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Research paper

Comprehensive analysis of manet routing protocols and quality of service metrics

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Abstract

The emergence of wireless technology has presented intriguing possibilities in the realm of communications. Because of this, data may be manipulated using wirelessly connected, portable nodes and possess limitations such as low storage capacity, reliance on autonomous energy sources, and restricted bandwidth. A mobile ad-hoc network (MANET) is a type of wireless network that consists of mobile nodes that do not rely on any immovable structure. In this research, the nodes are observed to be able to move and autonomously arrange themselves freely into a network structure. Various protocols have been devised to improve the routing process and provide a path among any two hosts in a computer system. Providing quality of service (QoS) ensures that MANETs pose significant challenges compared to wireline networks. These challenges primarily arise from node movement, multi-hop communications, conflict for channel access, and the absence of central collaboration. The challenges associated with ensuring such guarantees have meaningfully constrained the practicality and effectiveness of MANETs. There has been a dramatic uptick in studies over the past few decades dedicated to addressing the issue of QoS assurances in MANET protocols. This research paper analyses various routing protocols and QoS metrics in MANETs.

Keywords: *MANET; Mobile Nodes; Routing Protocol; Quality of Service; Wireless Communication.*

1. Introduction

MANETs refer to a collection of mobile radio devices that possess the ability to autonomously configure their parameters to establish connections with other nodes, without the need for a centralized base station system. Due to their versatile communication capabilities, MANETs have attracted a lot of research. Despite their limited capacity and capabilities, MANETs have been proven to be a superior solution in various fields, including medical services [1], [2], automated transportation, military [3], safeguard and recovery following disasters [4], smart commerce, intelligent farming [5], and have the potential to make major improvements to the future of the Internet. MANET routing protocols may contrast based on use case and network design. It is common practice to divide routing protocols into two broad categories: unicast and multicast. The routing challenge in mobile ad hoc networks is addressed in a variety of ways by various routing protocols. It recognizes that there is no universally applicable protocol for MANET Networks due to the wide variety of use cases, network architectures, and user behaviors. For example, reactive routing techniques are good for large-scale MANETs with modest or fewer topology modifications, whereas proactive routing strategies are appropriate for small-scale MANETs with significant mobility. Finding a middle ground between proactive local routing and reactive long-distance routing is the purpose of hybrid routing technologies. Table 1 presents a summary of several research studies conducted to enhance routing protocols and address specific issues in MANETs. Bairwa's work in 2022 introduces an uninformed update to the AODV formula to improve Quality of Service (QoS) in emergencies. Kachooei's study in 2021 compares the CALAR-DD protocol with other routing protocols, highlighting its superiority concerning delay and packet transmission success. Alameri's research in 2020 involves a comparative analysis of AODV and DSDV, though it faces limitations due to the use of limited measurement metrics. In their 2019 paper, Quy et al. offer Q-AODV, a versatile and bandwidth-efficient approach for supporting multimedia applications. Ideal Multi Secure Routing Protocol (IMSRP) is proposed for optimal security transportation in a 2018 study by Thakkar and Kumar. In 2018, Quy et al. extended AODV with AERP to handle high data rates and meet Quality of Service demands in 5G networks effectively. Lastly, Goswami's research in 2017 focuses on the Ideal Multi Secure Routing Protocol (IMSRP) to achieve enhanced secure routing in MANETs. These studies contribute valuable insights into the optimization and enhancement of routing protocols in MANETs to address specific challenges and improve overall network performance.

2. State of the art

2.1. MANET architecture

Due to their independence from fixed facilities like routers and entry points, MANETs stand apart from more conventional cable networks. The network structure is comprised of the mobile nodes themselves, forming a cohesive system. The network exhibits dynamic adaptability to variations in node positions and network topology. In Fig. 1, an ad hoc system is depicted in an open environment. The system consists of several nodes that are capable of wireless communication. Each node has a range within which it can transmit and receive signals. The lines connecting the nodes represent wireless links or communication channels. Due to their independence from fixed facilities like firewalls and entry points, MANETs stand apart from more conventional cabled networks, The packet must traverse multiple intermediate nodes in a hop-by-hop manner. The packet is received by every router in the network, where it is then processed before being sent on to the next hop based on the routing protocol being used. The routing protocol used in the MANET determines how the intermediate nodes make forwarding decisions.

