International Journal of Scientific Research in Computer Science, Engineering and Information Technology
ISSN : 2456-3307 (www.ijsrcseit.com)
doi : https://doi.org/10.32628/IJSRCSEIT

A Review : Mobile Ad-Hoc Network Using Routing Protocols

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ARTICLEINFO

Article History:

Accepted: 08 Feb 2023
Published: 25 Feb 2023

Publication Issue
Volume 10, Issue 1
January-February-2023

Page Number
287-293

ABSTRACT

Mobile Ad-hoc Networks (MANETs) has revolutionized the landscape of wireless communication by enabling seamless and dynamic network formations without any fixed infrastructure. This thesis presents a comprehensive review of the current state of MANET research, focusing on its underlying principles, routing protocols, challenges, and potential applications. This Paper begins by elucidating the fundamental concepts of MANETs, highlighting their decentralized nature, self-organizing capabilities, and limited resources. A detailed examination of prominent routing protocols follows, including proactive protocols like OLSR and DSDV, reactive protocols such as AODV and DSR, and hybrid solutions like ZRP. Comparative analyses of their strengths, weaknesses, and suitability for different scenarios offer valuable insights.

Challenges inherent to MANETs, such as node mobility, scalability, security threats, and energy efficiency, are systematically expounded. Noteworthy efforts in addressing these challenges are discussed, encompassing techniques like trust-based security, energy-aware routing, and Quality of Service (QoS) optimization. Furthermore, the review explores the manifold applications of MANETs across domains like disaster recovery, military operations, Internet of Things (IoT), and vehicular networks. Real-world deployment scenarios and case studies underscore the practical significance of MANETs in enabling resilient and adaptable communication infrastructures

Keywords: Mobile Ad-hoc Network (MANET), Routing Protocols, Decentralized Networks, Security Threats, Applications.

I. INTRODUCTION

Mobile Ad-hoc Networks (MANETs) have emerged as a dynamic and versatile paradigm in wireless communication systems. These networks, characterized by their decentralized nature and the absence of a fixed infrastructure, have garnered significant attention from researchers, engineers, and policymakers due to their potential to reshape the landscape of modern connectivity [1]. This thesis aims to provide a comprehensive review of the evolving field of Mobile Ad-hoc Networks, shedding light on the core principles, routing protocols, challenges, and diverse applications that underpin this dynamic domain.

a. Principles of Mobile Ad-hoc Networks

The fundamental principle that distinguishes MANETs from traditional wireless networks is their self-organizing capability. Unlike conventional networks that rely on fixed base stations, MANETs consist of mobile nodes that spontaneously form an ad-hoc network. This unique feature allows for rapid deployment in situations where infrastructure is damaged or non-existent, such as disaster-stricken areas or military operations. Cite (Perkins et al., 2001) noted this inherent flexibility, which has led to significant interest in MANETs for various applications [2-3].

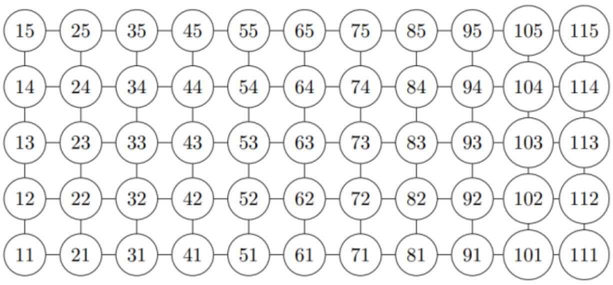

Figure .1 Architecture of Mobile ad-hoc network

The essence of MANETs lies in their ability to establish communication without the need for a pre-existing network infrastructure. Nodes within the network act both as end-user devices and as routers, relaying data for each other. This decentralized approach contributes to network robustness and adaptability, making MANETs well-suited for scenarios where conventional networks would fail. MANETs exemplify the "network of the future" where devices collaborate seamlessly, adapting to changing conditions [3].

