Network Structure Based Routing Protocols In Wireless Sensor Networks

[1]Brahm Prakash Dahiya, [2]Dr. Shaveta Rani, [3]Dr. Paramjeet Singh,
[1]Research Scholar, CSE, I.K.G. Punjab Technical University, Punjab, India.
[2]Professor, CSE, Giani Zail Singh Campus College of Engineering and Technology, Punjab, India.
[3]Professor, CSE, Giani Zail Singh Campus College of Engineering and Technology, Punjab, India.

Abstract- *Wireless Sensor Networks (WSN) collection of nodes with sensing, computation, and communications capabilities. By help of sensor node senses the data and sends data to the base station for further processing. These sensor nodes mainly suffer from more batteries consumption and decreases the lifetime of the network. In order to solve this problem, various routing techniques are introduced to improve the lifetime of WSN. In wireless sensor network routing techniques play important roles. By help of various routing techniques many research have completed and some under process to improve the lifetime of WSNs. This paper based on comparative study of WSN routing protocols. Routing techniques are divided into three sub-categories network structure based, protocols operation based and route discovery based respectively. We presented comparative study of routing techniques based on network structure in wireless sensor networks. The network structure based routing techniques are divided in three categories: flat, hierarchical, and location-based routing protocols. In this survey we also discussed advantages and disadvantages of each routing techniques.*

Keywords- WSNs, QoS, SPIN, LEACH, MECN.

I. INTRODUCTION

In the recent decade, there have been increasing advances in wireless technologies, embedded systems, and software engineering leading to the evolution low-cost, low-power, and small-size devices with wireless communication capabilities and embedded sensing. The wireless sensor networks (WSNs) are composed of many sensors devices which use the wireless channel to carry out distributed sensing tasks [1]. As it is known, sensor nodes are equipped with limited batteries capacity; routing algorithm in sensor networks becomes more challenging as compared to ad hoc networks. Moreover, as sensor nodes have limited batteries power, energy efficiency is an important design issue in order to maximize the lifespan of WSNs. Many routing protocols [6], [2][3] have been proposed for WSNs to save energy of the sensor nodes which transmit sensed data to the sink through cluster heads (CHs). Classical WSN routing protocols are categorized to three main categories: network structure-based, protocols operation based and route discovery based routing. In this paper we survey the proposed routing protocols in WSNs. Firstly we will outline the classification of routing protocols of WSNs routing protocols. This will secondly followed by comparison between the first categories of WSNs routing protocols. In last conclusion of the paper provides a good insight to future research areas in network structure based routing in WSNs.

II. CLASSIFICATION OF ROUTING PROTOCOLS

Classification of routing protocols in Wireless Sensor Networks is done in different levels [4].

2.1 Network Structure this describes the characteristics of a network, which can be divided into two groups; the characteristics of base stations and the characteristics of sensor nodes [4].

2.1.1 Flat based: In these networks, all nodes play the same role and there is absolutely no hierarchy.
2.1.2 Hierarchical based: This approach set out to efficient energy level by arranging the nodes into clusters.
2.1.3 Location based: Most of the routing protocols for sensor networks require location information of nodes which is needed to calculate the distance between two particular nodes so that energy consumption can be estimated [4].

2.2 Protocol Operation: It defines routing protocols based on communication pattern, hierarchy, delivery method, computation, next- hop [4].

2.2.1 Negotiation based: In negotiation based protocols, the nodes exchange a number of messages between themselves before transmission of data.
2.2.2 Multipath based: In this case, the network derives benefit from the fact that there may be multiple paths between a node and the destination Query based.
2.2.3 QoS-based: QoS based protocols have to find a trade-off between energy consumption and the quality of service.

2.2.4 Coherent-based: Coherence based protocols focus on how much data processing takes place at each node.

2.3 Route Discovery Protocols: To route data packets from a source node to a destination node, a path is required in the network through which data packets can be transmitted. So, a route discovery mechanism is used to discover a path from a source node to a destination node in the network [4].

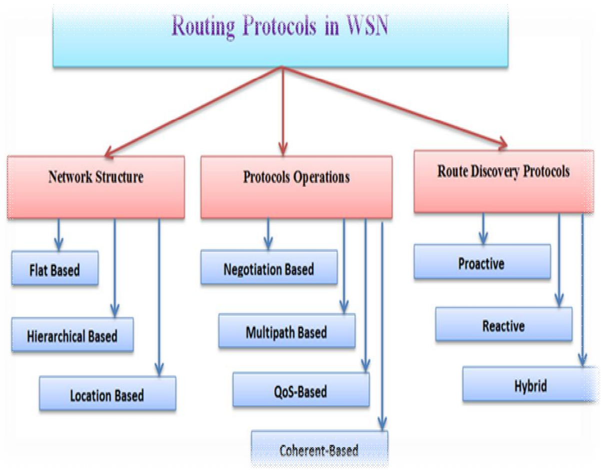

Fig. 2 Classification of routing protocols

III. COMPARISON BETWEEN NETWORK STRUCTURE BASED ROUTING PROTOCOLS

3.1 Network Structure: this describes the characteristics of a network, which can be divided into two groups; the characteristics of base stations and the characteristics of sensor nodes [22].