Table 1: Comparative Analysis of MANET Routing Protocol

Ref	Protocol/Technique Used	Issues/Limitations	Advantages
[19]	A variant of the AODV algorithm	Emergency	Improvement in Quality of Service (QoS)
[20]	CALAR-DD protocol	Latency problem	When contrasted with OLSR and AODV, it achieves better results in delay and packet delivery rates.
[21]	AODV, DSDV	Proportional investigation	Limited measurement metrics
[22]	Q-AODV	To support multimedia applications	Flexible and bandwidth-efficient handling of multimedia applications.
[23]	Ideal Multi Secure Routing Protocol (IMSRP)	Optimal secure routing	Enhanced secure routing
[24]	AERP (extension to AODV)	Address high data rates and QoS demand	Capable of coping with high data rate demands in 5G networks.
[25]	Ideal Multi Secure Routing Protocol (IMSRP)	Optimal secure routing	Enhanced secure routing

There is various routing protocols intended for MANETs, such as Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Optimized Link State Routing (OLSR). These protocols establish routes dynamically as needed and adapt to the changing network topology.

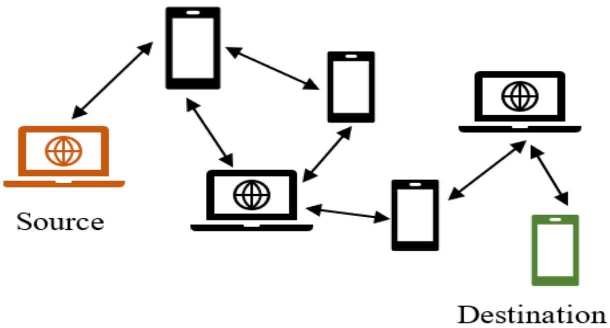

Fig. 1: MANET Structure.

A MANET can be represented mathematically using graph theory notation. Let's define the structure of a MANET using the following mathematical notation is modelled in Eq. (1):

$$G = (V, E) \quad (1)$$

Where, G represents the MANET as a graph, VIt is the set of nodes or vertices in the MANET. E is the set of edges or links between the nodes. In a MANET, the nodes represent the mobile devices or network entities, and the edges represent the wireless links or communication channels between them. Mathematically, the nodes can be represented as Eq. (2):

$$V = \{v_1, v_2, v_3, \ldots, v_n\} \quad (2)$$

Where $v_1, v_2, v_3, \ldots, v_n$ are the individual nodes in the MANET. The edges or links between the nodes can be represented as Eq. (3):

$$E = \{(v_i, v_j) \mid v_i, v_j \in V\} \quad (3)$$

Where (v_i, v_j) denotes an edge between node v_i and node v_j in the MANET. To represent the connectivity or adjacency between nodes, an adjacency matrix or an adjacency list can be used. The total number of vertices in a MANET determines the measurement of the matrix used to represent their connections, or the matrix of adjacency A. The elements of the matrix A[i][j] repesent the connectivity between nodes v_i and v_j. $A = [a_{ij}]$, where $a_{ij} = 1$ if $(v_i, v_j) \in E$ (there is an edge between v_i and v_j, and $a_{ij} = 0$ otherwise).

An adjacency list is a data structure that represents the connectivity between nodes. It stores a list of neighbours for each node in the MANET is shown in Eq. (4).

$$\mathrm{Adj}(v_i) = \{v_j \mid (v_i, v_j) \in E\} \text{ for all } v_i \in V \quad (4)$$

2.2. MANET routing protocols

In a MANET, no permanent facilities, such as firewalls or access points, is required for handheld devices to connect with one another. Routing protocols are essential in those networks because they determine which devices may talk to one another. To overcome difficulties brought on by MANETs' ever-evolving topology, several routing methods have been created.