b. Routing Protocols in MANETs

One of the cornerstones of Mobile Ad-hoc Networks is the dynamic nature of their topology. Nodes are mobile, which leads to constant changes in network connectivity. To facilitate efficient data transmission, various routing protocols have been developed. Proactive protocols like Optimized Link State Routing (OLSR) maintain up-to-date routing tables for all nodes, whereas reactive protocols like Ad-hoc On-Demand Distance Vector (AODV) establish routes only when needed. Hybrid solutions, like the Zone Routing Protocol (ZRP), combine elements of both proactive and reactive approaches [4-5].

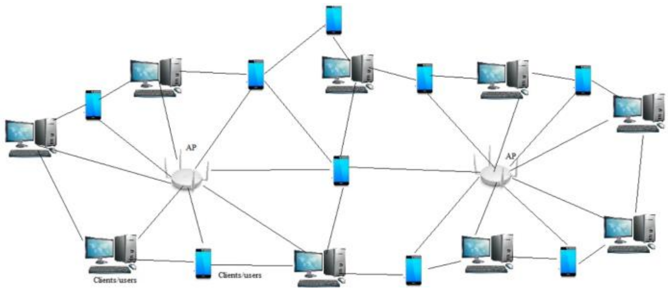

Figure .2 Mobile ad-hoc network connection with network

The choice of routing protocol depends on the specific application and network conditions. OLSR, for example, is well-suited for networks with high stability, while AODV excels in highly dynamic environments. Pointed out, understanding these protocols and their trade-offs is crucial for effective MANET design.

c. Challenges in MANETs

While the promise of MANETs is alluring, they also present a unique set of challenges. Node mobility can disrupt established routes, leading to frequent route rediscovery. Scalability can be an issue as the number of nodes increases, and maintaining network security in a decentralized environment poses significant hurdles. Additionally, energy efficiency is a critical concern, as nodes often rely on limited power sources [6].

Researchers and engineers have been tirelessly addressing these challenges. Trust-based security mechanisms, energy-aware routing algorithms, and Quality of Service (QoS) optimizations have emerged as potential solutions. Demonstrated the importance of addressing these challenges to ensure the reliability and viability of MANETs in practical scenarios [7].

d. Applications of MANETs

The versatility of MANETs extends to a wide array of applications. From disaster recovery operations that demand rapid deployment of communication networks to military scenarios where traditional infrastructure is absent, MANETs play a pivotal role. In the context of the Internet of Things (IoT), MANETs facilitate seamless device-to-device communication, while in vehicular networks, they enable vehicles to communicate and cooperate, enhancing road safety and traffic management. understanding these applications is essential for harnessing the full potential of MANETs and guiding their development in a way that aligns with the needs of various sectors.

II. RELATED WORK

Mobile Ad-Hoc Networks (MANETs) have gained significant attention in recent years due to their applicability in a wide range of scenarios, including disaster recovery, military communications, vehicular networks, and IoT applications. A MANET is a self-configuring network of mobile devices connected by wireless links, where each device can act as a router, forwarding data packets to other devices. In this comprehensive review of related work, we delve into the evolution of MANET research, highlighting key contributions, challenges, and trends that have shaped the field [8].

The concept of ad-hoc networks dates back to the 1970s, but it was not until the late 1990s that MANETs gained prominence with the advent of wireless technology. In the early years, much of the research focused on routing protocols. One of the seminal works in this area was the Destination-Sequenced Distance Vector (DSDV) routing protocol proposed by Perkins and Bhagwat in 1994. DSDV introduced the concept of sequence numbers to avoid routing loops, setting the stage for subsequent routing protocols [9].

The evolution of routing protocols has been a cornerstone of MANET research. In 1999, the Ad Hoc On-Demand Distance Vector (AODV) routing protocol was introduced by Perkins and Royer. AODV improved scalability by establishing routes on-demand and maintaining them only as long as they were needed, took a different approach by including the entire route in packet headers, eliminating the need for route discovery [10].