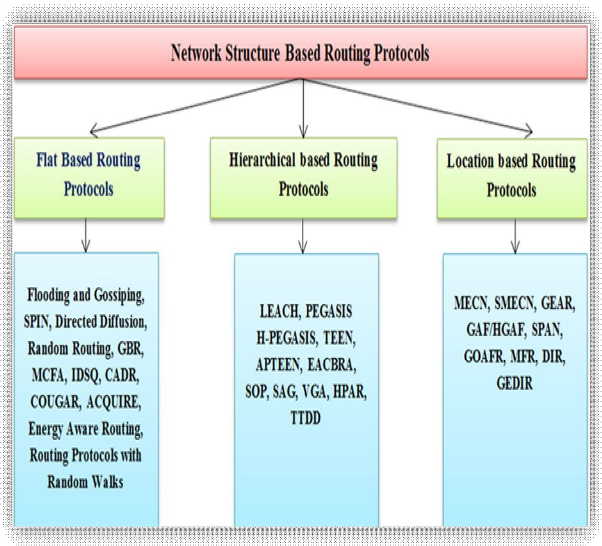

Fig. 3 Network Structure Based Routing Protocols

3.1.1 Flat Based Routing Protocols:

The following protocols are discussed in this category:

3.1.1.1 Flooding and Gossiping:

In flooding data transmission from sensor node to the base station in WSNs. The source node broadcast the data packet to the immediate neighbor. After receiving the data packet each sensor node rebroadcast the data packet to their neighbor. This process will continues until the nodes in network receive the packets [5][6].

The advantages of Flooding and Gossiping are:

i. Flooding guarantee the data packet to reach the destination.
ii. It is very simple to design.

The disadvantages of Flooding and Gossiping are:

i. It suffers from the heavy traffic and measure should be taken so that packet does not travel through the network indefinitely.
ii. Also suffers from implosion. It is caused by receiving duplicate data packets on the same node.

3.1.1.2 SPIN (Sensor Protocol for Information via Negotiation):

SPIN (Sensor Protocol for Information via Negotiation) that send information among sensors in an energy-constrained wireless sensor network and overcome the problem of implosion and overlap occurred in flooding. Sensor nodes running a SPIN communication protocol with high-level data descriptors, called metadata. SPIN nodes negotiate with each sensor node before transmitting data. Negotiation helps to ensure that the transmission of redundant data throughout the network is eliminated and only useful information will be transferred. The SPIN family of protocols includes many protocols that conserve energy [7].

The advantages of SPIN protocol are:

i. Avoid unnecessary network layer operation.
ii. Path can be repaired.
iii. Save energy, when repairing any path.
iv. No need of node addressing mechanisms.
v. Node can perform aggregation and caching of data in addition to sensing task.

The disadvantages of SPIN protocol are.

i. It is not sure about the data will certainly reach the target or not.

ii. It is also not good for high-density distribution of nodes.
iii. Matching process also consumes energy and space.
iv. Extra overhead of saving multiple path information.
v. Cannot be applied to every application of sensor network because it is only query driven.
vi. Naming schemes are application dependent and require being set manually again and again.
vii. SPINs data advertisement mechanism cannot guarantee the delivery of data.

3.1.1.3 Directed Diffusion:

The author proposed a popular data aggregation paradigm for wireless sensor networks called directed diffusion. Directed diffusion is data-centric and all nodes in a directed diffusion-based network are application-aware. This enables diffusion to achieve energy savings by selecting empirically good paths and by caching and processing data in network [8].

The main advantages of directed diffusion are:

i. It is data-centric, communication with neighbor-to-neighbor and no requirement for a node addressing mechanism. Each node can do aggregation and caching, in addition to sensing. Caching is a big advantage in term of energy efficiency and delay.
ii. Direct Diffusion is highly energy efficient and on demand protocols so there is no need for maintaining global network topology.
iii. Directed diffusion allows on demand data queries

The main disadvantage of direct diffusion is:

i. Directed Diffusion is not a good choice for the application such as environmental monitoring because it require continuous data delivery to the sink will not work efficiently with a query driven on demand data model.

3.1.1.4 Rumor Routing:

Rumor routing is proposed in which allows queries to be delivered to events in the network. It is mainly determined for context in which geographic routing criteria is not applicable. Rumor routing is a logical compromise between flooding queries and flooding events notification. Rumor routing is tunable and allows for tradeoff between setup overhead and delivery reliability. Normally directed diffusion floods the queries to the entire network and data can be sent through multiple paths at lower rates but rumor routing maintains only one path between source and destination. Rumor routing protocol is reliable in terms of delivering queries to events in large network, handle the node failure very smoothly and degrading its delivery rate linearly with the number of failure nodes. It also achieves significant energy saving over event flooding [9].

The main advantages of Rumor Routing are:

i. It can efficiently handle node failure.
ii. It saves more energy than direct diffusion.

The main disadvantages of Rumor Routing are:

i. It does not perform well when very large numbers of events are generated together.
ii. Overhead of adjusting parameters again and again like time to live for queries and agents.

3.1.1.5 Gradient-Based Routing:

The algorithm makes an improvement on Directed Diffusion, in order to get the total minimum hop other than the total shortest time. In the traditional gradient minimum hop count algorithm, hop count is the only metric, which measures the quality of route. Gradient routing protocol which not only consider the hop count but also energy of each node while relaying data from source node to the sink. This scheme is helpful in handling the frequently change of the topology of the network due to node failure. A new gradient routing scheme also aims path from the source node to the sink [10].
The main advantage of Gradient-Based Routing is:

i. It balances the load across the entire network.

Disadvantage of Gradient-Based Routing are:
i. Node failure recovery is absent.
ii. Do not guarantee data delivery at destination node.

3.1.1.6 Minimum Cost Forwarding Algorithm (MCFA):

Minimum Cost Forwarding Algorithm (MCFA) sets up a backoff based cost field to find the optimal cost path from all the nodes to the sink. Once the field is established, the message, carrying dynamic cost information, flows along the minimum cost path in the cost field. This protocol consists of two phases. In first phase is called setup phase. It used for setting up the cost value in all nodes. In the second phase, the source broadcasts the data to its neighbors. To reduce the number of broadcast messages, the MCFA was modified to run a backoff algorithm at the setup phase. The backoff algorithm dictates that a node will not send the updated message until backoff time units have elapsed from the time at which the message is updated [11].