Ad hoc On-Demand Distance Vector (AODV): AODV is an on-demand routing technique that uses a reactive strategy. Mobile Ad hoc Networks (MANETs) have been the subject of extensive research over the past few decades, driven by the increasing demand for flexible and scalable wireless communication solutions. Early work by Perkins and Royer (1999) introduced the Ad hoc On-Demand Distance Vector (AODV) protocol, a key routing protocol that allows nodes in a MANET to dynamically discover routes as needed [6]. A node will send out a route request (RREQ) packet to find the path that will allow it to interact with a different node. Intermediate nodes forward the RREQ until the destination is reached or an existing route is found. AODV is relatively efficient for small and medium-sized networks. AODV, or There are two primary processes integral to the functioning of the routing protocol known as Ad hoc On-Demand Distance Vector. The first mechanism is route detection, which is accountable for discovering a suitable route to a desired destination within the ad hoc network. The second mechanism is route maintenance, which ensures the stability and reliability of the established routes by detecting and reporting any potential errors that may arise due to the transient nature of network routers. These mechanisms work in tandem to facilitate efficient and effective communication within the ad hoc network. The proposed protocol employs a flooding technique to identify roads that are prone to experiencing significant traffic congestion. Additionally, it introduces an initial delay when transmitting the first packets to an unfamiliar destination.

Recent years have seen AI become a strong tool for optimizing routing algorithms and improving QoS in Mobile Ad-hoc Networks. MANETs struggle to maintain consistent communication and network performance due to changing topologies, limited resources, and high mobility. AI methods like Machine Learning (ML) and Reinforcement Learning (RL) may help solve these problems by providing adaptive and intelligent routing and resource management decisions. AI-based methods allow the network to learn and adapt to changing circumstances in real time, improving QoS. Reinforcement Learning (RL) algorithms dynamically pick optimum routing pathways depending on network congestion, bandwidth, and node mobility to keep the network running effectively. ML techniques like Supervised Learning and Unsupervised Learning forecast network traffic, categorize traffic flows, and discover problems before they affect the network, enabling proactive QoS management. MANET routing increasingly uses Deep Learning (DL), a subset of AI. In complicated and time-varying network settings, DL models like CNNs and RNNs have been used to forecast routing pathways and optimize bandwidth distribution. DL algorithms' capacity to learn hierarchical features from big datasets has improved network performance by automating operations that would otherwise need user intervention or rule-based techniques.

Algorithm 1: AODV Routing Protocol Pseudocode

```
InitializeRoutingTable()
while (true) {
 if (ReceiveMessage(message)) {
 ProcessMessage(message)
 }
 if (NeedRoute(destination)) {
 InitiateRouteDiscovery(destination)
 }
 if (CheckRouteExpiry()) {
 RemoveExpiredRoutes()
 }
}
function ProcessMessage(message) {
 if (message.type == RREQ) {
 ProcessRREQ(message)
 } else if (message.type == RREP) {
 ProcessRREP(message)
 } else if (message.type == RERR) {
 ProcessRERR(message)
 }
}
function InitiateRouteDiscovery(destination) {
 RREQ = CreateRREQ(destination)
 Broadcast(RREQ)
 StartTimer(RREQ)
}
function ProcessRREQ(RREQ) {
 if (IsDestination(RREQ.destination)) {
 RREP = CreateRREP(RREQ)
 SendToSource(RREP)
 } else if (IsRouteKnown(RREQ.destination)) {
 ForwardRREQ(RREQ)
 }
}
function ProcessRREP(RREP) {
```

```
 UpdateRoutingTable(RREP)
}
function ProcessRERR(RERR) {
 UpdateRoutingTableWithRERR (RERR)
}
function RemoveExpiredRoutes() {
 for each route in RoutingTable {
 if (IsRouteExpired(route)) {
 RemoveRoute(route)
 }
 }
}
```

