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Review: Comparative Study of Wireless Sensor Network Protocols

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Abstract: Wireless Sensor Network is a diverse network and in this resource-constrained sensor nodes are deployed in the monitoring region for collecting data and transmit it to the destination via routing. An optimal selection of a route for the data transmission helps to extend the lifetime of a network by consuming less energy. In this paper, the different routing protocol strategies have been discussed based on a routing path. However, dynamical changes in the network such as mobility, node density, and traffic cause connection breakage, routing overhead, node failure, delay and thereby data loss may occur. It can affect the overall network performance. In order to overcome these problems, efficient routing protocols were introduced. The significance of this survey is to investigate the impact of overhead, mobility as well as scalability factors on a wide range of routing protocols. All routing protocols are described under their specific category i.e. reactive, proactive and hybrid. Further, a performance comparison among routing protocols is discussed on the basis of some parameters like mobility, scalability, energy efficiency etc.

Keywords: Wireless Sensor Network, Optimal Path Decision, Routing Protocols, Energy efficiency, Network Lifetime.

I. INTRODUCTION

From the past few years, sensor networks reached a great instant level and it is required that sensor networks provide different services like surveying, mapping and providing geographical information. In the wireless communication, sensor networks should have distinctive properties by considering small size of nodes which are light weighted, cost effective so that it consumes less power and provides high reliability.

Wireless sensor network (WSN) can be considered as child root of ad hoc network which is comprised of interconnected autonomous nodes for monitoring environmental conditions such as temperature, pressure etc and forwards the received data from nodes to the Base Station (BS) via a wireless communication channel and forming a network [1]. The mobile sink is used in the network to collect information from the resource-constrained nodes and then it can directly communicate with the BS. BS is a fixed central controller and aggregates the data from respective nodes which are participating in the network. Each and every sensor node has its sensing system like sensor for data acquisition, a processing system for processing sensor signals, a memory for storing the measured data, a communication system for radio transmission and power supply system for performing operation and additional components such as Global Positioning System (GPS) for tracking the location and mobilizer for supporting movement among nodes. In tracking and monitoring applications, WSNs plays a significant role for location tracking and mapping of traffic and vehicles, animals in habitat area, enemy and interruptions in military field as well as monitoring other fields such as structural health monitoring, chemical monitoring, machine monitoring, patient monitoring, environment monitoring like temperature, weather, pressure, humidity, light etc [2].

The performance of WSNs is proportional to routing protocol schemes. Basically, routing means to determine the path between source to destination for transmission purpose as well as reception of data packets within a network. In WSNs, the network layer is mainly responsible for executing the routing of a received data packet. To improve the communication stack among networks, designing of routing protocol plays an important role. So it's necessary that routing protocol should be designed in most effective and efficient way. Due to resource constrained nature of devices in terms of storage capacity, limited battery and computing power in WSNs, routing protocols helps to ensure reliable communication in a network. There are other certain issues in the field of sensor network related to changing network conditions such as scalability, dynamic topological changes like failures and fading, mobility in network and irregularity in the routing of data packets.

The dynamic nature of WSN results in energy consumption, more chances of node failure which can affect connectivity and network lifetime. To resolve these issues, the development of routing protocols is very challenging and important for the route establishment and maintenance among the nodes in a network. Thus, various routing protocols are proposed for wireless networks that can be distinguished into three categories such as reactive, proactive and hybrid protocols. Figure.1 depicts the basic architecture of WSN. In this, numbers of homogeneous nodes are scattered in a monitoring region having the sensing as well as wireless communication capabilities. The mobile sink is used to aggregate the data from the sensor nodes [3]. Both of them will communicate only with those sensor nodes which are in a range of the respective mobile sink. The significance of employing mobile sinks in the network is for reducing the number of hops needed for data delivery from a sensor node to BS. This approach helps in minimizing the consumption of energy which can affect the overall performance of a network. Gateway acts as an interface between the BS and monitoring area which firstly receives data from mobile sinks and after that decodes it and then forwards directly to the BS. BS further processes the data as per application requirement.