The main advantages of MCFA is:

i. It helps to find optimal path from source to destination.
ii. The base-station broadcasts a message with the cost set to zero while every node initially set its least cost to the base-station to infinity.

Disadvantage of MCFA:

i. It suffers with high consumption of bandwidth and it may cause duplicate copies of sensor messages to arrive at the sink.
ii. This may result in some nodes having multiple updates and those nodes far away from the base-station will get more updates from those closer to the base-station.

3.1.1.7 Information-driven sensor querying (IDSQ) and Constrained anisotropic diffusion routing (CADR:)

CADR aims to be a general form of directed diffusion. The idea is to query sensors and route data in the network such that the information collection is maximized while latency and bandwidth are minimized. CADR applied queries by using a set of information criteria to select which sensors can get the data. This is achieved by using only the sensors that are close to a particular event and dynamically adjusting data routes. The main difference from directed diffusion is the consideration of information gain in addition to the communication cost. In CADR, each node evaluates an information and routes data based on the local information and end-user requirements. Estimation theory was used to model information utility measure. In IDSQ, the querying node can determine more suitable node that provide useful information with the additional advantage of balancing the energy cost. However, IDSQ does not define how the query and the information are routed between sensors and the BS. Therefore, IDSQ can be seen as a complementary optimization procedure. Simulation results showed that these approaches are more energy-efficient than directed diffusion where queries are diffused in an isotropic fashion and reaching nearest neighbors first [12].

The main advantage of IDSQ & CADR:

i. These techniques are more energy efficient as compare to directed diffusion.
ii. These techniques distributed anytime algorithms to mitigate the risk of node failures.

Disadvantage of IDSQ & CADR:

i. We cannot implement IDSQ & CADR for global computation.

3.1.1.8 COUGAR:

Another data-centric protocol called COUGAR views the network as a huge distributed database system. The key idea is to use declarative queries in order to abstract query processing from the network layer functions such as selection of relevant sensors and so on. COUGAR utilizes in network data aggregation to obtain more energy savings. The abstraction is supported through an additional query layer that lies between the network and application layers. COUGAR incorporates architecture for the sensor database system where sensor nodes select a leader node to perform aggregation and transmit the data to the BS. The BS is responsible for generating a query plan, which specifies the necessary information about the data flow and in network computation for the incoming query and send it to the relevant nodes. The query plan also describes how to select a leader for the query. COUGAR provided network layer independent methods for data query [13].

The main advantage of COUGAR:

i. The architecture of provides network computation ability that can provide energy efficiency in situations when the generated data is huge.
ii. It provided network layer independent methods for data query.

Disadvantage of COUGAR:

i. The addition of extra query layer on each sensor node may add an extra overhead in terms of energy consumption and memory storage.
ii. To obtain successful in-network data computation, synchronization among nodes is required (not all data are received at the same time from incoming sources) before sending the data to the leader node.
iii. The leader nodes should be dynamically maintained to prevent them from being hot-spots (failure prone).

3.1.1.9 Active Query forwarding in sensor networks (ACQUIRE)

ACQUIRE views the network as a distributed database where complex queries can be divided into several sub queries. The operation of ACQUIRE can be described as follows. The BS node sends a query, which is then forwarded by each node receiving the query. During process each node tries to respond to the query partially by using its pre-cached information and then forward it to another sensor node. If the pre-cached information is not up-to-date, the nodes gather information from their neighbors within a look-ahead of d hops. Once the query is being resolved completely, it is sent back through shortest-path to the BS. Hence, ACQUIRE can deal with complex queries by allowing many nodes to send responses [14].

The main advantage of ACQUIRE:

i. It can reduce the energy consumption by more than 60% as compared to expanding ring search.

Disadvantage of ACQUIRE:

i. ACQUIRE as a highly scalable technique that deserves to be incorporated into a portfolio of query mechanisms for use in real-world sensor networks.

3.1.1.10 Energy Aware Routing:

It maintains a set of paths instead of maintaining one optimal path at higher rates. These paths are selected based on a certain probability. The value of this probability depends on low the energy consumption. By having paths chosen at different times, the energy of any single path will not deplete quickly. Thus using a simple mechanism to send traffic though different routes helps in using the node resources more equitably. Using probabilistic forwarding to send traffic on different routes provides an easy way to use multiple paths without adding much complexity or state at a node. [15].

The main advantage of Energy Aware Routing:

i. It improves WSNs network lifetime.

Disadvantage of Energy Aware Routing:

i. Need do more work on network survivability.

3.1.1.11 Routing Protocols with Random Walks:

Routing Protocols with Random Walks work based on load balancing in a statistical sense and by making use of multi-path routing in WSNs. This technique considers only large scale networks where nodes have very limited mobility. In this protocol, it is assumed that sensor nodes can be turned on or off at random times. A truly novel feature of our formulation is that the algorithms we obtain are able to route messages along all possible routes between a source and a destination node, without performing explicit route discovery/repair computations, and without maintaining explicit state information about available routes at the nodes [16].

The main advantage of Routing Protocols with Random Walks:

i. It improves WSNs network lifetime and perform network load balancing.

Disadvantage of Routing Protocols with Random Walks:

ii. The main concern about this protocol is that the topology of the network may not be practical.

3.1.2 Hierarchical protocols:

The data-centric and flat-architecture protocols suffer from data overload close to the sink as the density increases. The nodes which are located near the sink route more information than nodes in other parts of the network. As a result, these nodes die faster and produce a disconnection between the sink and the WSN. Consequently, flat-architecture protocols result in uneven energy consumption throughout the network and limit the scalability of the protocols. The drawback of the flat-architecture protocols can be solved by forming a hierarchical architecture, where the nodes are grouped in clusters and the local interactions between clusters members are controlled through a cluster head. Hierarchical clustering in WSN is an energy efficient protocol with three main elements: Sensor Nodes (SN), Base Station (BS) and Cluster Heads (CH). The SNs are sensors deployed in the environment to collect data. The main task of a SN in a sensor field is to detect events, perform quick local data processing, and transmit the data. The base station is the data processing point for the data received from the sensor nodes, and from where the data is accessed by the end-user. The CH acts as a gateway between the SNs and BS. The CH is the sink for the cluster nodes, and the BS is the sink for the cluster heads. This structural idea formulated for the sensor nodes, the sink and the base station can be replicated many times, creating the different layers of the hierarchical WSNs [17].

