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Routing Protocols for MANETS: Issues and Challenges

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Abstract

Wireless communication technologies have experienced a gigantic leap in terms of communication methods and speed of communication coupled together with mobility. Conventional wired methods of communication have been fast replaced with wireless technologies with state of art infrastructure less Ad-Hoc networks. One such innovative concept is the mobile ad hoc network or Mobile Ad-hoc Network (MANET) which is finding widespread utility in remote installations for monitoring, surveillance and control. Nodes form the back bone of MANETs and incorporation of a strong routing mechanism ensures the optimal and efficient implementation of MANETs for given application. However, routing is a complex research issue as it has to take into consideration a collection of attributes before dictating the routing path. Based on the several bounds and constraints, the application to which it is being put used to, routing methods are classified into proactive, reactive and hybrid protocols. An elaborate and systematic review of several research issues clouding the performance of routing methods has been discussed in this review article with briefings on concepts of clustering to reduce network complexity.

Keywords: *Wireless sensor networks, MANETs, Routing, Clustering, Performance constraints.*

1. Introduction

Communication technologies have witnessed a great revolution in recent times with the advent of state-of-the-art communication gadgets powered by strong information processing and storage mechanisms. Research in communication technologies and miniaturization technologies have led to production of hand held and portable communication and sensing gadgets which are capable of providing high resolution and precise inputs the form of multimedia content, documents etc. Wireless sensor networks play a critical role in such developments and have alleviated the growth rate of wireless communication to great extents. The broad classification of wireless networks is depicted in figure 1.

The Ad Hoc networks do not rely on preexisting infrastructure for carrying out their communication processes. This to a great deal reduces the cost of installation and maintenance of hardware for such communication methods. One such derivative being researched and employed in a wide range of applications in recent times is the MANETs which have stretched the limits of mobility its freedom to users thereby increasing the QoS factor to a great extent. An essential feature of MANETs, lie in the provision of providing exhaustive freedom to the mobile users on the go to access information from the servers or base station without any hassle by utilizing high speed communication bands from the RF spectrum.

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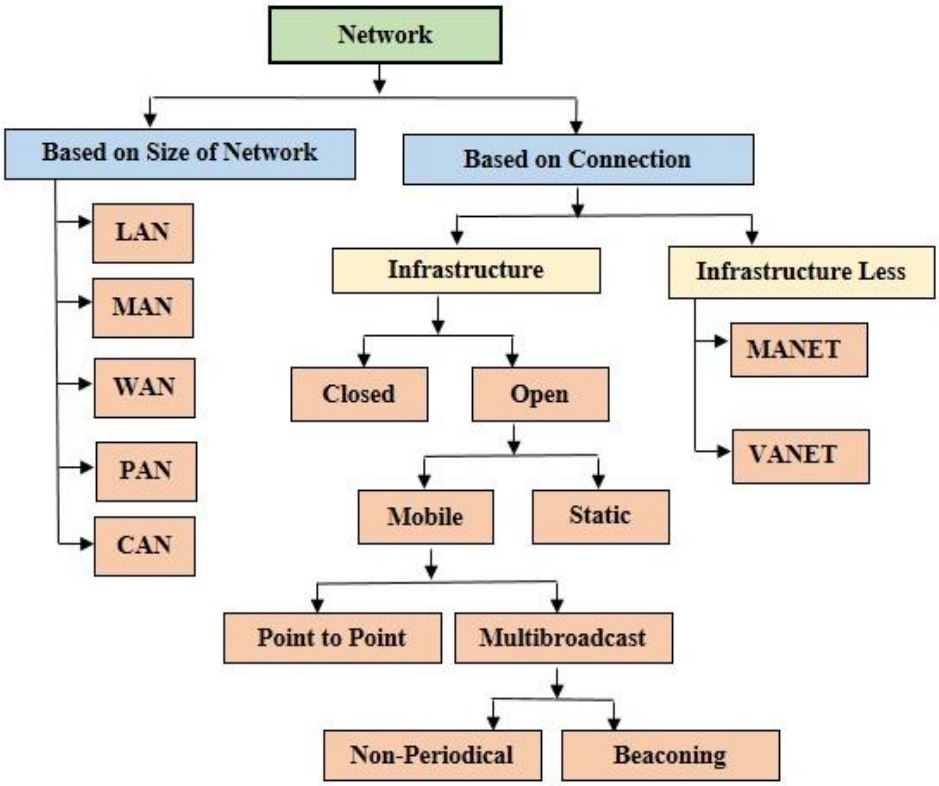

