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Mobile Ad hoc Networks- A Review of Routing Protocols

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***Abstract*- Recently MANETs (Mobile Ad hoc Networks) generated tremendous interest among the research community due to their infrastructure less requirements and dynamic nature. Also due to its diverse applications for areas like disaster recovery, there is a lot of potential yet to be explored in MANETs in time to come. MANETs rely on TCP/IP network stack and due to its mobility nature, routing, and security become an important challenging area. In this article, we present our contribution by studying various routing protocols categories available for MANETs and discuss their features, limitations, and challenges which could restrict these routing protocols to a certain extent.**

Keywords- *Mobile Ad hoc Networks, Routing Protocols, MANETs*

I. INTRODUCTION

Mobile Ad hoc Networks are decentralized wireless networks consisting of mobile devices, that communicate with each other without the need of any centralized entity and existing network infrastructure. In a MANET, the mobile devices act as both hosts and routers, sending and receiving data for other devices in the network.

The main characteristics of MANETs are as follows-

- MANETs are self-organizing networks where each device can join or leave the network freely. All devices cooperate to maintain network connectivity.
- MANETs use wireless communication technologies, such as Wi-Fi or Bluetooth for device-to-device communication. Devices may communicate directly or indirectly through intermediate nodes to reach the destination.
- The network topology in a MANET changes frequently as devices move in and out of range due to changes in their positions.

Key challenges in MANETs are as follows-

- Due to its dynamic nature and constant changes in the network topology, there is a challenge in routing and maintaining connectivity.
- Mobile devices in MANETs typically have limited battery power and may have limited processing and storage capabilities. Efficient resource management and optimization are crucial for network performance.
- Due to the absence of centralized authority, MANETs are susceptible to various security threats like routing attacks and malicious code injection.

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Fig. 1 shows a typical mobile ad hoc network. Each device can communicate to other devices either directly or through some other device. The network topology keeps on changing in such networks.

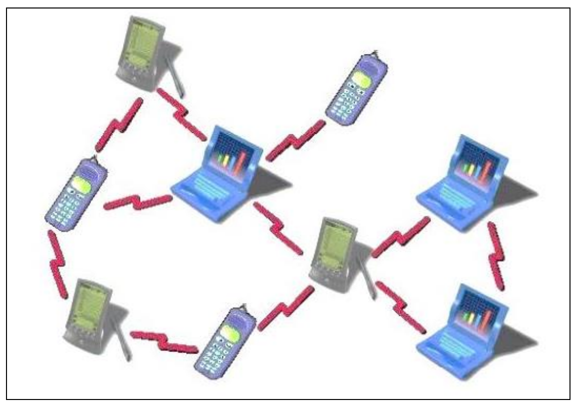


Fig. 1- A Typical Mobile Ad hoc Network

II. ROUTING PROTOCOLS

In order to establish a connection or join a MANET, a node needs to announce its arrival and should listen to similar announcements from broadcasts made by other nodes. That forms the basis for routing in such networks. There are several routing protocols specially designed for Mobile Ad hoc Networks to address the dynamic nature of such networks. These protocols can be classified into Proactive (Table-driven) protocols, Reactive (On-demand) protocols, and hybrid protocols.

Proactive (Table-driven) Protocols- These types of protocols maintain and continuously update routing information in routing tables throughout the network. Nodes exchange periodic updates to keep their routing tables synchronized. This approach provides fast routing decisions when a data packet needs to be transmitted to other nodes. Examples of proactive protocols include Optimized Link State Routing (OLSR) and Destination-Sequenced Distance Vector (DSDV).

Reactive (On-demand) Protocols- These protocols establish routes on demand when a source node wants to send data to a destination. Typically, these protocols initiate route discovery processes by flooding route requests across the network, with the cooperation of intermediate nodes a path is established between a source node and a destination node. Examples of reactive protocols include Ad hoc On-demand Distance Vector (AODV) and Dynamic Source Routing (DSR).

Hybrid Protocols- These protocols take hints from both proactive and reactive protocols to leverage efficient routing. They maintain routing information for some nodes proactively while using the reactive approach for other nodes. The objective of such protocols is to achieve a balance between overhead and route setup time. An example of a hybrid protocol could be Zone Routing Protocol (ZRP).

Fig. 2 shows the classification of MANET routing protocols briefly discussed here. The choice of choosing the right routing protocol depends on the specific requirements, network conditions, and other factors like network latency, scalability, and energy efficiency.