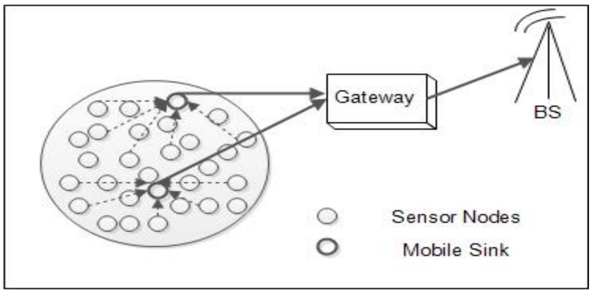

Figure 1: Layout of Wireless Sensor Network

II. ROUTING PARAMETER FEATURES AND DESIGN ISSUES IN ROUTING PROTOCOLS

The routing protocol design for WSN should have the following features:

1) Routing protocols should identify and maintain the optimal routes to guarantee reliable communication and to minimize delay in routing.
2) To avoid clogging, there must be various routes within a network to hand-off the information from source to destination and to achieve robustness.
3) Routing protocols should be designed in such a way that they must accomplish high reliability even if prone to error, noise and time variations in wireless channels.
4) Try to design the routing protocols more energy efficient to expand the network lifetime.
5) Routing protocols for sensor network should be scalable in a case of different size of networks and adaptable in highly dynamic network conditions.
6) The protocols that are proposed for communication in sensor networks should utilize the bandwidth of a network in an efficient manner.
7) The routing protocols for sensor network should be designed in such a way that it can fulfil the quality of service metric of particular application [4].

The routing protocol design for WSNs is impacted by numerous challenging factors as summarized below:

1) Deployment of nodes: Routing protocol algorithms depend on the network architecture. The arrangement of nodes in a network either manually or randomly is proportional to an application demand as it greatly influences the performance of the routing protocol. However, the non-uniform distribution of nodes may lead to disconnection of a network as compared to the uniform distribution that helps to make the network more stable.

2) Dynamic Network Situations: In case the deployed sensor nodes are either increasing or either decreasing, failure of nodes while transmission and reception of data, energy depletes by sensor nodes, these above mentioned factors can affect the network topology. Most of the network design follows the static sensor node scenario, however other use mobile sensors. While taking mobile sensors, communication among the sensor nodes becomes a challenging issue so the stability of route is a vital factor along with energy and bandwidth consumption.

3) Energy conservation: Due to limited battery power of nodes, it can affect the overall performance of an entire network. After the long transmission in a network, sensor nodes consume a high level of energy and there will be more chances of early energy depletion. This results in the network disconnection earlier because the number of dead nodes is more as compared to alive nodes. The direct communication consumes less energy, but in case if the destination is far away from the source then it consumes high energy as compared to multi-hop routing. Thus, there is a need to design energy efficient routing protocols in order to prolong the lifetime of a network [4].

4) Fault tolerance: In case sensor nodes failure occurs, routing protocols must be able to establish the new connections so that failure of the nodes could not affect the overall performance of a network.

5) Scalability: To design a network, if the requirement of node density is high, in that case routing protocols should be designed in such a way so that they have the capability to perform well in such type of networks without affecting the network's performance.

6) Data fusion: Implosion problem occurs when duplicate data packets come from multiple nodes in a network. Redundant data can be reduced by applying the data fusion scheme; thereby the number of transmissions will be less. It helps to achieve an energy efficient network [5].

The remaining survey paper is organized as follows: In Section II challenges and design parameters for routing protocols are highlighted. In Section III, presents the various routing techniques of a sensor network. A comparison table between these protocols is also included. Section IV discusses proactive, reactive and hybrid protocols. Finally, Section V represents the conclusion of various routing protocols.