Figure 1. Classification of Wireless Network

The architectural illustration of MANETs is depicted in figure 2 and it could be seen that wireless nodes form the back bone of MANETs connected through wireless connectivity. Movement of nodes between one network and another network is possible in MANET in order to avoid delay and disruption [1]. These nodes are provided with limited processing and battery power to perform simple to medium level operations based on their deployments and purpose of deployment. The overall functioning of MANETs is to transmit the sensed information or data from one user to the destination known as sink or control station through a set of nodes formally termed as the member nodes.

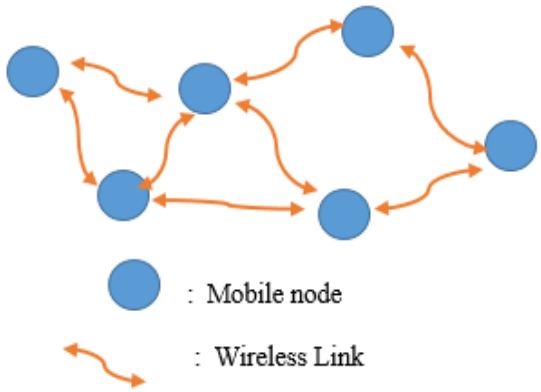

Figure 2. Simple Structure of MANET

The research challenges pertaining to investigations on MANET arise at this point which could be summarized as follows.

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- The primary research issue in MANETs lies in the fact that the overall efficiency in implementation of MANETs is dictated by utilization of a proper and efficient routing protocol.
- The routing protocol defines the set of nodes that are to participate in the routing process, the nodes that are to be idle and switched over to idle state thereby contributing to energy savings of MANET.
- Route discovery, maintenance and establishment of alternate path in case of link or node failure in the shortest time possible.
- Reduction in computational complexity and elimination of redundant nodes by utilizing concepts of clustering and optimization into MANET routing methods.

Comparison of various networks using different parameters like distance, IEEE standards, modulation, frequency, data rate, security and cell radius is shown in table 1.

Table 1. Comparative analysis of Wireless Networks

Parameters	Type of Network				
	Wireless Wide Area Network	**Wireless Metropolitan Area Network**	**Wireless Local Area Network**	**Wireless Personal Area Network**	**Wireless Ad Hoc Network**
Example	General Packet Radio Service	Cable TV Network	IEEE 802.11 SIUS/Lawn	Infrared, Bluetooth	Emergency Relief, Military
Distance	11000 m	1000 m	100 m	10 m	On the Fly
IEEE Standard	IEEE 802.11	IEEE 802.16	IEEE 802.11b IEEE 802.11g	IEEE 802.15.1	IEEE 802.11ax
Known as	Wireless Broadband	WiMAX	Wi-Fi	Bluetooth	Spontaneous Network
Modulation	Frequency Modulation	QPSK	OFDM, DSSS	FHSS	Independent on Pre-existing infrastructure
Frequency	300 Hz to 3.4 kHz	10-66 GHz	2.4 GHz & 5 GHz	2.4 GHz	UHF(300-3000 MHz) SHF(3-30 GHz) EHF (30-300 GHz)
Data rate	625 Mbps or much more	134 Mbps	11 Mbps & 54 Mbps	3 Mbps	Variable Data Rates
Security	Very Important	Very Important	Important	Important	Very Important
Cell radius	3218.68 – 4828.08 m	1000 m - 50,000 m	1-500 m	1-10 m	Depends on Transceiver power

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Based on the research issues discussed above, an elaborate survey of routing methods and strategies have been presented in this review paper by analyzing and studying recent contributions from the literature related to them.