Also dependent on source navigation, DSR is a dynamic technology [7]. Based on the time-tested distance-vector technique [8], DSDV is an active navigation technology. The sequence code and measurement for every location are kept in a routing database that is updated at each node. Periodic updates are sent to all nodes to maintain the routing information. DSDV is suitable for small networks but may suffer from high overhead in large, dynamic networks. Proactive networking is what sets OLSR apart, which minimizes control overhead by utilizing multi-point relays (MPRs) [9]. Nodes elect MPRs that can efficiently broadcast messages on behalf of their neighbors, reducing the number of redundant transmissions. OLSR works well in large and dense MANETs. TORA is a highly adaptive, reactive routing protocol that uses a distributed algorithm to establish multiple routes to a destination [10]. It maintains a Directed Acyclic Graph (DAG) of routes, adapting quickly to topology changes. TORA is efficient for networks with frequent topology changes and dynamic conditions. ZRP combines proactive and reactive methods by dividing the network into zones [11]. It uses proactive routing within a node's local zone and reactive routing among different zones. ZRP seeks to provide a balance between overhead and route setup time. Within each zone, proactive routing is employed to maintain up-to-date routing information. Proactive protocols maintain routing tables in all nodes, ensuring that routes are readily available when needed. This approach works well in small and stable zones, reducing the route discovery latency within the zone.
Optimization algorithms can be used to enhance routing protocols in MANETs by improving various aspects of the protocols, such as routing efficiency, reliability, scalability, and adaptability to changing network conditions. Table III lists various optimization algorithms applied to enhance specific MANET routing protocols.

Table 2: Optimization Algorithm for MANET Routing Protocol

Reference	Algorithm	Protocol
D. Sarkar et.al [12]	Ant Colony Optimization (ACO)	Ad-hoc On-Demand Distance Vector (AODV)
S. M. Alkahtani et.al [13]	Dynamic MANET on demand (DYMO)	Dynamic Source Routing (DSR), AODV
M. Sindhwani et.al [14]	ACO	AODV
M. Alnabhan et.al [15]	position-based routing	DSR, AODV

In this research [12], the authors applied the ACO algorithm to enhance the AODV routing protocol. ACO is inspired by the foraging behavior of ants, and it has been adapted to advance the route detection process in AODV. The ACO-based AODV variant aims to find more efficient and reliable routes by mimicking the pheromone-based communication between ants in search of food sources. In this work [13], the authors propose the DYMO algorithm and apply it to two routing protocols: DSR and AODV. DYMO is a new routing algorithm designed to adapt to the dynamic nature of MANETs. By integrating DYMO into DSR and AODV, the routing protocols are expected to achieve better performance regarding route establishment, stability, and adaptability. Similar to the first entry, this research [14] applies the ACO algorithm to recover the AODV protocol. The use of ACO in AODV aims to enhance the route detection procedure and potentially find better routes by exploiting the positive aspects of ant colony behavior. This study [15] suggests a position-based routing algorithm to enhance the DSR and AODV protocols. Position-based routing uses the geographical location information of nodes to make routing decisions. By incorporating this approach into DSR and AODV, the routing protocols can achieve better routing decisions based on node locations, improving route efficiency and adaptability. A route record is appended to a packet whenever a node wishes to communicate the order of nodes via which the message should go. A node will send out an inquiry about a route to other nearby nodes if it does not already know the path to the target. DSR can work well in small networks, but becomes less scalable as the network grows. This technique [16] allows nodes to find a source route to any destination node over several network hops. DSR's primary functions are route finding and route maintenance. Before transferring data using the DSR protocol, mobile hosts must first verify their route cache to see whether there is already an established connection to the destination [17]. When a host is reachable over the network, a packet is forwarded to it. Let's pretend the host node doesn't have a route. Let's assume the route hasn't been shut down and is still in use. It does so by delivering a route request packet, which contains information about the destinations, the mobile source host, and a unique identifier. Using the DSR routing protocol, each network node may check if it has a path to the packet's destination [18].

3. Proposed methodology

AI methods, notably Machine Learning (ML) and Reinforcement Learning (RL), are used to dynamically anticipate and choose the optimum routing pathways depending on network circumstances. Our routing protocol uses AI-driven decision-making to improve QoS metrics, including packet delivery ratio, end-to-end latency, and network throughput, while reducing energy consumption, which is important for MANETs' battery-operated mobile devices. The technique also includes a hybrid optimization strategy, which combines the benefits of proactive, reactive, and hybrid routing protocols. By combining these methodologies with AI-based optimization, the suggested solution achieves a combination of low latency, high throughput, and energy efficiency. The method's versatility enables it to function well in both low-density and high-density network situations, making it suited for a broad variety of MANET applications, including disaster recovery networks, military, and IoT. The following Algorithm 2 represents the Zone Routing Protocol (ZRP).
Algorithm 2. Zone Routing Protocol (ZRP)