3.1.2.1 Low Energy Adaptive Clustering Hierarchy (LEACH):

This is one of the most energy efficient routing protocols for any research work. The model was introduced in 2000 and has considered designing an effective radio and energy model, which is highly adopted even in current studies. LEACH algorithm considers homogenous wireless sensor network where the base station is located in the Centre of the simulation area and surrounded by multiple clusters. The selection of the cluster head is always done depending on the highest residual energy. The cluster head uses TDMA scheduling to aggregate the physical data from the member nodes on one cluster. The entire operation of the LEACH is carried out using set up phase and steady phase. The energy depletion is reducing the cost of communication between the member node and cluster head using sleep scheduling algorithms. Hence, lifetime of the network is maximized in LEACH [18].

The main advantage of LEACH is:

i. The clusters are easily formed and very useful in data aggregation which removes the chances of data duplication at sink node.

The main disadvantage of LEACH is:

i. Energy consumption is high which reduces the network lifetime of the network.

3.1.2.2 PEGASIS and Hierarchical-PEGASIS

PEGASIS (Power-Efficient Gathering in Sensor Information Systems) is an improved version of LEACH. It is optimal chain based protocol that Instead of forming multiple clusters, PEAGSIS construct a node chain when nodes are placed randomly in a play field. Here each node make communication with a close neighbor node and give turn transmitting to the base station, thus reducing the amount of energy spent per round [19].

Hierarchical-PEGASIS further make improvement and it allows concurrent transmission when the nodes are not adjacent. Compared with LEACH, the two algorithms eliminate the overhead of forming cluster, but both of them do not take the energy condition of next hop into consideration when choosing a routing path, so they are not suitable for heavy when the amount of nodes is very large in WSNs, the delay of data transmission is very obvious, so they do not scale well and also are not suitable for sensor networks where such global knowledge is not easy to obtain [19].

The main advantage of PEGASIS:

i. PEGASIS is able to increase the lifetime of the network twice as much the lifetime of the network under the LEACH protocol.

The main disadvantage of PEGASIS:

i. All sensor nodes have the same level of energy and they are likely to die at the same time.

3.1.2.3 TEEN and APTEEN

TEEN stands for Threshold sensitive protocol based on hierarchical grouping which divides sensor nodes twice for grouping cluster in order to detect the scene of sudden changes in the sensed attributes as temperature. It use soft and hard threshold during transmission interval. The main drawback of this scheme is that it is not well suited for applications where the user needs to get data on a regular basis. Another possible problem practical implementation would have to ensure that there are no collisions in the cluster. TDMA scheduling of the nodes can be used to avoid this problem but this causes a delay in the reporting of the time-critical data.

The Adaptive Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN) is an improvement of TEEN and aims at both capturing periodic data collections and reacting to time critical events. The architecture is same as in TEEN. In APTEEN once the CHs are decided, in each cluster period, the cluster head broadcasts the parameter such as attributes, threshold, and schedule and count time to all nodes [20].

The main advantages of TEEN and APTEEN are:

i. Save a lot of energy in communication.
ii. Node failure and hence path failure are very less
iii. TEEN includes its suitability for time critical sensing applications. At every cluster change time, fresh parameters are broadcasted and the user can change them as required.

The main disadvantages of TEEN and APTEEN are:

i. Gateway is to be set up manually, and random deployment is not possible.
ii. Not suitable for all kind of applications of WSN.
iii. The main drawback of this scheme is that, if the thresholds are not received, the nodes will never communicate, and the user will not get any data from the network at all. These two approaches are the overhead and complexity associated with forming clusters at multiple levels, the method of implementing threshold-based functions, and how to deal with attribute based naming of queries.

3.1.2.4 Energy-aware cluster-based routing algorithm

The author proposed Energy-Aware, Cluster-Based Routing Algorithm (ECRA) for wireless sensor networks to maximize the network’s lifetime. The ECRA selects some nodes as a cluster-heads to construct Verona diagrams and cluster-head is rotated to balance the load in each cluster [21]
The main advantages of ECRA:

i. Reduce energy consumption, and increase the lifetime of the sensor network.
ii. Lower time complexity proved by analysis and the experimental results is present to show it can balance node's energy consume effectively.

The main disadvantages of ECRA:

i. Not applicable for multi-path routing.

3.1.2.5 Self Organizing Protocol (SOP):

It used to support heterogeneous sensors. It is more applicable where communication to a particular node is required. It maintains routing table on a small cost and keeping a balanced routing hierarchy. Another issue is related to the formation of hierarchy. It could happen that there are many cuts in the network, and hence the probability of applying reorganization phase increases, which will be an expensive operation [22].

The main advantages of SOP:

i. It is more energy efficient as compare to the SPIN protocol.

The main disadvantages of SOP:

i. This protocol, suffers to extra overhead.

3.1.2.6 Sensor Aggregates Routing:

A sensor aggregate routing sets comparison with those nodes in a network that fulfill a grouping predicate for a collaborative supportive processing task. The parameters of the predicate depend on its resource requirements. Sensors are divided into clusters based on their sensed signal strength, so that there is only one peak per cluster. Then, local cluster leaders are elected. One peak may present one target, multiple targets, or no target in case the peak is generated by noise sources. To select a leader, information exchanges between neighboring sensors are compulsory. If a sensor, after exchanging packets with all its one-hop neighbors, finds that it is higher than all its one-hop neighbors on the signal field landscape, it declares itself a leader. This leader-based algorithm proposes the unique leader knows the geographical region of the collaboration [23].