2. Survey of Routing Methodologies in MANETs

As mentioned in previous sections, routing plays a major and critical role in defining the overall efficiency and purpose for which MANETs are deployed. A survey of literature [2] [3] [4] indicates a broad categorization of routing methodologies as depicted in figure 3 shown below.

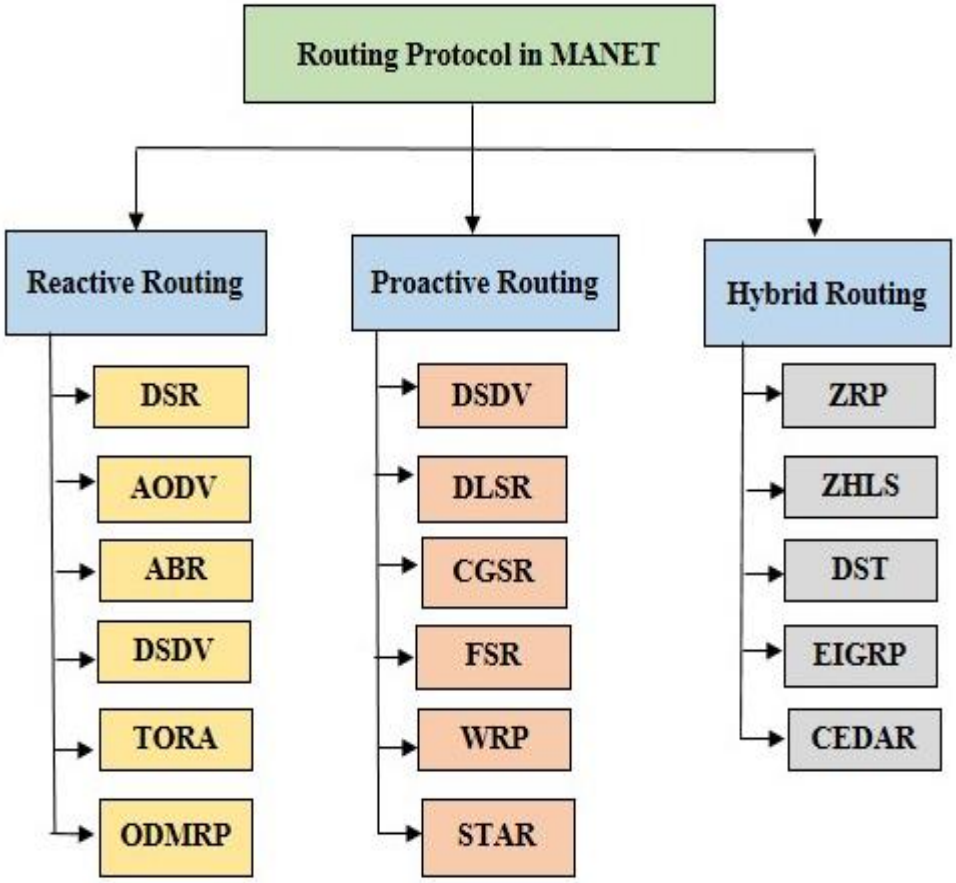

Figure 3. Classification of Routing Protocols in MANET

2.1. Reactive Routing Protocols

Reactive routing protocols derive their nomenclature based on the fact that a route is searched by the source node only when it wants to send a packet of data to the target node. Hence need for transmitting a data via a route is taken to the action and search process is taken to be the reactive process in RRP methods in MANETs. They are implemented in two phases namely route discovery [5] and route maintenance [6] [7]. Incremental search based methods are more prominent in RRP protocols where the source node maintains a register containing the details of every neighbor node in its vicinity or connectivity range with their associated costs [8] [9] refreshed then and there on a periodical basis by computing the time taken to transmit and receive ECHO packets to the neighbors and dividing them by two. When the source node decides to send a packet of data to the target node, it checks its routing table [5] [10] [11] for any possible routes towards the destination or target. If no optimal route or path is available [12], it sends out a route discovery packet which contains relevant information such as address of source