III.EXISTING ROUTING TECHNIQUES IN WSN

Routing protocols can be categorized according to the method of establishment of routing paths. The establishment of routing paths is done by three ways, namely reactive, proactive or hybrid. Proactive protocols first compute all the paths by flooding periodic messages among the nodes and updates path information in node's routing table. Optimized Link State Routing (OLSR), Destination Sequenced Distance Vector (DSDV) and Fisheye State Routing (FSR) are some of the proactive protocols. Reactive protocols compute paths by initiating route discovery procedure only when routes are needed. Ad hoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Temporally Ordered Routing

Algorithm (TORA) are reactive protocols. The hybrid protocol is a fusion of advantageous features of both proactive and reactive protocols. Zone Routing Protocol (ZRP), Zone-based Hierarchical Link State (ZHLS) and Landmark Ad hoc Routing (LANMAR) are hybrid protocols.

On the basis of network structure, these routing protocols can be further categorized into flat, hierarchical or location-based protocols. When all sensor nodes within a network play an identical role, it is called flat routing, and when all nodes play different roles, it is termed as hierarchical routing. However, when for routing data in the network, node's position is used; it is termed as location routing. Figure.2 demonstrates the classification of WSN routing protocols.

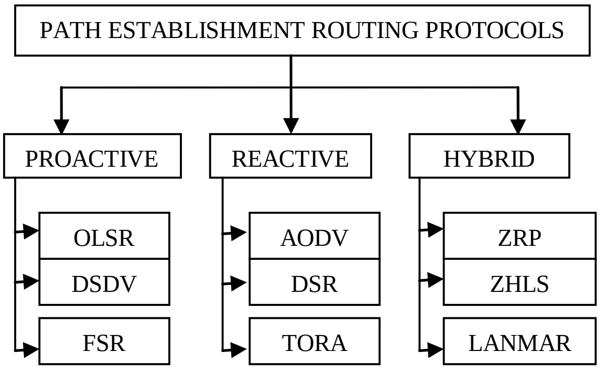

Figure 2: Classification of Routing Protocols

IV. DESCRIPTION OF VARIOUS EXISTING ROUTING PROTOCOLS

A. Proactive routing protocol

These are table-driven protocols as the routing information about each node within a sensor network is maintained at regular intervals in the routing tables. The routing table consists of source and destination address [6]. In case, if link connections are changed, routing tables are updated periodically throughout the network. This type of routing avoids the loop formation in the routing table. Moreover, in this, each node inside a network has its own routing table for storing routing information about all the neighboring nodes in the network. If the source has a data to transmit to another node, first of all, it fetches address information regarding the destination node, and then the source node is able to send data to destination without any interruption. In this way, the delay prior to data transmission is minimal. Hence, no latency time occurs during the route establishment. However, it has some disadvantages. Route computation is performed by all the nodes before routing the packet to the destination, this results in more memory and energy consumption. However, if there is a change in topology of a network; proactive protocols maintain all the routes among nodes including its next hop address, destination address, etc. Along with the routing path, these protocols also gather information related to unused paths, but unused paths and their maintenance consume more time, energy and bandwidth available in the network. In node mobility case, delays can occur due to moderate response to the network. If the network is high node density, thus there is a need to maintain large entries in routing tables for each node but a periodic distribution of routing information creates high overhead, therefore, proactive protocols don't support the routing in large networks. Thus, reactive routing protocols arrived to overcome the above-mentioned limitations. The various well known proactive protocols named as DSDV, OLSR, FSR and their functionalities are described below:

1) OLSR (OPTIMIZED LINK STATE ROUTING) PROTOCOL:

OLSR is the improvement over conventional link-state algorithm [7]. This protocol uses link state messages for exchanging routing information within a network and then computes the optimal forwarding paths locally. It uses a Multipoint relays (MPR) technique to forward the control traffic among the whole network. For the selection of MPR set, it requires the information about the neighboring nodes that are at a distance of two hops by periodically exchanging HELLO messages and Topology Control (TC) messages. These selected set of neighboring nodes will perform the retransmissions of packets. During updating route procedure, OLSR helps in minimizing the message size and the rebroadcasting nodes by utilizing its MPR strategy. Hence, it is more scalable in dense environments as it limits retransmissions of control packets by using the MPR concept. Also, it has a less average delay since OLSR generates TC messages only when MPRs status changes [8]. Although OLSR uses MPR for minimizing the load but computation of MPR set for a node with the help of maximum periodic messages generates additional overhead and consumes more bandwidth. Another disadvantage associated with the OLSR is while searching for an alternate route for transmission, as the additional power is required and whenever there is a need to rediscover the fault connection, it consumes the more time.