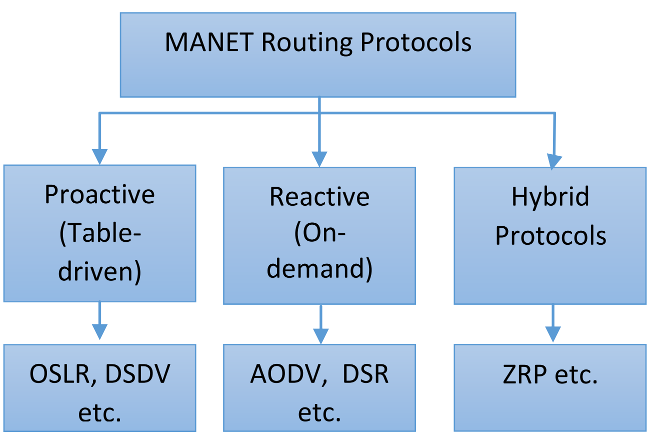


Fig 2- A MANET Routing Protocol Classification

III. PROACTIVE ROUTING PROTOCOLS

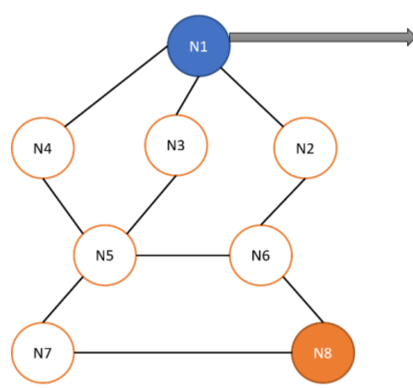
In these protocols, each node maintains a separate routing table that contains the information on the routes to all the possible destination mobile nodes. These routing tables are updated periodically and when the network topology changes. It has a limitation that it doesn't work well for large networks as the entries in the routing table could grow big since they need to maintain the route information to all possible nodes.

Destination Sequenced Distance Vector Routing Protocol (DSDV)
DSDV is one of the early routing protocols developed for MANETs and provides a foundation for more advanced protocols that have been developed to date. DSDV is considered more suitable for smaller networks or networks in which a stable network topology is maintained. DSDV provides loop-free and loop-free routing in MANETs. To address this, DSDV introduces sequence numbers and forces node to update their routing tables only with higher sequence numbers.

The key characteristics of DSDV protocol include-

- *Routing Tables* – Each node maintains a table that contains information about destination nodes, next-hop nodes, hop count or sequence numbers. These tables are periodically updated and exchanged with neighbouring nodes to keep the network topology information up to date.
- *Sequence Numbers* – DSDV utilizes sequence numbers to track and identify the freshness of routing information. Each routing update carries a sequence number assigned by the originating node. Nodes update their routing tables only if the received update has a higher sequence number.
- *Limited Overhead* – DSDV minimizes routing overhead by only transmitting updates when there are changes in the routing table or when the sequence numbers of route change. This reduces the amount of control traffic in the network.

Fig 3 shows an example of routing table in DSDV. There are 8 nodes where routing table of N1 node is displayed.



Dest	Next	Dist
N1	N1	0
N2	N2	1
N3	N3	1
N4	N4	1
N5	N3	2
N6	N2	2
N7	N3	3
N8	N2	3

Fig 3- An example of a Routing Table in DSDV

Optimized Link State Routing (OLSR)
OLSR is well suited for networks with a medium to large number of nodes and moderate mobility. It is capable of providing near-optimal routes and fast convergence in such scenarios. It is an optimization of the traditional Link State Routing (LSR) protocol.

The key characteristics of OLSR protocol include-

- *Multipoint Relaying* – OLSR introduces the concept of Multipoint Relaying (MPR) to reduce the overhead of flooding control messages. MPR nodes are selected strategically in each network to act as relay nodes for broadcasting control messages.
- *Topology Control* – OLSR performs topology control by exchanging and maintaining information about the network's connectivity. This information is used to construct and update a global network topology view, which enables efficient route calculation.
- *Multiple Routes* – OLSR supports the establishment and maintenance of multiple routes between a source and destination. This redundancy provides alternative paths between in case of link failures or changing network conditions.

However, OLSR may introduce higher control message overhead compared to other routing protocols, particularly in large-scale networks.

Other Proactive Routing Protocols
Wireless Routing Protocol (WRP), Fish-eye State Routing (FSR), and Cluster-based Routing Protocol (CBRP) are available which use the routing table approach with some improvements over other protocols.

