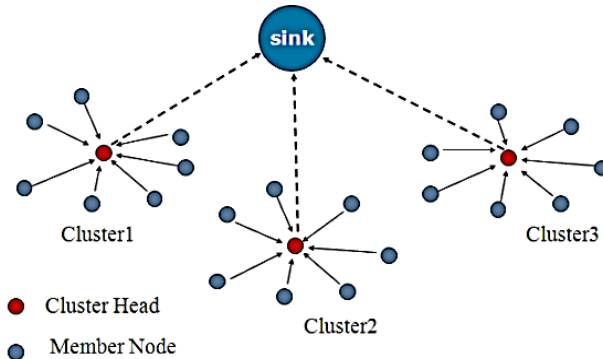


Fig.5:-Illustration of LEACH Algorithm

Advantages: Energy Cluster Heads aggregates the whole data which lead to reduce the traffic in the entire network. Minimizes energy dissipation since transmissions are managed by cluster heads. It increases the lifetime of the sensor network.

Disadvantages: Cluster formation with uneven size and does not provide information about the number of cluster head.

Greedy Perimeter Stateless Routing (GPSR)

GPSR is a routing Protocol to transfer data packets in wireless datagram network which is based on combining Greedy Packet Forwarding and Perimeter forwarding Methods. In this routing, neighbor node for routing the data from source nodes are identified using greedy approach. It works well for ad-hoc network [7].

Advantages: Complexity of routing message in this routing is small and is extremely robust for packet delivery.

Disadvantages: As mobility increases, it generates constant low volume routing message and produces traffic in routing with the increase in the length of the routes.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS)

PEGASIS is a chain-based protocol which structures sensor nodes in a chain by using greedy approach. In this, for increasing the lifetime of the network, data from source nodes are transmitted to that node which lies at optimal distance and these nodes further transmits the data to their closest neighbor node turn by turn until base station receives them. to the source node. A new round starts when all nodes in previous round finish communicating with the Base Station, and so on. Thus, the power requirement for transmitting data gets reduced as the power per round draining is spread uniformly over all nodes [12].

Advantages: Avoids random formation of cluster head as it uses concept of single chain for transferring data. Thus, preserves energy consumption.

Disadvantages: Huge delay in data transmission, thus not applicable for real time environment.

Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN)

It is a type of cluster based hierarchical routing protocol in which sensor nodes are organized into cluster, each cluster led by cluster head. In this, it is assumed that initially base station and sensor node have same energy levels and base station can send data to all nodes. Teen may involves forming Hard Threshold or Soft Threshold for controlling transmission of data from source node to base station. Implementation of TEEN with Hard Threshold involves transmitting of data if

the sensed data lies within the range of interest. On the other hand, TEEN with Soft Threshold involves transmitting of sensor data if there occur small change in sensed data. This type of routing protocol is not applicable if it requires periodic reporting of sensor data because sensor data would not get transmitted if threshold values are not reached [7].

Advantages: It is suitable for long term time critical sensing application because the energy consumption in this scheme is less than in proactive networks.

Disadvantages: The user will not be able to get any data from the network when the value of the sensed data does not reach to the thresholds.

Location Based Routing Protocol

A location-based routing protocol, also called Position Based Routing protocol, uses location information of the sensor node for communication [2]. In this protocol, if the sensor nodes are attached with small low power GPS receiver then the geographic location the sensor node is determined by communicating with satellite. Also, the location information of the sensor node can be determined by calculating difference of distances between sensor nodes [7]. Location based routing protocol are energy aware routing protocol since they reduce energy consumption in the network and increases the lifetime. Examples of location-based routing protocols are discussed as follows:

Geographical Adaptive Fidelity (GAF)

GAF is an energy efficient location-based routing protocol introduced for MANETs which is being widely used in wireless sensor network. This protocol focuses on extending lifetime of the sensor network by conserving the energy. It involves use of location information to identify sensor nodes for setting route in order to transmit data to sink node. Thus, sensor nodes which do not take part in routing the data

can be turned off. This results in preserving energy of sensor node in the network which in turn increases the lifetime of the network. GAF works on three stages, namely, Sleeping, Discovery and Active states. At first, the node starts with discovery state and after time T_d , it broadcasts discovery message. Then it

moves towards active state where it sets Timer T_a . Nodes then after re-broadcast the discovery message periodically in active state. After T_a , nodes return to discovery state and into sleeping state if nodes with higher priority appear in active state [3]. Figure 6 illustrates the working mechanism of GAF.