2) DSDV (DESTINATION-SEQUENCED DISTANCE VECTOR) PROTOCOL:

It utilizes distributed Bellman-Ford (DBF) [9] scheme for finding shortest paths from a source to destination. Because of the use of destination sequence number like in DBF, there is less possibility that count to infinity problem occurs and hence DSDV also ensures loop-free paths. In DSDV, every node has its own routing table that includes next hop, number of hops to all possible destination nodes. These tables are exchanged periodically among the neighboring nodes to keep the freshest information about the topology of a network [10]. DSDV transmits a packet only at the best possible routes which are validated by the protocol, thus results in more accurate routing and also limits the space utilization in the routing table. For lowering network overhead, DSDV uses incremental update packets mechanism that carries only the changed topology information and sends this packet more frequently as compared to a packet that contains all the available routing information. Hence, this protocol is considered more adaptable to mobile environments. DSDV also takes the benefit of triggered messages in case

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of link breakage for providing route accuracy but triggered messages create routing overhead which results in more consumption of network bandwidth. However, it suffers more delay while searching the available routes in the network followed by selection of appropriate route among them and also an unnecessary advertisement of unstable routes causes overhead and more bandwidth wastage. Because each node has to maintain the routing tables of its own and neighboring nodes; hence it is not scalable for a large network. This protocol has a large overhead because of regular occurrence of topological changes inside a network due to which there is need to exchange the more routing tables among all neighboring nodes.

3) FSR (FISHEYE STATE ROUTING) PROTOCOL:
This unicast routing protocol is based on a link-state algorithm for maintaining up-to-date routing information in a network. It utilizes multilevel fisheye scope. This protocol periodically exchanges routing updated information more frequently and accurately among the neighboring nodes but as the distance increases among the nodes, the accuracy of routing information decreases and also has larger intervals [11]. FSR reduces the overhead that results from routing updates and utilizes the network bandwidth efficiently by minimizing control traffic only to restricted transmission range within a large network. This protocol helps to reduce the update message size as it shares routing information more frequently for the nodes that are in its transmission range in contrast to the destination nodes that are outside its scope. Thus, FSR exhibits a better scalability in low node density as compared to other link state protocols as it need not maintain the routing information of all nodes in the network at the same level in a network. As a result, the route information accuracy is inversely proportional to the distance. However, in the case of mobility and high node density, it suffers high delay as a route is very far away from the destination node and it becomes less accurate.

TABLE I COMPARISON AMONG PROACTIVE ROUTING PROTOCOLS

	DSDV	**OLSR**	**FSR**
Routing Structure	Flat (Distance Vector)	Flat (Link state)	Flat (Link state)
Updates Frequency	Periodic broadcast and as required	Periodic	Periodic but within limited range
Merits	Loop-free, least delays, Scales best, performs best in mobile environment	Loop-free, low delay, low overhead, scales best in dense environment	Low control overhead, scales well in dense environments, performs well in mobility
Demerits	Requires full routing information, High routing and control overhead in large network size	Requires information about 2-hop neighbors, high routing load, poor performance in mobile environment	Less route accuracy, high routing and memory overhead