Algorithm ZRP_{Routing}(src, dest):
 define zone radius R

```
if dest is within R hops (intra-zone):
use proactive protocol to discover route
look up route in intra-zone routing table
else:
initiate Inter-Zone Routing Protocol (IERP)
broadcast RREQ to peripheral nodes (border of zone)
for each peripheral node that receives RREQ:
if it is within R hops of dest:
use intra-zone protocol to discover route to dest
send RREP with complete route back to src
else:
forward RREQ to its zone's peripheral nodes
if RREP received by src:
store route in routing table and begin packet transmission
else:
retry RREQ process as needed
```

Table 3: Merits And Demerits of MANET Routing Protocol

Routing Protocol	Merits	Demerits
AODV	On-demand route establishment	High control overhead and route discovery latency
DSR	Efficient route caching	Large overhead due to maintaining route records
DSDV	Loop-free routing	High update overhead and susceptibility to loops
OLSR	Multi-point relay optimization	Increased control overhead in large networks
TORA	Highly adaptive to dynamic topology changes	Complexity and overhead in maintaining a DAG
ZRP	Proactive and reactive approach combination	Additional complexity in managing zones

Table II presents a general overview of the merits and demerits of routing protocols. The actual performance and suitability of a routing protocol depend on various factors such as network size, mobility patterns, traffic load, and application requirements. It's essential to consider these factors when selecting a routing protocol for a specific MANET deployment.

QoS route selection in topology-based routing systems is based on topological data. Table-driven, on-demand, and hybrid architectures are the further categories as shown in Fig. 2. Each node in a table-driven protocol stores routing data for the whole network. The communication path between two nodes in an on-demand protocol is set up now of communication itself. Both table-driven and on-demand features may be found in the hybrid routing system.

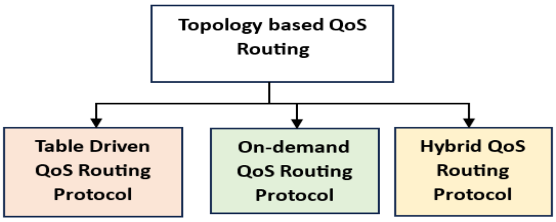

Fig. 2: Topology-Based QoS Routing.

In a table-driven protocol, each node is responsible for updating and maintaining its local copy of the network's routing tables. The path overhead in table-driven networks is considerable because of the need to constantly update the routes that connect each node. Routing data is periodically shared between nearby nodes. When data has to be sent between two far-flung nodes, the sending node instantly consults the routing table for directions. The node in an on-demand routing protocol does not save routing data for the full network infrastructure. The on-demand routing protocol design process may be broken down into two stages: route detection and route preservation. When two nodes establish contact, a route is discovered between them; routes are maintained until they are broken.

4. Results and discussion

The examination of the Quality of Service (QoS) metrics for the MANET routing protocols documented in Table IV portrays varying trends for routing protocols in terms of end-to-end delay, packet delivery ratio, jitter, throughput, and energy consumption. DSDV and OLSR, as proactive protocols, have a low end-to-end delay since routing information is altered regularly, enhancing applications that do not require high delays. DSDV policy provides available routes and reduces waiting time, but frequent route updating requires much energy and incurs a high overhead cost. Using MPRs ensures that OLSR has an even larger packet delivery ratio of 90 percent and quite low jitter thus permitting good communication in large, densely populated networks. This stability in the axis plane is also improved by moderate consumption of energy. Therefore, it makes OLSR favourable to those environments where meeting deadlines and consistency in packet delivery are vital.

Table 4: QoS Metrics for MANET Routing Protocols

Protocol	End-to-End Delay (ms)	Packet Delivery Ratio (%)	Jitter (ms)	Throughput (kbps)	Energy Consumption (J)
AODV	Moderate	85	Moderate	250	High
DSR	Moderate	82	High	230	Moderate
DSDV	Low	80	Low	260	High
OLSR	Low	90	Low	270	Moderate
TORA	Moderate	88	High	255	High
ZRP	Low (intra-zone)	87	Moderate	265	Moderate

On the other hand, protocols such as DSR and AODV can achieve moderate end-to-end delay due to their ability to perform on-demand route discovery. The use of DSR, in this case, allows for a reduction in delays thanks to its route caching feature. However, it cannot assist in reducing the jitter level, so it remains high and thus a threat to any real-time type of application. One advantage of these protocols is that they do not require constant maintenance of the established routes, which does help save some energy; however, the time taken to determine the route adds to the latency, which affects the QoS of time-sensitive applications. ZRP implements a combination of proactive routing and reactive routing, allowing it to operate in a zone such that, for the inter-zone routing, the reactive routing is performed, hence allowing it to have a good balance in not only the inter-zone time but also in the zone packet delivery ratio, averaging around 87%. At the same time, the energy and jitter levels are minimal.