3.1.2.7 Virtual Grid Architecture routing (VGA):

Virtual Grid Architecture routing is a GPS-free technique. It breaks the network topology into logically symmetrical, side by side, equal and overlapping frames and the transmission is performed grid by grid. VGA provides the capability to aggregate the data and during network processing, it increase the life time of the network [24] [25].

The main advantages of VGA:

i. The location of the base station is not required at the extreme corner of the grid; rather it can be located at any arbitrary place.

The main disadvantages of VGA:

i. In each zone, cluster head is selected for local aggregation. A subset of those cluster heads, called Master nodes, is optimally selected to do global aggregation.

3.1.2.8 Hierarchical Power-aware Routing (HPAR):

An online algorithm max-min zPmin based on Hierarchical Power-aware Routing and showed that it had a good empirical competitive ratio to the optimal off-line algorithm that knows the message sequence. Next term, zone based power-aware routing divides the ad-hoc network into a small no of zones. Every zone can calculate its power level with a fast protocol. A global path for each message is selected across zones. Within each zone, a local path for the message is computes so as to not decrease the power level of the zone too much [26].

The main advantages of HPAR:

i. It works well with respect to network of large number of nodes.

The main disadvantages of HPAR

i. Maintaining global data is quite infeasible task.

3.1.2.9 Two-Tier Data Dissemination (TTDD):

Two-Tier Data Dissemination (TTDD) provides data delivery to multiple mobile stations. These sensor nodes are stationery and location-aware. But in case of sinks changes locations automatically. In grid structure, a data source chooses itself as the start cross point of the grid, and sends a data announcement message to each of its four adjacent crossing points using simple greedy geographical forwarding. When the message reaches a node that is close to the crossing point, it will stop. During this process, each intermediate node stores the source information and further forwards the message to its adjacent crossing points except the one from which the message comes from. This process continues until the message stops at the border of the network [27].

The main advantages of TTDD

i. TTDD is an efficient routing approach.
ii. TTDD achieve longer lifetime as compare to directed diffusion.
iii. TTDD assumed the availability of very accurate positioning system.

The main disadvantages of TTDD:

i. This protocol, suffers to extra overhead.

3.1.3 Location-Based Routing (Geographic Protocol)

Most of the routing protocols require right location information for sensor nodes in wireless sensor networks to calculate the distance between two particular nodes on the basis of signal strength so that energy consumption can be reduced. It is also utilized in routing data in energy efficient way when addressing scheme for sensor network is not known. It is worth noting that there have been many location-based protocols in Ad Hoc networks and it makes great effects when we transplant those research achievements for wireless sensor networks in some ways [28].

3.1.3.1 MECN and SMECN

Minimum Energy Communication Network (MECN) establishes a minimum consumption network for wireless sensor network. A minimum energy consumption topology for stationary nodes together with a master node is found. MECN assumes a master location because the info sinks, that is often the case for sensor networks.

The Small Minimum Energy Communication Network (SMECN) [29] is an extension to MECN. In MECN, it's assumed that each node will transmit to each different node, that isn't attainable movement. However, the network continues to be assumed to be totally connected as within the case of MECN. The subnet work created by SMECN for minimum energy relaying is incontrovertibly smaller (in terms of range of edges) than the one created in MECN if broadcasts square measure able to reach to all nodes in a very circular region around the broadcaster. As a result, the number of hops for transmissions can decrease. Simulation results show that SMECN consumed less energy than MECN and maintenance cost of the links is less. However, finding a sub-network with smaller range of edges introduces more overhead within the formula [29].

The main advantage of MECN and SMECN is:

i. Save lot of energy used in transmission of data

The main disadvantage of MECN and SMECN is:

i. Sub-network with smaller numbers of nodes introduces more overhead in finding the routes.

3.1.3.2 GEAR (Geographic and Energy Aware Routing)

The aim is to reduce the number of Interest in Directed Diffusion and add geographic information into interest packet by only considering a certain region rather than sending Interest to the whole network by means of flooding. GEAR uses energy efficient and geographically informed neighbor selection heuristics to route a packet towards the target region. Therefore, GEAR helps in balancing energy consumption in this way and increase the network lifetime. When a closer neighbor to the destination exists, GEAR forwards the packet to the destination by picking a next-hop among all neighbors that are closer to the destination [30]

The main advantage of GEAR is:

i. It reduces energy consumption.
ii. Packet delivery is very good as compare to other protocols.

The main disadvantage of GEAR is:

i. There is extra overhead of selecting the next neighbor for forwarding the data packets.

3.1.3.3 GAF and HGAF:

GAF (Geographic Adaptive Fidelity) is adaptive fidelity algorithm in which large numbers of sensor nodes are placed in observed area and only few nodes in the observed area are selected to transmit messages, while the other nodes sleep. In this way, GAF reduces network infrastructure and saves nodes battery. Hierarchical Geographical Adaptive Fidelity (HGAF) consumes less battery by increase the cell of GAF. GAF saves battery power by enlarging the size of the cell. The connectivity between active nodes in two adjacent cells must be guaranteed because active nodes works as cluster heads to deliver packets between cells [31][32].

The main advantage of GAF and HGAF is:

i. Increase network lifetime

The main advantage of GAF and HGAF is:

i. One of the nodes in grid act as a leader, but it does not perform any data aggregation and data fusion task.

3.1.3.4 Self-Powered Ad-hoc Network (SPAN):

Another position based algorithm called SPAN selects some nodes as coordinators based on their positions. It coordinates with network backbone to forward messages. A node may become a coordinator if two neighbors of a non-coordinator node cannot reach each other directly. So it is necessary to design less energy efficient because of the need to maintain the positions of two or three hop neighbors in the complicated SPAN algorithm [33].