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and sink, distance-based identification number [8][13]. This route discovery packet is broadcast to all neighbors of the source node and after receiving the packet, each neighbor checks its own routing table for any matching and near matching entries. At a time, it is possible that multiple paths may be discovered and sent to the source node which decides a single path based on optimality [14] [15-16]. When no paths are discovered, the source comes to the conclusion that no valid paths are available. Route maintenance for servicing of broken links is done on the other hand by a surroundings repair method based on hop entries and analysis of previous hop patterns. A number of reactive routing protocols are experimented in the literature out which a few outstanding and prominent ones are discussed in this section. This includes Dynamic source routing (DSR) [2] [7], Ad hoc on demand distance vector (AODV) [5] [16] [17], Associative based routing (ABR) [11] [14], and Admission controlled enabled on demand routing (ABR) [4] [18] [19] [20].

AODV routing protocols are based on distance vector-based routing methods and applicable for unicast and multicast methods involving three phases namely route discovery, route messaging and route maintenance. It is based on computation of distance-based cost functions from the source to reaching the destination [21-22]. The process initiates by sending a route request message when there is demand for route to be established from source to destination (RREQ) followed by a reply message and error message. Literature studies [22] [20] indicate utilization of HELLO packets to achieve the route discovery process. AODV based methods are found to overcome the count to infinity problem [23] [24] addressed in the literature by following a systematic method of hop sequence computation. AODV protocols are more suitable for dynamically changing topological conditions which is characteristic of MANET structures. MANET structures contain nodes which can leave or enter the environment at will [7] [25] thus causing a continuous change of topological structure. On the other hand, literature works [22] [26] indicate that they are more vulnerable to a wide range of attacks like flooding attacks, sink hole attacks [4] [26] and further fail where all the nodes do not cooperate with each other [27] [28]. Moreover, the route discovery and maintenance overhead increase with increasing network size and its associated distance-based cost functions [29] [30] thus incurring heavy overheads on the bandwidths. AODV protocols are found to be more secured with additional security features incorporated into them like the secured AODV (SAODV) and A-SAODV (adaptive secured AODV) by incorporating digital signatures to ensure authenticity and integrity of data packets. Cross layer designs of AODV routing protocols such as CAODV [31] have been used by violating the network layer protocols to provide improvement in the routing performance. Conventional AODVs suffer from network overheads which are efficiently addressed by these cross-layer designs. Such cross-layer designs have also been extended as PC-AODVs to improve the power consumption by intelligent utilization of battery power for routing process by eliminating consumption of power by idle nodes. Stability and energy aware routing are proposed in the literature [3] [4] [16] to address the joint approach of stability of routing towards dynamically varying workloads and minimizing energy consumption. Concepts of optimization [18] have been utilized in a hybrid approach with AODV methods to improve the throughput, bit rate and reduce the packet loss. Most of power aware routing protocols aim to reduce the energy consumed by one packet and increase the network connectivity. The literature includes performance simulations for the AODV, SAODV and-SAODV protocols in a free-attack scenario where simulated threats attack the network. However, the AODV protocol features no security mechanisms meaning this is not a fair comparison; the results for AODV should only be used as a benchmark for comparison. Simulations collected number of important metrics but were only performed using a random waypoint mobility model with very high node speeds of 40m/s limiting the applicability of the results in a real-world scenario as not many networks feature such high node speeds.