Subsequently, many variations and improvements were proposed, including the Temporally Ordered Routing Algorithm (TORA) and the Optimized Link State Routing (OLSR) protocol. More recent developments incorporate machine learning techniques to enhance routing, such as reinforcement learning-based routing algorithms, which adapt to network conditions dynamically [11].

Security remains a critical concern in MANETs, especially given their decentralized and dynamic nature. The work of Papadimitratos and Haas in 2002 introduced the concept of Secure Routing in Ad Hoc Networks (SEARAN). They addressed issues like secure route discovery and secure route maintenance. This laid the foundation for subsequent research on secure MANETs, including intrusion detection systems and trust management mechanisms [12].

Trust management mechanisms, such as the Trust-Based Secure AODV (TSAODV) protocol, have been proposed to mitigate attacks on routing protocols. These mechanisms assess the trustworthiness of nodes based on their past behavior and interactions within the network.

Ensuring Quality of Service in MANETs is a complex challenge due to the dynamic nature of these networks. Research by Perkins and Belding-Royer in 1999 proposed the Ad Hoc QoS On-Demand Distance Vector (AODV-QoS) extension, which aimed to provide QoS support by considering metrics like delay and bandwidth in route selection. Further research has explored advanced QoS provisioning techniques, including traffic engineering and resource management. MANETs often operate in resource-constrained environments, making energy efficiency a critical concern. Protocols like the Power-Aware Routing in Mobile Ad Hoc Networks (PARMAN) and the Energy-Aware Routing (EAR) algorithm have been developed to optimize energy consumption by selecting routes that minimize energy usage, thus prolonging the network's lifetime [13].

The proliferation of multimedia applications has driven research into multimedia support in MANETs. The work of Zhu and Corson in 2003 introduced the concept of Ad Hoc Multicast Routing Protocol (AMRoute) for efficiently delivering multimedia content in MANETs. AMRoute was designed to support multicast communication and minimize control overhead. Cross-layer design has gained prominence in MANET research. It involves interactions between different network layers to optimize performance. One notable contribution is the Cross-Layer Optimization Mechanism for Multimedia Traffic (XOMMT) framework, which optimizes the delivery of multimedia content by considering interactions between the physical, MAC, and application layers [14].

MANETs have found applications in diverse fields, including military and emergency response. The Tactical Ad Hoc Networks (TACAN) project, initiated by the U.S. military, has spurred advancements in MANET technology for tactical communication in battlefield scenarios. Additionally, vehicular ad-hoc networks (VANETs) have emerged as a subdomain with applications in intelligent transportation systems. Despite significant progress, MANETs still face several challenges, including security threats, scalability issues, and QoS provisioning in dynamic environments. Future research directions include the integration of blockchain technology for enhanced security, machine learning for adaptive routing and resource allocation, and the exploration of novel applications in the era of 5G and beyond [15].

III. CLASSIFICATION OF ROUTING PROTOCOLS

Routing protocols are essential components of computer networks that determine how data packets are forwarded between devices in a network. These protocols are classified into several categories based on various criteria, including their behaviour, characteristics, and use cases. Here are some common classification categories for routing protocols:

a. Routing Algorithm Type:

Distance Vector Protocols: These protocols, such as RIP (Routing Information Protocol), use hop count as the metric to determine the best path to a destination. They periodically exchange routing tables with neighbouring routers.

Link-State Protocols: Examples include OSPF (Open Shortest Path First) and IS-IS (Intermediate System to Intermediate System). These protocols maintain a detailed map of the network topology and use metrics like bandwidth and link cost to calculate paths.

Hybrid Protocols: Protocols like EIGRP (Enhanced Interior Gateway Routing Protocol) combine aspects of both distance vector and link-state protocols. They use a metric based on bandwidth, delay, reliability, and load [16].

b. Network Scale:

Interior Gateway Protocols (IGPs): These protocols operate within a single autonomous system (AS). Examples include RIP, OSPF, and EIGRP.