B. Reactive routing protocols:
These are on-demand protocols since routing paths are established only when it is required. It mainly includes two operations viz. Route Discovery and Route Maintenance. For the route discovery, it invokes Route Request (RREQ) and Route Reply (RREP) process. In case the link is disconnected, maintenance of route is invoked by passing a Route Error (RERR) message to an initiating node and this process repeats until it finds out the destination node [12].The route discovery process ends either when a route has been determined or when not a single route is available after examining all route permutations. The distinct advantage of the reactive protocol is that it has lower traffic and routing overhead since they maintain only active routes of the network and transmits a packet only when the source node aggregates the data and wants to send it. Thus, they consume less bandwidth, power and have better scalability as compared to proactive protocols [13]. However when a node detects a topology change due to mobility, there may be the chances of disconnection for active routes. Therefore, route maintenance is vital thus reactive protocols involves in route search procedure for new route formation by flooding the control traffic packets globally, but this results in significant network congestion. Moreover, the data may lose if the route to the destination is changed. However while searching the route; source nodes suffer from higher latency time before the transmission of the packets and results in more energy expenditure. Therefore, hybrid routing protocols arrive to overcome the above-mentioned limitations. AODV, DSR, TORA are some of the reactive protocols in WSNs and their functioning is discussed below:

1) AODV (AD HOC ON-DEMAND DISTANCE VECTOR ROUTING) PROTOCOL:
AODV is reactive, unicast as well as a multicast routing protocol. AODV is based on DSDV protocol; hence, it finds a route by periodically flooding a beacon message and destination sequence number among its neighboring nodes [14]. AODV keeps the topology information regarding the active paths at nodes routing tables. If a particular route entry in the routing table is not used till the setup threshold time value, it is deleted and provides vacant space for active paths. If source node wants to send a data packet to the destination but has no route available

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in its routing table to forward it, then AODV initiates a route discovery procedure as used in DSR. For determining a path, the source node floods a RREQ packet which has the address of a source and its sequence number, destination address and its sequence number and identification of broadcasted packet [15]. AODV utilizes the benefits of the sequence number of destination in order to guarantee the loop-free as well as up-to-date routes available at all times. It also minimizes the overhead that results from flooding process by discarding the identical copies of RREQ packets. To ensure the up-to-date route information, a RREP packet is generated and is sent back to the source node only. AODV follows symmetric links for transmitting the RREP for acknowledgment to the respective RREQ packet. Whenever any source node encounters a failure of a link in the network then this protocol helps to broadcast the RERR packet among its neighbors, which further transmit this packet towards those nodes which acts as neighboring nodes for the previous nodes and whose paths may get affected by this link disconnection. Thus, if the affected source still has the data to be transmitted then it can restart a process of route discovery. The novelty of this protocol is that there is a little routing overhead as the packets stores only the destination address instead of full routing information from the source node to the destination as in DSR. Another advantage of AODV, being energy and bandwidth efficient protocol, it is highly adaptable to the dynamic network conditions. But in AODV, due to on-demand connection setup procedure, latency is higher in massive networks and additional delays may be experienced in case of link disconnections among network nodes as a node has to reinitiate the operation of route discovery. Moreover, in correspondence to a single periodic RREQ, there are multiple RREP packets in response, this will cause an extensive control overhead and there may be the chances for an unnecessary occupation of the bandwidth for validating a route.

2) DSR (DYNAMIC SOURCE ROUTING) PROTOCOL:

DSR follows the unicast routing and on-demand route formation mechanism. It utilizes source routing algorithm and route caching scheme before initiating a route discovery operation. In this, the source node is mainly responsible for making the forwarding decision. It basically consists of route discovery phase and route maintenance phase. When a source node has to forward its data packet to the destination, initially it will look for the required route in its route cache. If source node is able to find out the route, then it will add the routing information to a data packet prior to packet final transmission. Otherwise, route discovery phase is initialized by the source node in which RREQ packet is flooded among the neighboring nodes [16]. On the reception of an RREQ packet, neighboring nodes check their route cache. If the desired route is found, neighboring node or reached destination will generate the RREP packet and respond back by forwarding this packet to a source node. Otherwise, nodes include their own address into the route record field of the RREQ packet and further pass this packet among its neighboring nodes. Whenever there is a link breakage, source nodes are notified with the RERR packet and hence they can re-initiate the route discovery procedure and source node will further aware other nodes in the network about the link breakdown by piggybacking the RERR packet with the RREQ packet. Since DSR employs route caching scheme which stores multiple routes to the destination thus it reduces routing overhead problems for searching a valid route before initializing route discovery process [17]. This protocol doesn't require periodic exchange of hello or beacon messages; therefore, DSR helps nodes to go into sleep mode and thus helps in saving their battery power as well as conserving bandwidth of a network. Moreover, it performs better in networks that are moderate in size and has low mobility than AODV and TORA. But performance of DSR degrades in case of high control overhead due to complete routing information within the header of the data packet, results in an increase in the size of the packet and hence the length of the route which may further cause network clogging. Hence, it does not scale well in huge and dynamic networks because growth in network size leads to more packets overhead and thereby more bandwidth utilization and even may consume an additional power while processing in contrast to other existing protocols. Another disadvantage of this protocol is that nodes suffer larger delays while establishing the connection and route maintenance is also poor.