Literature also presents combinations of DSDV and DSR to provide the merits of AODC with an objective of reducing the overall bandwidth overhead requirement. There have been numerous research contributions for implementing AODV protocols for improving the packet delivery ratio

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the findings of few of which are briefed in this section. OMNET simulators have been successfully used to study the behavior of AODV protocols and it is found to remove the overall overhead in maintaining routing entries in tables thus accounting for the reduced computational complexity and processing time.

Another dominant routing under reactive mechanism is temporarily ordered routing protocol (TORA) [32] with several research contributions in this segment. They eliminate the congestion problems reported in previous works by establishing multiple routes and they operate in a distributed manner. They are basically a three-phase process namely creation of route, maintenance of route [25] and erasing the route. Unlike the other two protocol, a metric in terms of height is used to direct the link between the nodes [33]. Height is determined on the basis of direction of node from lower to higher node or vice versa. A node is one which needs a link to a destination. Since it has no downstream neighbors for sets its route-required flag and it directs a query packet. The packet which contains the destination details or label is tagged the QUERY packet. The acknowledgment provided to the QUERY packet is named as UPDATE. It holds the height of the neighbor node and the destination field which communicates two actions namely QUERY packet discard or QUERY packet rebroadcast. Research papers have focused in computation of packet delivery ratio, throughput and end to end delay [34]. The performance of the protocols Temporally Ordered Routing Algorithm TORA and Improved TORA were measured with respect to metrics like, throughput, end-to-end delay and packet delivery fraction. Simulations were carried out with identical topologies and running different protocols with different number of nodes. The results of the simulation indicate that performance of TORA protocol has been improved over traditional TORA protocol.

In dynamic source routing protocol [25] the wireless and autonomous mobile nodes are given the flexibility to discover routes which may be a single hop or multi hop from source to destination. Experimental investigations in the past indicate degradation in quality in cases of increasing volumes of traffic. DSRs [33] [35] are made up of two components namely route maintenance and route discovery. Route discovery mechanism is activated, when a source node desires to send a packet of information to a destination node. During transmission of packets from source to destination, when a link failure is identified, the node transmits detection of nonexistence of the link to the source node thereby invoking the route discovery again for finding an alternative path.

TORA represents the entire network by means of a directed acyclic graph or DAG and similar to weights in other networks [2], height values are associated with each node. Individual DAGs need to be constructed for each new path to be established. When a node detects a partition in the given network due to node failure or link failure, the values entered into the height label associated with each node is made to NULL. TORA supports multiple source destination pairs and even if one node fails, an alternate path is established in a very short interval of time. However, it greatly depends on the global synchronized clock given to all nodes. A comparative scenario of reactive routing protocols is summarized in table 2.

Table 2. Comparative analysis of Reactive Routing Protocols

Parameters	Reactive Routing Protocols		
	DSR [8][7]	AODV [36]	TORA [2]
Topology	Full	Full	Reduced
Update Information	Route Error	Route Error	Node Height
Method	Unicast, Broadcast	Unicast, Broadcast	Broadcast
Update destination	Source	Source, Neighbor	Neighbor

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Multiple path	Yes	No	Yes
Mechanism of routing	Shortest Routing	Next Hop	Next Hop
Source routing	Yes	No	No
Routing structure	Flat	Flat	Flat
Routes	Multiple	Single	Multiple
Beacon	No	Yes	No
Route maintenance	Route Cache	Route Table	Route Table
Route metric method	Shortest path	Shortest path	Shortest path/next available
Update period	Event driven	Event driven	Table driven
Configuration	Erase route and notify source	Erase route and notify source	Route repair