Table 5: Protocol Resilience and Adaptability in MANETs

Proto-col	Mobility Handling (High /Medium /Low)	Route Recovery Speed (ms)	Scalability (High/Me-dium/Low)	Resistance to Packet Loss (%)	Suitability for High Traffic (High /Medium /Low)
AODV	Medium	80	Medium	85	Medium
DSR	Low	90	Low	80	Low
DSDV	Low	70	Low	78	Low
OLSR	Medium	60	High	90	High
TORA	High	85	High	88	Medium
ZRP	High	75	Medium	87	High

The assessment of the resilience and adaptability of some MANET protocols in respect of mobility, route recovery speed, scalability, packet loss, and reconciliation of high packet traffic is presented in Table V. The proactive protocols, namely DSDV and OLSR seem to maintain a constant packet loss, with OLSR sustaining this at 90%. OLSR MPRs enable rapid and efficient broadcast dissemination as well as Rapid Route Repair (60 ms), making OLSR more suitable for high packet traffic environments. Although DSDV has a low Route Recovery Time (70 ms) its features relating to scalability and mobility management render it less viable in dynamic high-density networks. The reactive protocols, especially AODV and DSR, handle medium mobility but have dissimilar speeds while recovering affected routes. AODV can restore routes albeit moderately (80 ms), with improved scalability and packet loss tolerance compared to DSR. DSR, on the other hand, appears to be more appropriate in low mobility environments since it is a high overhead, low scalability protocol, making it unsuitable for high frequency switches or high mobility traffic load. The hybrid ZRP protocol provides evidence of being adaptable, with route recovery time being less than 75 ms, moderate scalability, and being able to handle high mobile node density, with the provision of allowing quick route recovery, making it fit for use in medium or even large networks. TORA on the other hand develops a good degree of adaptability by having the ability to recover from changes of that take place within the structure of the network, being able to handle a high degree of mobility by quick means of recovering routes specifically over 85 ms and a tolerance for high packet loss of 88%. This enables TORA to work well in a highly dynamic network environment, however, this has medium adaptability under heavy network load because of the difficulties encountered in the maintenance of many routing paths.

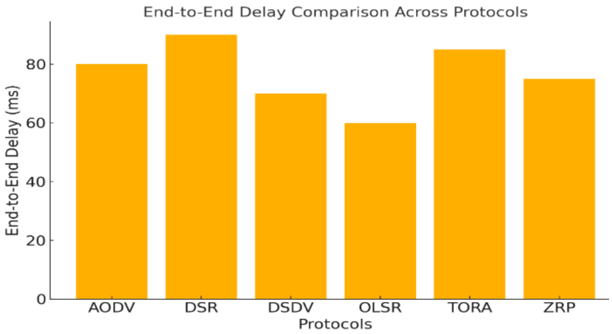

Fig. 3: End-to-End Delay Comparison Across Protocols.

Fig. 3 examines the end-to-end delay of various MANET routing protocols and appears to show that DSDV and OLSR, which are proactive protocols, end up delaying the delay the most. This can be ascertained by the fact that route information is constantly available, making it easy to forward a packet without waiting for it to be requested. On the other hand, delay times in the case of AODV and DSR are much higher in this case because they are waiting to be asked.

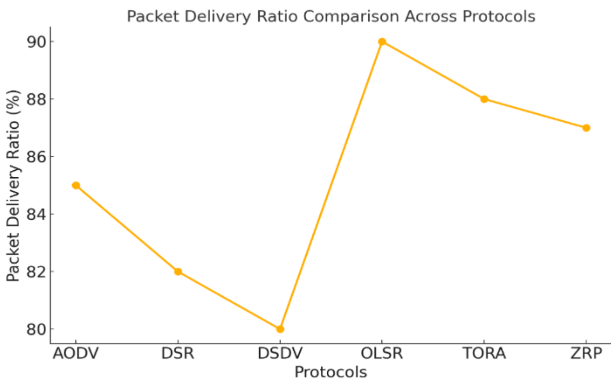

Fig. 4: Packet Delivery Ratio Comparison.