IV. REACTIVE ROUTING PROTOCOLS

These protocols are well-suited for scenarios where network topology changes are frequent, and route maintenance overhead needs to be minimized. These protocols dynamically discover and establish routes as when required, reducing control message overhead and conserving network resources.

Dynamic Source Routing (DSR)
In this type of routing, the route is discovered only when it is required or needed. DSR is known for its flexibility, support for multiple routes, and efficient route caching.

The key characteristics of DSR protocol include-

- *Route Discovery* – When a node wants to transmit data to a destination for which it does not have a route, it initiates a route discovery process. The source node broadcasts a Route Request (RREQ) packet throughout the network. The RREQ contains the address of the destination node and a unique identifier. Intermediate nodes, upon receiving the RREQ, store their own address in the packet before forwarding it. This establishes a reverse path back to the source.
- *Route Caching* – DSR utilizes route caching to improve routing efficiency. When a node receives an RREP, it stores the route information in its cache. If a subsequent data packet needs to be transmitted to the same destination, the source node can retrieve the route information from its cache, eliminating the need for another route discovery process. Route caching reduces control message overhead and improves route setup time for frequently communicated destinations.
- *Multiple Routes* – DSR supports the establishment and maintenance of multiple routes between a source and a destination. This allows for route redundancy and provides alternative paths in case of link failures or changing network conditions. Multiple routes increase the resilience and reliability of the network.

However, DSR may introduce increased overhead due to the inclusion of complete routes in the packet headers.

Ad hoc On-Demand Distance Vector (AODV)
It is a widely adopted reactive routing protocol. When a node wants to transmit data to a destination for which it does not have a route, it initiates a route discover process by broadcasting a Route Request packets. It is an extension of Dynamic Source Routing protocol. AODV is based on the classic distance vector routing algorithm, but with several enhancements to handle the unique characteristics of MANETs.

The key characteristics of AODV protocol include-

- *Route Discovery*- When a node wants to send data to a destination for which it does not have a route, it initiates a route discovery process. The source node broadcasts a Route Request (RREQ) packet throughout the network. The RREQ contains the address of the destination node and a unique identifier. Intermediate nodes receive and forward the RREQ based on certain conditions, such as not having seen the RREQ before or having a valid route to the destination.
- *Hop-by-Hop Routing*- AODV employs hop-by-hop routing, meaning that each node in the route maintains the next-hop information to forward packets to the next node along the path. Intermediate nodes update their routing tables based on the received RREP or RERR messages, allowing for dynamic routing.
- *Sequence Numbers*- AODV uses sequence numbers to ensure the freshness of routing information and avoid routing loops. Each node maintains a sequence number for its own routing table entries, and these numbers are incremented whenever there is a change in the routing information. Sequence numbers help nodes determine whether a route is valid and up-to-date.

Overall, AODV provides a robust and scalable solution for routing in MANETs, allowing for efficient data transmission even in highly dynamic environments.

Other Reactive Routing Protocols
Temporarily Ordered Routing Algorithm (TORA), and Dynamic MANET On-Demand (DYMO) are some other reactive protocols frequently used in MANETs. These routing protocols offer more flexibility and efficiency by establishing routes on demand. They are suited for highly dynamic networks.

V. HYBRID ROUTING PROTOCOLS

A Hybrid Routing Protocol in Mobile Ad hoc Networks (MANETs) combines the characteristics of both proactive (table-driven) and reactive (on-demand) routing protocols. It aims to leverage the benefits of both approaches to achieve efficient and reliable routing in dynamic and self-configuring networks.

Zone Routing Protocol (ZRP)

The Zone Routing Protocol (ZRP) is a hybrid routing protocol that divides the network into zones and utilizes proactive and reactive mechanisms within these zones. ZRP dynamically adjusts the size of the zones based on network conditions to optimize routing performance.

The key characteristics of ZRP protocol include-

- *Hybrid Nature-* ZRP combines proactive and reactive strategies to strike a balance between control overhead and routing efficiency. By proactively maintaining routes within zones and selectively initiating reactive route discoveries across zones, ZRP achieves faster route establishment and reduced overhead compared to fully proactive or fully reactive protocols.
- *Zone based Organization*- ZRP partitions the network into logical zones. Each node is responsible for maintaining routing information within its own zone. The size of the zone can vary based on network density and node mobility. Dividing the network into zones helps reduce control message overhead by limiting the scope of proactive updates.
- *Proactive Zone Routing (Intra-Zone)*- Within each zone, ZRP employs a proactive routing approach. Nodes maintain routing information about other nodes within their zone through periodic updates. This allows for efficient routing within the zone without requiring route discovery procedures for every packet transmission.
- *Reactive Zone Routing (Inter-Zone*)- When a node needs to communicate with a destination outside its zone, ZRP utilizes a reactive routing approach. It initiates a route discovery process similar to reactive routing protocols. The route request is broadcasted to neighboring zones, and once the route is established, it is stored in the node's routing table for future use. This on-demand routing strategy optimizes control overhead by limiting route discoveries to inter-zone communication.