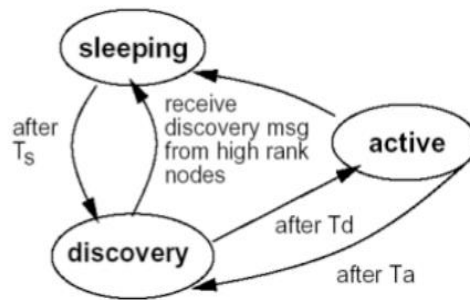


Fig.6:-Illustration of Working Mechanism of GAF

Advantages: Maximizes network lifetime by ranking the sensor node and by maintaining residual energy. High scalability.

Disadvantages: Broadcast high ranking discovery messages only, limited power management.

Geographic and Energy Aware Routing (GEAR)

GEAR is one of the location-based routing protocols used in WSN which uses energy aware and location information for routing sensor data from source node to sink node. The main concept behind GEAR is to restrict the quantity of interest in a focused diffusion by only contemplating a single area instead of transmitting interests to the whole network. In GEAR, forwarding a data packets from source node to sink node involves two processes: forwarding the packets towards the target region and forwarding the packets within the region [3].

Advantages: Reduces energy consumption for route setup and performs better in terms of packet delivery.

Disadvantages: Requires location services to map location and identity of nodes in network. It is not sensitive in case of location error.

Minimum Energy Communication Network (MECN)

MECN is also a location-based protocol introduced to maintain minimum energy in the sensor network by using low power GPS. It is focused on finding the routing path between source node and sink node through which sensor data can be transmitted with less power consumption. In this, an optimal spanning tree rooted at the sink, called minimum power topology, is computed which contains only the minimum power paths from each sensor to the sink. And a stationary node called master node is determined for transmitting data from source node to base station [8].

Advantages: Maintains fault tolerant energy network with low powers and optimal spanning.

Disadvantages: Fault tolerance of a network depends upon specific application.

Small minimum energy communication network (SMECN)

SMECN is a distributed location-based routing protocol which uses low power RF transceiver architecture to control power. It is an expansion to MECN. MECN considers that an individual node in a sensor network can send the data packets each of other nodes which are not conceivable at all the time. But, SMECN finds potential obstructions between sensor nodes and the sub-network so that the data packets can be transmitted in an energy efficient way. SMECN routing protocol builds a routing network that is smaller in size as compared to that of MECN [3].

Advantages: Less energy than MECN and less maintenance cost.

Disadvantages: Number of broadcast message is large and maximum power usage.

ROUTING PROTOCOLS BASED ON PROTOCOL OPERATION

In this section we have discussed various types of routing protocol as per the routing functionality. The various routing algorithms based on protocol operations are:

Multipath Routing Protocols

This routing protocol involves developing multiple routing paths between source and destination and using them for transmitting the data packets. The multi-path routing increases network performance by utilizing alternate paths between a source and a destination when the primary path fails. The multi-path routing provides benefits such as increased fault tolerance, load balancing, bandwidth aggregation, enhancing reliability, load balancing and improvement in QoS minimizing end-to-end delay. These are achieved at the cost of increased overhead in maintaining the alternate path. It employs a probabilistic flooding scheme to create multiple paths from the source to the sink. Each node is supposed to have knowledge of local

channel errors. Reliability can be achieved by presenting redundancy in the form of copies of each packet sent through multiple paths. Unfortunately, the routing maintenance cost is too high due to the frequent exchange of neighboring routing information.

Query-Based Routing

In query-based routing all the nodes may store the sensed information locally and only transmit in response to a query issued by the sink or nodes which needs the data. Therefore, the querying of sensors for desired information is a fundamental networking operation in WSNs. In this kind of routing, the queries are transmitted by destination nodes through the network, and a node matches with this query sends the data back to the node that initiated the query. Generally, these queries are described in natural language or high-level query languages [4].

Negotiation-Based Routing Protocols

Negotiation-based routing protocols exchange messages before actual data transmission begins; this helps in elimination of redundant data transmissions. The node in the network makes a decision whether the actual data is needed or not. This method reduces the number of transmissions and thus saves energy. The detection and elimination of redundant data are achieved by using high-level data descriptors to distinguish data. The overheads due to negotiation and size of data-descriptor must be smaller than the actual data size [2].