Hybrid protocols, such as ZRP, experience both proactive and reactive methods, resulting in an intermediate delay for intra-zone transfers and inter-zone exchanges. Such a comparison suggests that applications which operate within the OLSR time limits may find reactive protocols, tend to be efficient in low-size/less time-critical applications, useful. Identified in Fig. 4 is the packet delivery ratio for each protocol, while the delivery rate was highest for all the proactive protocols, particularly sectional OLSR, AODV, and Recursive Fueled DSR. Within OLSR, the Multi-Point Relay (MPR) system provides efficient and effective management of routes, allowing for a packet delivery ratio of 90%. As these protocols must rely on the discovery of routes, which is a reliance that is often counteractive to the growing nature of the dynamic networks and leads to packet loss, AODV and DSR generally fall behind in their respective delivery ratio. Likewise, the hybrid ZRP does record respectable scores in the number of packets sent, thanks to the fact that ZRP can accomplish general aim buffering from proactive management, but it does get delivery failures here and there due to weakness in inter-zone communication. Such a review stresses the critical consideration of the type of protocol to be used towards network and packet stability, with more hybrids and proactive protocols being ideal for situations with expected higher delivery rates.

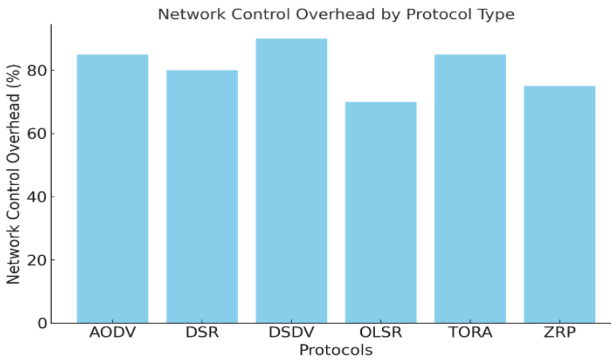

Fig. 5: Network Control Overhead by Protocol Type.

The Fig 5 shows the Network Control Overhead by Protocol. The AODV served to have control overhead while DSDV and TORA give the maximum overheads. A routing protocol of the DSDV type was described in which routing tables are updated regularly, hence, the overhead is high for large or dynamic networks. The introduction of MPRs by OLSR alleviates some of the control message overhead, however, it alleviates it to a moderate level. Whereas DSR last resorts to bandwidth overhead by sometimes not initiating the resource discovery under the assumption that the latency might be affecting it, AODV uses route resource limitation emissions whenever it is called for low overhead. ZRP, as a hybrid model, does mitigate the problem as it only allows proactive routing on a zone basis and reactive routing for crossing between zones. This chart demonstrates the fact that despite the reliability that most of the proactive protocols possess, they tend to be less efficient in overhead controls, while the opposite can be said about the resource-restricted conditions vis-à-vis reactive and hybrid protocols.

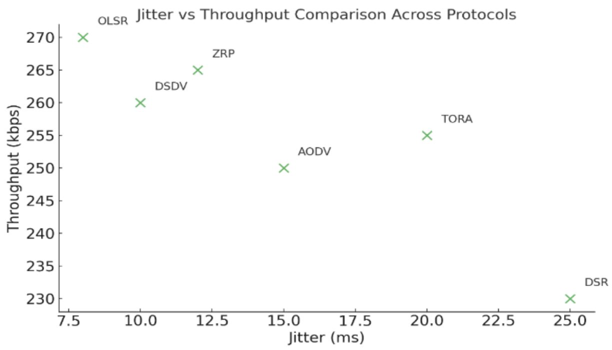

Fig. 6: Jitter vs Throughput Comparison Across Protocols.