2.2. Proactive Routing Protocols

In proactive protocol, each node maintains the complete routing information and based on the data with the node, the node decides to forward a packet of information on availability of route. Time delay owing to route search is eliminated in this method. Destination Sequenced Distance Vector (DSDV) Routing [37] and Optimized Link State Routing [38] are examples of proactive routing protocols. Findings of the survey indicate that DSDV is a proactive unicast MANET routing protocol and the update process about the current network parameters could be event driven or time driven. DSDV is basically a derivative of routing information protocol with attributes, sequence numbers added to the existing routing information protocol. In case on detection of movement of nodes with change of topological boundaries, the entry table is updated with new sequence numbers and availability information for transmission of next packet. It could be seen that at any point of time, entries are always available and ready and hence the work of node is only to make the decision to forward the packets resulting in quick response times. Other prominent proactive routing protocols observed in the literature include the optimized state link routing protocol (OLSR), Fisheye state routing (FSR) and cluster head gateway switched routing (CGSR). The OLSR protocol is basically derived from the original link state link algorithm where every node broadcasts its state link information to all other nodes in the network. Unlike the state link algorithm, the node overhead is drastically reduced in OLSR as only a few nodes broadcast the state link information. This is achieved by installation of multipoint relays which cover a two-hop neighborhood from the broadcasting node thus avoiding the excess node congestion problem. CGSR protocols are based on hierarchical routing strategy built with powerful cluster-based algorithms which reduce the computational complexity and time to a great extent by vesting major responsibilities to one best node known as cluster head through a cluster head selection process. Actual communication takes place through cluster heads thus reducing power consumption by nodes which do not take part in the communication process. Previous works to CGSR include the fisheye routing protocol (FSR) which is based on broadcasting topology maps to compute and update the shortest path. A comprehensive list of various parameters used for quantifying proactive routing protocols is listed in table 3 shown below.

Table 3. Comparative analysis of Proactive Routing Protocols

Parameters	**Proactive Routing Protocols**		
	DSDV [25][28]	**OLSR [14][23]**	**CGSR [18]**
Topology	Flat	Flat	Hierarchical

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Protocol type	Distance vector	Link state	Distance vector
Method	Unicast	Broadcast	Unicast
Update destination	Neighbour	Neighbour	Neighbour & Cluster head
Multiple path	Yes	Yes	Yes
Mechanism of routing	Shortest Routing	Shortest Routing	Shortest Routing
Routing complexity	High	Low	High
HELLO packets	Yes	Yes	No
Uniformity	Yes	No	No
Efficiency	Small Networks	Dense networks	Large networks
Route metric method	Shortest path	Shortest path	Shortest path/next available
Scalability	Yes	Yes	No
Control overhead	High	Reduced	Reduced
MPRs	No	Yes	No

2.3. Hybrid Routing Protocols

As the name indicates, hybrid protocols are formed by fusing features from both reactive and proactive protocols to remove the overheads concerned with traffic congestion, delays in location and finding of routes, establishing alternative routes in case of link failure and delay due to update of route entry tables. One such well known hybrid routing protocol is the zonal routing protocol (ZRP) [39] [38] developed with the sole objective of reducing the control overhead as well as the latency overhead in route discovery process. In this process, the entire network is divided in to zones with member nodes within a maximum hop distance accommodated inside the zone. Two types of zonal routing protocols have been found in the literature. Intra zonal routing protocol [40] and inter zonal routing protocol [41]. Experimental results indicate that configuration of Zone radius according to what type of application in which we use ZRP protocol. The high-density increases may increase the discovered services but it deteriorates their quality in terms of availability. If it is used for real time application likes video transmission then due to jitter effect performance decreases. In other application in which delay is consider then we can use the reduced Zone radius. Because as we increase the proactive part by increasing the Zone radius control traffic also increases. ZRP is suitable for the large network by providing the benefit of both proactive and reactive routing protocol.