3) TORA (TEMPORALLY ORDERED ROUTING ALGORITHM) PROTOCOL:

TORA exploits the benefits of the Lightweight Mobile Routing (LMR) protocol such as it uses the link reversal and route repair procedure [18]. TORA also includes the process of RREQ and RREP packets as in LMR for creating Directed Acyclic Graph (DAG). Hence, TORA considers the topology of a network as a DAG where unique height rank is issued to each network node. The packet flow takes place from a node higher height to a node lower with the lowest rank. The DAG construction within a network provides the capability for multipath routing to transmit a data packet from the source node to the destination and hence it ensures loop-free routes. Basically, TORA has three main functions, first, route creation for developing and creating a path from the source node to the destination, route maintenance for maintaining the route in case of link failure occurs and route erasure for deleting the invalid route by flooding the clear packets throughout the network [19]. In TORA, the disconnection in DAG occurs in case of node mobility. The distinct feature of the TORA is that whenever there is a change in network topology, the effect can be localized among that set of nodes only where the fault connection has occurred instead of all nodes within a network. Thus, it avoids extra delays for maintenance of the complete routes along with a reduction in memory requirement and control overhead. Moreover, TORA has multiple routes for forwarding packets to the destination, hence is considered more efficient and scalable protocol that is highly adaptable to changing network conditions. But

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TORA has the limitations that it requires all nodes in a network must have synchronized clocks. Also, it generates temporary invalid routes similar to the LMR, hence, nodes may suffer more delays while discovery a route. Maintenance of route in TORA is also poor as it introduces the large routing overhead and causes network congestion and results in large delay for data packets in reaching their destinations.

TABLE III COMPARISON BETWEEN VARIOUS REACTIVE PROTOCOLS

	AODV	**DSR**	**TORA**
Routing Structure	Flat	Flat	Flat
Multiple routes	No	Yes	Yes
Mode of Routing Metric	Freshest and shortest path in routing table	Shortest path or next available link in route cache	Shortest path or next available link in routing table
Route Reconfiguration	Route erasure then source notification or route repair locally	Route removal then source notification	Link reversal and route repair
Merits	Highly adaptable to dynamic network topology, lower routing overhead	Loop-free, Multiple routes in route cache, lower control overhead	Less communication overhead, less bandwidth utilization
Demerits	Scales poor, high delay, periodically exchanges HELLO messages, high control overhead	Scalability problems, higher delays, high routing overhead for longer paths, poor route maintenance	Temporary routing loops, more routing overhead, needs clock synchronizat-ion among nodes

C. Hybrid routing protocol:
These are constructed by combining the two different protocols namely; table-driven and on-demand which have distinct properties. Hybrid protocol partitions the network into routing zones in which each node has a fixed transmission range. In this, the source node with a data packet to transmit primarily looks for the destination by flooding the RREQ packet among the neighboring nodes that are localized within its routing zones. Upon the reception of RREQ packet, if receiver node knows the path to the destination, it notifies the source node by transmitting RREP packet in response, hence, performs routing proactively [20]. However, if the destination lies in another zone, then nodes employs reactive routing. Hybrid protocol eliminates the route setup delay within a zone, single point of failures and creation of bottleneck nodes within a network. It also requires less power and bandwidth and hence increases the network performance. Hybrid routing lowers the routing overhead that occurs due to longer routes in reactive routing. Therefore, it is more efficient and scalable protocol as compared to pure proactive and reactive protocols. But there is an issue of larger overlapping of routing zones. Moreover, there may be longer delays if the route is not found immediately [21]. ZRP, ZHLS, LANMAR are some of the hybrid protocols in WSNs and their operation is described below:

1) ZRP (ZONE ROUTING PROTOCOL):
ZRP is based on the concept of routing zones. ZRP partitions the network into overlapping zones on the basis of radius range of each node for maintaining the connectivity in the network. There are two routing schemes in ZRP to determine a routing link between source and destination viz. Intra-zone routing protocol (IARP) and Inter-zone routing protocol (IERP) [22]. In case if source and destination exists within a particular routing zone, then IARP proactive routing scheme is used for transmission purpose and the data packets will be transmitted directly on the available links to reach the border nodes in a specific zone. In IERP, reactive routing scheme is employed in case particular destination exists in another routing zone and source node has to perform a task of route discovery procedure. For determining the route, propagation of RREQ packet is done via border nodes [23]. The advantage of ZRP is that it minimizes the overhead which is caused due to flooding of periodic control packets in proactive routing scheme. Moreover, this protocol reduces route discovery latency that occurs in reactive routing scheme along with less bandwidth consumption. But, high overlapping of routing zones results in more overhead and complexity for finding a new path. As in the case of larger routing zones, ZRP works in proactive fashion whereas for smaller zones values, it works as a reactive protocol. Also, communication with the nodes that are in other zone becomes difficult or sometimes not possible.

2) ZHLS (ZONE-BASED HIERARCHICAL LINK STATE) PROTOCOL :
ZHLS is a zone based protocol that utilizes a hierarchical routing structure [24]. The network is partitioned into non-overlapping routing zones. In ZHLS, nodes are GPS-enabled and thus they are aware of the position of all other nodes participating in a network. Each node available in a network has its own node as well as zone ID which further helps to differentiate among all the nodes and will make the communication more effective. When the source node has to transmit the information, firstly it satisfies the

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condition by checking its routing table which includes a destination address, the hop count of destination available in an intra-zone. If the desired destination lies within the same zone in which source is present, then it has routing information readily available. Otherwise, a location request is sent by the source node to all other zones via gateway nodes. Upon receiving the location request, destination node respond back with a location reply that contains the zone ID of the destination [25]. ZHLS avoids the problem of single point of failure (SPF) and bottleneck. Moreover, it generates less overhead as compared to reactive protocols, thus, highly adaptable to dynamic network conditions because ZHLS utilizes the concept of node ID and zone ID of the destination for performing routing. It scales well in large and dynamic network hence, performs well. For efficient working, all nodes must contain a pre-programmed static zone map but, is infeasible for the applications where the geographical boundary of the network changes frequently.

3) LANMAR (LANDMARK AD HOC ROUTING) PROTOCOL:
LANMAR is an improvement over FSR protocol and is more scalable than it. It combines the features of both algorithms, link state as well as distance vector. In this, subnets of nodes are created logically according to their mobility patterns which probably move together as a group [26]. In each subnet, a LANDMARK node is elected to keep track of these subnet groups. In LANMAR, the nodes periodically maintain the routing information of neighboring nodes that are in scope and all LANDMARK nodes. When a source has to send a data packet to the destination that is in its neighboring scope, and for that it checks source's routing table to find out the address of the destination. If required destination is found, a packet is routed to that obtained address directly. Otherwise, a packet is sent towards the LANDMARK node of the logical subnet so that it can reach its closest destination. LANMAR is an efficient protocol as it has the ability to exchange accurate routing information. It reduces the routing table size and control overhead by utilizing short local routing table and routing information for remote nodes [27]. It is good only for specific application scenarios.