In Fig. 6 below, the variance between jitter and throughput for each protocol is illustrated. The proactive protocols, for instance, OLSR, have low jitter and high throughput, making them desirable to be used in applications that have the same emphasis on the quality of data transmission. In the case of DSDV, even though it has low jitter, the degree of throughput realised is lower than in the case of OLSR, but this is a pointer to the efficiency is small-scale networks. Some of the reactive protocols, for example AODV and DSR, are seen to throttle higher jitter, and particularly DSR has jitter owing to its route caching, which can contribute to route inconsistencies within the dynamic environment. As for hybrid protocols, ZRP does a little better in terms of average jitter and large throughput using a combination of intra-zone satiating routing and inter-zone, which is deleteriously progressive. The scatter graph tries to show that such protocols as OLSR, which have low jitter and high throughput values, are appropriate for real-time working environments. At the same time, AODV and DSR performance tends to favour later data transmission in smaller networks with little major activity.

Mobile Ad hoc Networks (MANETs) continue to be an active and vital area of research, deserving greater emphasis due to their potential uses in many fields, including emergency response, warfare, and Internet of Things rollouts. Efficiency is a critical factor in MANETs, and it is primarily evaluated based on factors like protocol difficulty, overhead, and end-to-end interruption. Improving efficiency is crucial to ensure smooth and dependable interaction despite change and limited means. Maintaining the confidentiality of information during transport is a major headache for MANETs. The lack of a fixed infrastructure and the open nature of the network make MANETs more vulnerable to numerous safety threats, such as eavesdropping, unauthorized access, and data interference. Therefore, enhancing the security mechanisms and designing robust cryptographic protocols is of paramount importance to safeguard sensitive information and maintain the privacy of communication. Addressing the efficiency and security concerns in MANETs requires continuous research and innovation. Researchers need to focus on developing lightweight, energy-efficient routing protocols and mechanisms that can adapt to dynamic network conditions. Furthermore, exploring novel encryption and authentication techniques to secure data transmission in such a challenging and dynamic environment remains a crucial research area. As we've seen, a Mobile multihop Ad-hoc Network must meet a wide variety of criteria, and choosing the right routing protocols is a crucial and difficult process due to factors like resilience, scalability, dependability, energy limitations, etc. Finding the best pathways and then keeping them updated is the core functionality of routing protocols. Various sorts of metrics must be considered when searching for the best route. The optimality constraint of the routing protocol may be set by adjusting the measurement parameters. Lack of suitable optimum routes causes connection failures and excessive energy consumption because of the ever-changing architecture of the system. While the mobile nodes of a Mobile Multihop Ad Hoc Network do keep track of routes, the network architecture is typically a moving target. Therefore, the two parameters impacting the load in routing are the number of pathways and how far away a node is from the hub. Many protocols have been described in the literature, with most of them concentrating on certain metrics such as hop count, end-to-end latency, packet delivery ratio, etc. An early focus of published protocols was on minimizing data traffic or reducing the number of network nodes along a given path. These protocols were created without taking quality of service into account. Finding the route that best satisfies QoS restrictions, such as packet loss, power consumption, delay, bandwidth, jitter, etc., is the primary focus of QoS routing. As a result, ensuring QoS in a wireless network relies on securing the optimum number of routing pathways. When quality of service (QoS) is achieved in wireless communication, network delays and dead ends are minimized. To ensure the reliable delivery of data packets, multipath routing employs the total number of possible routes from a starting point to an ending point.

5. Conclusion

In this study, we conducted an examination and discussion of various types of routing protocols and the challenges related to safety, energy efficiency, routing efficiency, and vulnerabilities to security attacks at different layers of data transmission. Our literature review aimed to address these security issues and propose potential solutions. The highlighted routing protocols have proven to be valuable and efficient for addressing current challenges, and they serve as a foundation for future research efforts. The research community continues to develop new approaches, rules, algorithms, and protocols to enhance routing solutions further. Despite significant progress, there remain research questions about which protocols, techniques, methods, algorithms, or procedures perform optimally in specific environments. While considerable advancements have been made in this field, several challenges and issues still require attention. MANET networking is considered a crucial and necessary method for preparing for the arrival of technology. Numerous fascinating research publications, initiatives, and concerns have developed in the field of MANET, which is seeing widespread adoption from universities and companies worldwide. However, there is a recognition that further efforts are needed to address the evolving demands and complexities of MANETs to create even more robust and secure networks for future applications.

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