Another routing strategy with respect to hybrid routing is the zone based hierarchical link state routing (ZHLS) [34] where a hierarchical addressing scheme is used to establish directionality to the links being established between two nodes in the zone. Other hybrid-based techniques involve integration with nature inspired optimization algorithms which simulate the real-life scenario and are best suited for the proposed MANET routing research problems. Predominant optimization algorithms include genetic algorithms [25], particle swarm optimization [42], ant colony methods [40] etc. Most of these optimization algorithms work with the objective of achieving and converging towards a target solution either on a search-based criteria or incremental strategy. Most optimization algorithms are integrated with cluster-based

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concepts which further help to reduce the network complexity. Clustering is based on the concept of grouping available set of nodes into sub sets based on some similarity features which may include distance, battery level, number of hops, bandwidth required etc. one among the given cluster becomes the cluster head based on a selection strategy which internally consists of several processes. This cluster head is vested with a major responsibility of coordinating the various routing strategies in the MANET. Distance source tracing (DST) [43] is yet another tree-based routing method which drastically reduces the routing overhead by adopting a tree-based structure with two nodes namely root node and internal node used to reduce the overall complexity.

Cluster heads [38] coordinate the transmission events within the cluster that can save a lot of resources used for retransmission resulting from reduced transmission collision [32]. The random mobility of nodes in MANET with continually changing topological boundary conditions make the problem of routing quite complicated. These hardness problems as described in chapter 1 are addressed by means of clustering [38] techniques where groups of similar nodes based on their proximity to each other are joined together to form groups or clusters of nodes [16]. The complexity is reduced to a great extent by cluster formation, route creation and route maintenance. A survey of cluster-based routing protocols is presented in this section.

The scalability of the MANET is affected by node mobility [44], limited energy level [22] [26] and limited bandwidth [35]. Nodes can indeed be mobile [44], but their movements are usually confined within a specific geographical area. Since many of these changes are limited to a relatively small region, the network can obtain a simpler topology and avoid the need to inform the entire network about the changes. The main objective of clustering [25] is to select suitable cluster heads and to store minimum control information. Each CH [39] performances as a temporary base station in its cluster, and links with other CHs. Clusters should be adaptive [38] to changes in the network topology with minimum clustering management overhead. A cluster structure provides many benefits. It facilitates the spatial reuse of resources to increase the system capacity. With the non-overlapping multi cluster structure [35], two clusters may deploy the same frequency or code set if they are not neighboring clusters [25]. A comparative study of hybrid routing protocols has been presented in table 4 shown below.

Table 4. Comparative analysis of Hybrid Routing Protocols

Parameters	Hybrid Routing Protocols		
	ZRP [45]	ZHLS [46][47]	DST [43]
Topology	Flat	Hierarchical	Hierarchical
Beacons	Yes	No	No
Multiple routes	No	Yes	Yes
Information storage	Intra & Inter zone	Intra & Inter Zone	Table
Mechanism of routing	Shortest Routing	Shortest Routing	Forwarding
Routing complexity	Reduced transmission	Reduced delay overhead	High delivery ratio

3. Conclusion

An extensive and elaborate survey of literature has been carried out and findings of recent research contributions have been presented in this review article to have an understanding of the different research issues and challenges that are prevalent in the field of routing in MANETs. Based on the findings of the survey, the following inferences could be summarized as listed below.

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- Most of existing works have been implementing distance-based routing algorithm namely AODV with different distance metrics such as Euclidean distance, Manhattan distance etc.
- AODV algorithms remove the computational overhead by eliminating the need for routing entry table but however suffer performance degradation with increasing network size.
- AODV has provided good compatibility with other algorithms like DSR, DSDV and other optimization algorithms to provide energy and load balancing routing algorithms which add merit to conventional AODVs
- Off late, cluster-based routing methods have been implemented in the literature as they drastically reduce the network complexity by grouping of available set of nodes into similar sets and role of cluster heads have been given more importance.
- Cluster based routing methods are gathering more momentum in recent times due to their meritorious set of features and their ability to be incorporated with optimization-based methods to address multi objective issues.

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