The main advantage of SPAN:

i. It integrated with AODV routing provides better lifetime.
ii. It is more energy conservation as compared to LEACH protocol.

Routing Techniques	Classification	Mobility	Position Awareness	Power Usage	Negotiation based	Data Aggregation	Localization	QoS	State Complexity	Scalability	Multipath	Query based
Flooding	Flat	Possible	NO	Limited	YES	YES	NO	NO	LOW	Limited	Yes	Yes
SPIN	Flat	Possible	NO	Limited	YES	YES	NO	NO	LOW	Limited	Yes	Yes
Directed Diffusion	Flat	Limited	NO	Limited	YES	YES	NO	NO	LOW	Limited	Yes	Yes
Rumor Routing	Flat	Limited	NO	NO	YES	YES	NO	NO	LOW	Limited	Yes	Yes
GBR	Flat	Limited	NO	Limited	YES	YES	NO	NO	LOW	Limited	NO	Yes
MCFA	Flat	NO	NO	NO	NO	NO	NO	NO	LOW	GOOD	NO	NO
IDSQ & CADR	Flat	NO	NO	Limited	NO	YES	NO	NO	LOW	Limited	NO	NO
COUGAR	Flat	NO	NO	Limited	NO	YES	NO	NO	LOW	Limited	NO	Yes
ACQUIRE	Flat	Limited	NO	No	NO	YES	NO	NO	LOW	Limited	NO	Yes
EAR	Flat	Limited	NO	No	NO	No	NO	NO	LOW	Limited	NO	Yes
R P R W	Flat	Limited	NO	Limited	NO	No	NO	NO	LOW	Limited	NO	Yes
LEACH	Hierarchical	Fixed BS	NO	Maximum	NO	Yes	Yes	NO	CHs	Good	NO	No
PEGASIS & H-PEGASIS	Hierarchical	Fixed BS	NO	Maximum	NO	No	Yes	NO	Low	Good	NO	No
TEEN & APTEEN	Hierarchical	Fixed BS	NO	Maximum	NO	Yes	Yes	NO	CHs	Good	NO	No
ECRA	Hierarchical	Fixed BS	NO	Limited	NO	Yes	No	NO	CHs	Good	NO	No
SOP	Hierarchical	No	NO	No	NO	No	No	NO	Low	Low	NO	No
SAR	Hierarchical	Limited	NO	No	NO	Yes	No	NO	Low	Good	NO	Possible
VGA	Hierarchical	No	NO	No	Yes	Yes	Yes	NO	CHs	Good	Yes	No
HPAR	Hierarchical	No	NO	No	NO	No	No	NO	Low	Good	NO	No
TTDD	Hierarchical	Yes	Yes	Limited	NO	No	No	NO	Medium	Low	Possible	Possible
MECN & SMECN	Hierarchical	No	No	Maximum	NO	No	No	NO	Low	Low	No	No
GEAR	Location	Limited	No	Limited	NO	No	No	NO	Low	Limited	No	No
GAF & HGAF	Location	Limited	No	Limited	NO	No	No	NO	Low	Good	No	No
SPAN	Location	Limited	No	No	Yes	No	No	NO	Low	Limited	No	No
GOAFR	Location	Limited	No	Limited	NO	No	No	NO	Low	Good	No	No
MFR	Location	Limited	No	Limited	NO	No	No	NO	Low	Limited	No	No
GEDIR	Location	Limited	No	Limited	NO	No	No	NO	Low	Limited	No	No

Fig. 4 Comparison of Network Structure Based Routing Protocols

3.1.3.5 The Greedy Other Adaptive Face Routing (GOAFR):

The GOAFR algorithm combination of greedy and face routing. It is a merge greedy routing and faces routing in the following sense: in a greedy manner; in order to overcome local minima with respect to the distance from the destination. In face routing manner, GOAFR restricts the searchable area and improves the performance of both average case and worst case networks [34].

The main advantage of GOAFR:

i. It achieved both worst-case optimality and average-case efficiency.

3.1.3.6 Most forward within radius (MFR):

Most forward within radius (MFR) algorithm is used to forward packets to the sink node. A node using MFR forwards data to a node in its transmission range, which is the nearest to the sink when projected to a line connecting the sender node and the sink. Sensor nodes in the network populate their routing table with the location of their neighbors and choose the nearest one as next hop for forwarding data to the sink [35].

The main advantage of MFR:

i. It needs less hops of routing.

The main disadvantages of MFR:

i. It exists loop routing.

3.1.3.7 Geographic Distance Routing (GEDIR):

These protocols work with distance, progress, and direction based methods. Main challenges are forward direction and backward direction. It is a variant of greedy algorithms, the two-hop greedy method, alternate greedy method, and DIR (a compass routing method). Geographic Distance Routing is a greedy approach. It moves the packet to the neighbor of the current vertex whose distance to the destination is minimized. It working fails when the packet crosses the same edge twice in succession. According to DIR algorithm the best neighbor has the closest direction toward the destination. That is, the neighbor with the minimum angular distance from the imaginary line joining the current node and the destination is selected [36][37].

IV. CONCLUSION

In wireless sensor network routing protocols play important roles. By help of various routing protocols many research have completed and some under process to improve the lifetime of WSNs. We presented comparative study of routing protocols based on network structure in wireless sensor networks. All routing techniques have the common objective to extend the lifetime of the WSNs. The network structure based routing techniques are divided in three categories: flat, hierarchical, and location-based routing protocols. In this survey we also discussed advantages and disadvantages of each routing techniques. This study will help researcher to select more suitable routing technology according to network topology design. In future work we will try to optimize routing technology to extend network lifetime.

ACKNOWLEDGEMENT

The authors acknowledge I. K. Gujral Punjab Technical University, Kapurthala for providing research facilities.