Exterior Gateway Protocols (EGPs): BGP (Border Gateway Protocol) is an example of an EGP, used to route traffic between different autonomous systems.

c. Protocol Behaviour:

Static Routing: Routes are manually configured by a network administrator. No automatic exchange of routing information occurs.

Dynamic Routing: Routing tables are updated automatically based on the information exchanged between routers.

Adaptive Routing: Routing decisions are adjusted based on real-time changes in network conditions [17].

Convergence: The speed at which routers agree on the best path after a topology change.

d. Routing Domain:

Intradomain Routing: Routing within a single administrative domain.

Interdomain Routing: Routing between different administrative domains.

e. Use Case:

Unicast Routing: Routing of data packets from a source to a single destination.

Multicast Routing: Routing of data packets from a source to multiple recipients.

Anycast Routing: Routing to the nearest or best of several possible destinations.

f. Protocol Dependency:

Open Standard Protocols: Protocols developed and maintained by open standards organizations, such as OSPF (open standard) and RIP (historically). Proprietary Protocols: Protocols developed by a specific vendor, such as EIGRP (Cisco proprietary) [18-19].

These classifications provide a framework for understanding the different types of routing protocols and their roles within a network. It's important to note that the choice of a routing protocol depends on factors like network size, complexity, desired performance, scalability, and vendor equipment being used [20].

IV. PERFORMANCE MEASUREMENT FOR MANETS

The performance Metrix for Mobile Ad Hoc Networks (MANETs) along with their mathematical formulas, without examples:

Throughput (TP):

TP = Total data delivered / Total time taken

Packet Delivery Ratio (PDR):

PDR = (Number of packets delivered / Number of packets sent) * 100

End-to-End Delay (EED):

EED = (Total delay of all packets / Number of packets) seconds

Routing Overhead (RO):

RO = (Total control packets generated / Total data packets delivered) * 100

Network Lifetime (NL):

NL = Energy of the first node to fail - Energy of the last node to fail

Jitter:

Jitter = |Packet Inter-arrival Time - Desired Inter-arrival Time|

Network Connectivity:

Connectivity = (Number of nodes in the largest connected component / Total number of nodes) * 100

Residual Energy:

Residual Energy = Initial Energy - Energy Consumed

Average Hop Count:

Average Hop Count = (Total hops in all routes / Number of routes)

Scalability:

Scalability = (Throughput with 'n' nodes / Throughput with 'n-1' nodes) * 100

These formulas are used to quantify and analyse the performance of MANETs, helping researchers and network administrators to evaluate and optimize their networks.

V. CONCLUSION

In this paper, Mobile Ad-Hoc Networks (MANETs) have revealed a dynamic and versatile field with immense potential for various applications. As we have explored throughout this review, MANETs offer a decentralized communication paradigm that enables wireless devices to collaborate and communicate without relying on a fixed infrastructure. This unique feature makes MANETs suitable for a wide range of scenarios, including military operations, disaster recovery, sensor networks, and even everyday communication in challenging environments.

However, it is crucial to acknowledge that MANETs also come with their fair share of challenges. The issues related to network security, routing protocols, scalability, and quality of service remain active areas of research and development. Furthermore, the ever-evolving landscape of wireless technologies and the increasing demand for reliable and efficient mobile communication solutions continue to drive innovation in the MANET domain.

As technology advances, we can anticipate the emergence of new MANET architectures and protocols that address these challenges more effectively. The future of MANETs holds promise for improved reliability, security, and scalability, making them an even more viable option for a broader spectrum of applications.

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Cite this article as :

Ramashray Kumar, Prof. Vinod Mahor, "A Review : Mobile Ad-Hoc Network Using Routing Protocols", International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT), ISSN : 2456-3307, Volume 9, Issue 1, pp.287-293, January-February-2023.