VI. CHALLENGES

Mobile Ad hoc Networks (MANETs) face several challenges in terms of routing protocols. Some of the key challenges include-

Dynamic Network Topology- MANETs consist of mobile nodes that frequently join, leave, or move within the network, resulting in a highly dynamic network topology. This dynamic nature poses challenges in maintaining up-to-date routing information and establishing efficient routes.

Limited Network Resources- MANETs often operate in resource-constrained environments with limited bandwidth, power, and processing capabilities. Routing protocols need to be designed to optimize the utilization of these limited resources while ensuring reliable and efficient communication.

Scalability- MANETs can have a large number of nodes, and routing protocols should scale well with the network size. As the number of nodes increases, the overhead associated with routing, such as control message exchange and route computation, should be minimized to avoid network congestion and performance degradation.

Energy Efficiency- In MANETs, nodes are typically powered by batteries, and conserving energy is crucial to prolong network lifetime. Routing protocols should consider energy constraints and aim to minimize energy consumption by employing energy-aware routing strategies, such as routing through nodes with higher residual energy or selecting shorter routes.

Security- MANETs are vulnerable to various security threats, including malicious nodes, eavesdropping, and tampering. Routing protocols must incorporate mechanisms to ensure secure and authenticated routing, detect and mitigate attacks, and provide confidentiality and integrity of transmitted data.

Quality of Service (QoS) Support- MANETs may require different levels of QoS for various applications, such as real-time multimedia streaming or critical data transmission. Routing protocols need to consider QoS requirements and provide mechanisms to prioritize and allocate network resources accordingly.

Lack of Centralized Control- MANETs typically lack a centralized infrastructure or a fixed network coordinator. Routing protocols need to be distributed and self-organizing, enabling nodes to autonomously discover and maintain routes without relying on a central authority.

Mobility Management- The mobility of nodes in MANETs introduces challenges in terms of route stability and handover management. Routing protocols should adapt to node mobility by efficiently updating routes, handling link failures, and supporting seamless handover to maintain connectivity.

Addressing these challenges requires the development of robust and adaptive routing protocols that can handle the dynamic and resource-constrained nature of MANETs while ensuring reliable, efficient, and secure communication.

VII. DISCUSSION

MANET routing protocols play a crucial role in enabling communication among these nodes by establishing and maintaining routes. These protocols face unique challenges due to the dynamic nature of MANETs, such as node mobility, limited resources, and changing network topologies. To reduce control overhead and improve routing efficiency, MANET routing protocols often utilize route caching. Caching stores recently discovered routes, allowing subsequent transmissions to reuse established paths. Additionally, some protocols, such as DSR, support route optimization by including complete routes in packet headers, eliminating the need for intermediate node route lookups. Energy conservation is critical in MANETs due to the limited battery life of mobile nodes. Many MANET routing protocols take energy efficiency into account by minimizing control message exchanges, reducing route discoveries, and optimizing route selection to minimize energy consumption. MANET routing protocols are continuously evolving to address the unique challenges of mobile, self-configuring networks. Researchers and developers strive to improve routing efficiency, scalability, adaptability, energy efficiency, and security to enable robust and efficient communication in MANETs. Different protocols are suitable for specific scenarios, and the choice of protocol depends on factors such as network size, mobility patterns, application requirements, and resource constraints.

VIII. CONCLUSIONS

In this work, we have studied different categories of routing protocols widely used in MANETs, and also looked at their features, limitations, and future challenges. We have arrived at the conclusion that proactive routing protocols are good for small to medium size MANETs where topology remains more or less fixed. While reactive routing protocols are good for medium to large-size MANETs where topology may change frequently. On the other hand, hybrid routing protocols take advantage of proactive and reactive types of protocols and are fit for large MANETs where there is a rapid change in the topology of such networks. But, there are many challenges as discussed in the previous section which restrict these protocols for extension and also with these challenges how new protocols can be developed which could be more effective in not only routing but also addresses security issues well.

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