REFERENCES

[1] R. Kumari and P. Nand, "Performance comparison of various routing protocols in WSN and WBAN," 2016 International Conference on Computing, Communication and Automation (ICCCA), Noida, 2016, pp. 427-431.

[2] H. Aznaoui, S. Raghay, L. Aziz and A. Ait-Mlouk, "A comparative study of routing protocols in WSN," 2015 5th International Conference on Information & Communication Technology and Accessibility (ICTA), Marrakech, 2015, pp. 1-6.

[3] Shazana Md Zin, Nor Badrul Anuar, Miss Laiha Mat Kiah, Ismail Ahmedy, Survey of secure multipath routing protocols for WSNs, Journal of Network and Computer Applications, Volume 55, 2015, ISSN 1084-8045, pp. 123-153.

[4] Eliana Stavrou, Andreas Pitsillides, A survey on secure multipath routing protocols in WSNs, Computer Networks, Volume 54, Issue 13, 2010, ISSN 1389-1286, pp. 2215-2238.

[5] Xianlong Jiao, Wei Lou, Xiaodong Wang, Junchao Ma, Jiannong Cao, Xingming Zhou, On interference-aware gossiping in uncoordinated duty-cycled multi-hop wireless networks, Ad Hoc Networks, Volume 11, Issue 4, 2013, ISSN 1570-8705, pp. 1319-1330.

[6] Martin Jacobsson, Cheng Guo, Ignas Niemegeers, An experimental investigation of optimized flooding protocols using a wireless sensor network testbed, Computer Networks, Volume 55, Issue 13, 2011, ISSN 1389-1286, pp. 2899-2913.

[7] B. Mbarek and A. Meddeb, "Energy efficient security protocols for wireless sensor networks : SPINS vs TinySec," 2016 International Symposium on Networks, Computers and Communications (ISNCC), Yasmine Hammamet, 2016, pp. 1-4.

[8] N. S. Samaras and F. S. Triantari, "On Direct Diffusion Routing for Wireless Sensor Networks," 2016 Advances in Wireless and Optical Communications (RTUWO), Riga, 2016, pp. 89-94.

[9] Hamid Shokrzadeh, A.T. Haghighat, Abbas Nayebi, New routing framework base on rumor routing in wireless sensor networks, Computer Communications, Volume 32, Issue 1, 2009, ISSN 0140-3664, Pages 86-93.

[10] Tao Liu, Qingrui Li, Ping Liang, An energy-balancing clustering approach for gradient-based routing in wireless sensor networks, Computer Communications, Volume 35, Issue 17, 2012, ISSN 0140-3664, pp. 2150-2161.

[11] Yating Wu, Bin Kuang, Tao Wang, Qianwu Zhang, Min Wang, Minimum cost maximum flow algorithm for upstream bandwidth allocation in OFDMA passive optical networks, Optics Communications, Volume 356, 2015, ISSN 0030-4018, pp. 103-108.
[12] Kemal Akkaya, Mohamed Younis, A survey on routing protocols for wireless sensor networks, Ad Hoc Networks, Volume 3, Issue 3, 2005, ISSN 1570-8705, pp. 325-349.
[13] Yao ,Johannes Gehrke, The Cougar Approach to In-Network Query Processing in Sensor Networks, SIGMOD Record, Vol. 31, No. 3, September 2002, pp. 9-18.
[14] N. Sadagopan, B. Krishnamachari and A. Helmy, "The ACQUIRE mechanism for efficient querying in sensor networks," Proceedings of the First IEEE International Workshop on Sensor Network Protocols and Applications, 2003., 2003, pp. 149-155.
[15] P. Duan, K. Wang, X. Yu, L. Liu, H. Gu and Y. Guo, "Flow Driven Energy-Aware Routing Algorithm in Data Center Network," 2016 17th International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT), Guangzhou, 2016, pp. 280-285.
[16] P. Nayak and P. Sinha, "Analysis of Random Way Point and Random Walk Mobility Model for Reactive Routing Protocols for MANET Using NetSim Simulator," 2015 3rd International Conference on Artificial Intelligence, Modelling and Simulation (AIMS), Kota Kinabalu, 2015, pp. 427-432.
[17] Wang Ke, Ou Yangrui, Ji Hong, Zhang Heli, Li Xi, Energy aware hierarchical cluster-based routing protocol for WSNs, The Journal of China Universities of Posts and Telecommunications, Volume 23, Issue 4, 2016, ISSN 1005-8885,pp. 46-52.
[18] Wafa Akkari, Badia Bouhdid, Abdelfettah Belghith, LEATCH: Low Energy Adaptive Tier Clustering Hierarchy, Procedia Computer Science, Volume 52, 2015, ISSN 1877-0509, pp 365-372.
[19] Rina Mahakud, Satyanarayan Rath, Minu Samantaray, BabySradha Sinha, Priyanka Priya, Ananya Nayak, Aarti Kumari, Energy Management in Wireless Sensor Network Using PEGASIS, Procedia Computer Science, Volume 92, 2016, ISSN 1877-0509, pp. 207-212.
[20] DaWei Xu, Jing Gao, Comparison Study to Hierarchical Routing Protocols in Wireless Sensor Networks, Procedia Environmental Sciences, Volume 10, 2011, ISSN 1878-0296, pp. 595-600.
[21] Ado Adamou Abba Ari, Blaise Omer Yenke, Nabila Labraoui, Irepran Damakoa, Abdelhak Gueroui, A power efficient cluster-based routing algorithm for wireless sensor networks: Honeybees swarm intelligence based approach, Journal of Network and Computer Applications, Volume 69, 2016, ISSN 1084-8045, pp. 77-97.
[22] Akiya Kamimura, Kohji Tomita, A self-organizing network coordination framework enabling collision-free and congestion-less wireless sensor networks, Journal of Network and Computer Applications, Volume 93, 2017, ISSN 1084-8045, pp. 228-244.
[23] X. Lu, L. Cheng and N. Yang, "A Data-Aggregated Unequal Clustering Routing Protocol for Wireless Sensor Networks," 2010 2nd International Workshop on Intelligent Systems and Applications, Wuhan, 2010, pp. 1-4.
[24] J. N. Al-Karaki, A. E. Kamal and R. Ul-Mustafa, "On the optimal clustering in mobile ad hoc networks," First IEEE Consumer Communications and Networking Conference, 2004. CCNC 2004, Las Vegas, NV, USA, 2004, pp. 71-76.
[25] Laiali Almazaydeh, Eman Abdelfattah, Manal Al- Bzoor, and Amer Al- Rahayfeh, PERFORMANCE EVALUATION OF ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS, International Journal of Computer Science and Information Technology, Volume 2, Number 2, April 2010,pp. 64-73.
[26] Qun Li, Javed Aslam, Daniela Rus, Hierarchical Power aware Routing in Sensor Networks, Journal of Network and Computer Applications, Volume 93, 2017, ISSN 1084-8045, pp. 228-244.
[27] Bidi Ying, Huifang Chen, Wendao Zhao and Peiliang Qiu, "A Diagonal-based TTDD in Wireless Sensor Networks," 2006 6th World Congress on Intelligent Control and Automation, Dalian, 2006, pp. 257-260.
[28] K. Yadav and P. Rana, "Position Based Routing Schemes in Wireless Sensor Networks: A Review," 2016 Second International Conference on Computational Intelligence & Communication Technology (CICT), Ghaziabad, 2016, pp. 316-320.
[29] J. Grover, Shikha and M. Sharma, "Location based protocols in Wireless Sensor Network — A review," Fifth International Conference on Computing, Communications and Networking Technologies (ICCCNT), Hefei, 2014, pp. 1-5.
[30] K. Maarouf and T. R. Sheltami, "Simulation-Based Analysis for GEAR Performance Optimization," 22nd International Conference on Advanced Information Networking and Applications - Workshops (aina workshops 2008), Okinawa, 2008, pp. 910-915.
[31] T. Osawa, T. Inagaki and S. Ishihara, "HGAF-h: A Hierarchical Honeycomb Cooperative Power Saving Architecture for Sensor Networks," 2009 Tenth International Conference on Mobile Data Management: Systems, Services and Middleware, Taipei, 2009, pp. 542-547.