TABLE IIIII COMPARISON BETWEEN VARIOUS HYBRID PROTOCOLS

	ZRP	**ZHLS**	**LANMAR**
Routing Structure	Flat	Hierarchical	Hierarchical
Multiple routes	No	No	No
Routing Metric Mode	Shortest path maintained in intra-zone and inter-zone tables	Shortest path or next available link maintained in intra-zone and inter-zone tables	Local shortest path in routing tables at landmark
Route Reconfiguration Approach	Route repair at failure point and source notification	Location request sent	Source notification
Merits	Low control overhead, lower delay, consumes less bandwidth, reduced retransmission	Avoids SPF, low control traffic , scalable	Minimizes the size of routing table, scalable, low control overhead
Demerits	Overlapping of zones	Need Static zone map	Communication complexity

TABLE IVV COMPARISON OF PROACTIVE, REACTIVE AND HYBRID PROTOCOLS

Protocols	**Structure**	**Features**	**Merits**	**Demerits**
Proactive	Flat or Hierarchal routing protocol	• Periodic route updates so route always available • Scalable usually up to 100 nodes • Main categories- DSDV, OLSR etc	• Less setup delay • Loop-Free	• More resources consumption such as memory, power, bandwidth • High routing overhead in case of scalability • More delays occur in case mobility
Reactive	Mostly Flat routing protocol	• On- demand route updates • Scalable up to few hundred nodes • Main categories- AODV, DSR etc	• Saves resources • Lower routing and control overhead • Loop-free	• Large delay due to on-demand route discovery • No up to date routes • More control overhead in case of mobility

Hybrid	Both Flat or Hierarchal routing protocol	• Both Periodic and on-demand route updates • Scalable up to 1000 or more nodes • Main categories- ZRP, ZHLS etc	• Limited setup delays for local destinations • Less power and bandwidth consumption • Low routing overhead for longer routes • Good scalability	• High delay for Inter-zone routing techniques • Large overlapping of routing zones • More complexity

TABLE V COMPARISON AMONG VARIOUS ROUTING PROTOCOLS

	DSDV	OLSR	FSR	AODV	DSR	TORA	ZRP	ZHLS	LANMAR
Protocol Type	P	P	P	R	R	R	H	H	H
Hello message	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
Multicasting	No	Yes	No	Yes	No	No	No	Yes	Yes
Loop-free	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Bandwidth	High	High	Less	Less	Less	Less	Less	High	Less
Routing Overhead	High	Low	Low	Low	Low	Medium	Low	Low	High
Control Overhead	More	Less	Less	Average	More	Less	Less	Less	Less
Scalability	Low	Good	Good	Medium	Low	Good	Medium	Good	Medium
Mobility	Good	Poor	Poor	Limited	Limited	Good	Limited	Limited	Poor
Delay	Small	Small	Large	Large	Large	Small	Small	Small	Large
Energy efficiency	Medium	High	High	Low	High	High	Medium	High	Low

P: Proactive R: Reactive H: Hybrid

V. CONCLUSION

In WSN, source and destination communicate or connect via wireless media, thus, a large bandwidth is required. The bandwidth is the critical resource, it can cause various challenges in design and maintenance of routing protocols. The energy utilization is dominated whenever a single node is transmitting or receiving packets from its neighboring nodes or communicating with the BS or when mobile sink aggregates the data from sensors nodes in a network. Thus, there is a need to make network energy efficient without any data loss by designing effective routing protocols. In this paper, we have reviewed a variety of routing protocols which are distinguished on some parameters including scalability, mobility, bandwidth, overhead, and delay. DSDV, OLSR, FSR, AODV, DSR, TORA, ZRP, ZHLS and LANMAR protocols are discussed. In this paper, in the case of proactive routing protocol, OLSR performs well as it has low routing overhead as compared to DSDV and FSR. In reactive protocols, AODV performs better than DSR and TORA but TORA has a minimum delay. In hybrid protocols, ZHLS outperforms ZRP and LANMAR as it has low overhead and non-overlapping zones but LANMAR has hierarchical routing in which energy dissipation is uniform and it can't be controlled.

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