QoS-based Routing

In WSN, quality-of-service relates to the ability of the network to provide data on a consistent and timely basis. In a sensor network, metrics such as bandwidth, high throughput or delivery power etc. is not adequate to fulfill delay criteria of the application. Consequently, the speed with which to propagate information could be

as important as the throughput speed. Thus, QoS-based routing protocol is introduced to satisfy QoS metrics of the sensor network. In this routing protocol, routing path is selected using different QoS metrics such as reliability, end-to-end latency, energy usage or bandwidth [5].

Coherent and Non-Coherent Processing

The sensor nodes deployed in the WSNs are used to collect the data of the surrounding environment. So, the processing of gathered data is the most important task and required at each node. The collaborative effort among the sensor nodes is required to process this data. In WSNs, data processing is divided into two methods, namely coherent and non-coherent data processing-based routing [7].

In Coherent Data processing-based routing, the minimum data processing activities such as time stamping, is carried out by each node and then the data is forwarded to the next level nodes called aggregators for further processing. Coherent data processing normally selected to perform energy efficient

routing. On the other hand, in Non-Coherent Data processing routing, nodes in sensor network locally process the sensed data and transmit them for further processing.

Comparison of Routing Protocols for WSN

In WSN, number of routing protocols are introduced with an aim to achieve significant improve in the performances of sensor network. They are introduced with a motive to handle issues with routing data from source node to sink node such that energy consumption gets reduced and network life time gets increased [9]. However, these protocols exhibit different characteristics in terms of energy efficiency, scalability, routing, data aggregations, QoS etc. Some of them give priority in conserving energy where some gives priority for reducing redundant data. Some of them are more focused on scaling change on network topology and some are focused on providing security to routing data [14]. Table given below presents a comparative study of various routing protocols used in WSN.

Table 1: Comparison of WSN Routing Protocol

Routing Protocol	Classification	Data Aggregation	QoS	Scalability	Multipath	Query Based
SPIN	Flat	Yes	No	Limited	Yes	Yes
Directed Diffusion	Flat	Yes	No	Limited	Yes	Yes
Rumor Routing	Flat	Yes	No	Good	No	Yes
LEACH	Hierarchical	Yes	No	Good	No	No
PEGASIS	Hierarchical	No	No	Good	No	No
TEEN	Hierarchical	Yes	No	Good	No	No
GEAR	Location	No	No	Limited	No	No
GAF	Location	No	No	Good	No	No
MCEN	Location	Yes	No	Low	No	No
SAR	QoS Based	Yes	Yes	Limited	No	Yes
SPEED	QoS Based	No	Yes	Limited	No	Yes

ROUTING IN WSN: FUTURE DIRECTIONS

WSN, in future, will include implementation of a range of dispersed sensors over ad-hoc network to take benefit of spatially and temporally dense sensing and to communicate with physical

phenomena. It will involve building a network with sensor nodes having coordinating functionality in them for executing high level tasks. Though, comprehensive attempts have been made for handling issues with routing in WSN, still there exists difficulties in deriving

effective and efficient routing protocols. One of those is tight coupling of sensor node with its physical environment. Sensor nodes in WSN are distributed over ad-hoc network.

Generally, they are dispersed in the area or systems where human user cannot be embedded for collecting data. And in most of the applications, these nodes are stationary. But, for some applications, there may require mobility of sensor nodes. Such situations are not properly handled by routing protocols available today. Thus, routing protocols should be introduced for handling such cases effectively. Also, future routing protocols should consider reusability of resources.

CONCLUSION

Wireless sensor network is the network of sensor nodes which are distributed over an ad-hoc environment for sensing physical phenomena. It has a wide range of applications in real world and has become one of the research areas for researchers. Since, WSN involves distributing large number of sensor nodes over any geographical area for sensing event around its environment, its architectural design possesses several challenges. In order to effectively deal with such challenges, various routing protocols has been proposed. These protocols are broadly classified into two categories, namely, Network Structure Based Routing protocol and Operation Based Routing Protocol. Network structure-based routing protocol are further categorized as Flat, Hierarchical and Location based routing protocol. On the other hand, Operation based routing protocol is classified as QoS-based, Query-based, Multipath and Negotiation based routing protocols. This study involves analyzing the design trade-offs of routing protocols in terms of energy conservation and communication overhead. It also involves pointing

advantages and disadvantages of using a particular routing protocol.

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