[32] Takashi Osawa, Tokuya Inagaki and Susumu Ishihara, "Implementation of Hierarchical GAF," 2008 5th International Conference on Networked Sensing Systems, Kanazawa, 2008, pp. 247-247.

[33] R. Vaidya and D. R. Dandekar, "Comparison of SPAN and LEACH protocol for topology control in wireless sensor networks," 2013 International Conference on Signal Processing , Image Processing & Pattern Recognition, Coimbatore, 2013, pp. 20-23.

[34] Haesu Hwang, In Hur and Hyunseung Choo, "GOAFR plus-ABC: Geographic routing based on Adaptive Boundary Circle in MANETs," 2009 International Conference on Information Networking, Chiang Mai, 2009, pp. 1-3.

[35] Khaled Ahmed AboodOmer, Analytical Study of MFR Routing Algorithm for Mobile Ad hoc Networks, Journal of King Saud University - Computer and Information Sciences, Volume 22, 2010, ISSN 1319-1578, pp. 29-35.

[36] T. Takehira and H. Higaki, "IRDT-GEDIR: Shorter delay wireless multihop routing in sensor networks," 2012 IV International Congress on Ultra Modern Telecommunications and Control Systems, St. Petersburg, 2012, pp. 857-863.

[37] J. N. Al-Karaki and A. E. Kamal, "Routing techniques in wireless sensor networks: a survey," in IEEE Wireless Communications, vol. 11, no. 6, pp. 6-28, Dec. 2004.

Author's Profile:

Mr. Brahm Prakash Dahiya got his Mr Brahm Prakash Dahiya pursed B.Tech degree (Information Technology) from P.T.U. University Punjab, India, in 2009 and received his M.Tech in (Computer Science and Engineering) from Maharshi Dayanand University, Rohtak, Haryana, India, in 2011. He is pursuing his Ph.d Degree from I. K. Gujral Punjab Technical University, Jalandhar, India. He has published more than 25 research papers in reputed national and international journals and conferences. His research interests include in Soft-Computing, Image Processing, and Wireless Sensor.

Dr. Shaveta Rani pursed B.Tech. (CSE) and M.S. (Software Systems) from BITS Pilani in 2009. She has completed Ph.D. from BITS Pilani in 2009 and currently working as Professor in Department of Computer Science & Eng., Giani Zail Singh Campus College of Engineering and Technology, Punjab. She has published more than 80 research papers in reputed international journals including Thomson Reuters (SCI & Web of Science) and conferences including IEEE, Her main research work focus on Cryptography Algorithms, Network Security, Cloud Security and Privacy, Big Data Analytics, Data Mining, IoT, Wireless Sensor Network and Computational Intelligence based education. She has 18 years of teaching and Research Experience.

Dr. Paramjeet Singh pursed B.Tech. (CSE) and M.S. (Software Systems) from BITS Pilani in 2009. He has completed Ph.D. from BITS Pilani in 2009 and currently working as Professor in Department of Computer Science & Eng., Giani Zail Singh Campus College of Engineering and Technology, Punjab.He has published more than 80 research papers in reputed international journals including Thomson Reuters (SCI & Web of Science) and conferences including IEEE, His main research work focuses on Cryptography Algorithms, Network Security, Cloud Security and Privacy, Big Data Analytics, Data Mining, IoT, Wireless Sensor Network and Computational Intelligence based education. He has 18 years of teaching and Research Experience