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Examining Optimization Strategies in MANET Routing Protocols: A Critical Review

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Abstract—Routing protocols face several challenges, including node mobility, resource constraints, error-prone channel states, and issues with hidden and unprotected terminals. This article offers an overview of these protocols, highlighting their associated problems and suggesting improvements. In wireless communication, cell phones enable communication between mobile stations (MS), mobile units, and base stations, facilitating connectivity even as units move. A Mobile Ad Hoc Network (MANET) comprises devices that connect and communicate independently. MANETs have garnered interest from military, law enforcement, and emergency services due to their ability to provide high-quality service. Path loss (PL) is a significant issue in wireless communication, often caused by obstacles or signal sources being distant from their destinations. Multipath propagation, path loss, and interference can degrade the network's Quality of Service (QoS). To address these challenges, routers employ dynamic routing protocols to determine the best route, updating routing tables accordingly and selecting alternate paths when necessary. Improving routing protocols in MANETs is crucial for overcoming these obstacles and enhancing network performance and reliability.

Keywords—Routing protocols, Optimization Network, Metaheuristics Optimization, Path loss, quality of service.

1. Introduction

Mobile Ad-hoc Networks (MANETs) are dynamic networks composed of mobile nodes communicating via wireless links, operating without the need for centralized access points or established infrastructure. Nodes within MANETs move freely, leading to unpredictable topology changes, making the network self-organizing and adaptive. This unique characteristic lends itself to various applications, including emergency rescue operations, disaster relief efforts, military battlefield communication, and enhancing cellular-based mobile network infrastructure.

In MANETs, each node serves as both a host and a router, facilitating communication among nodes. To establish communication between two nodes, the transmitting node checks if the receiving node is within its transmission range. If so, direct communication occurs; otherwise, intermediate nodes assist in relaying messages. Cooperation among nodes is crucial for successful information exchange, a process known as routing.

MANETs offer an inexpensive alternative for data exchange among cooperative mobile nodes, with each node playing a vital role in facilitating communication. Routing protocols and mechanisms ensure efficient message delivery within the network, enabling seamless communication despite the dynamic nature of MANETs.

In Mobile Ad-hoc Networks (MANETs), routing information needs to adapt to changes in link connectivity due to node mobility. Routing protocols play a crucial role in finding efficient paths from source to destination nodes, considering factors such as convergence time after topology changes, bandwidth overhead, power consumption, and error handling capability. The performance of MANETs heavily relies on the efficiency of these routing protocols.

Efficient routes in MANETs often involve multiple hops between nodes, making route selection and Quality of Service (QoS) improvement at the transport layer challenging. The effectiveness of proactive and reactive routing communication protocols, such as AODV, DSR, and DSDV, can be evaluated based on QoS metrics like throughput, delay, packet delivery ratio (PDR), and packet loss ratio (PLR), considering varying network loads and sizes.

The objective of this paper is to assess the performance of different routing protocols in MANETs under varying conditions, providing insights into their strengths and weaknesses. By evaluating these protocols based on QoS frameworks, such as throughput, delay, PDR, and PLR, the study aims to inspire further research for enhancing existing protocols or developing new ones to address the challenges inherent in MANETs. This research can contribute to improving the overall efficiency and reliability of communication in MANETs, thus facilitating their deployment in various real-world scenarios.

2. Mobile AD-HOC network

A mobile ad hoc network (MANET) refers to a group of mobile devices that connect and interact without relying on a preexisting infrastructure [11]. Unlike uniform or focused organizations, MANETs typically operate using self-organizing and self-managing networks instead of permanent infrastructure [1]. In MANETs, each node serves both as a host and a router due to the limited wireless transmission range of each node. This architecture allows MANETs to be rapidly deployed in any location and adapt to changing circumstances, making them particularly valuable in military, police, and emergency service applications, especially in chaotic or hostile environments [21], [22].

Business applications leveraging MANETs have also emerged, with standards like IEEE 802.11 continuously evolving to support their deployment. MANETs can function independently or interface with cellular networks or the Internet, enabling a wide range of innovative applications such as emergency and rescue operations, conference or university settings, vehicle networks, and personal networking.

MANETs employ both static and dynamic routing technologies. Static routing protocols are used when the network topology remains fixed, similar to the physical connection between nodes in a LAN network [23]. In contrast, dynamic routing protocols are employed in ad hoc networks where nodes and links exhibit mobility. Routers in dynamic routing systems autonomously learn routing information and update their routing tables accordingly, ensuring optimal route selection even in dynamically changing network environments. This adaptability is crucial for maintaining connectivity and communication reliability in MANETs.

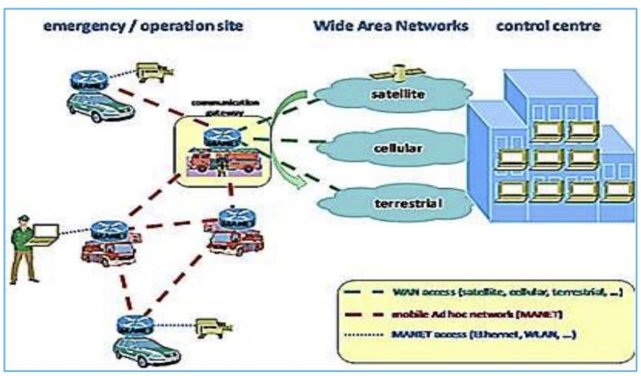

Fig. 1. General architecture of MANET

Radio frequencies serve as wireless media for transmitting data between nodes in ad hoc networks [24]. However, these networks often encounter interference, which can stem from various sources such as weather conditions, frequencies of nearby devices or networks, and physical obstructions caused by individual devices [21]. Interference can disrupt the transmission of data between network nodes, leading to signal degradation and communication issues.

Multipath propagation is another challenge in wireless communication, where signals are reflected from obstacles, resulting in multiple signal paths with different delays. This phenomenon occurs due to the scattering of signals from hard surfaces, causing delayed reception of the same signal from multiple paths.

Path loss (PL) is a significant problem in wireless communication, arising from factors such as the distance between the signal source and destination in the network or multiple reflections from obstacles [24], [25]. The calculation of path loss is based on the ratio of the transmitted signal power to the received signal power. Equation 1x is typically used to calculate path loss [26].

3. Quality of service (QoS)

A Quality of Service (QoS)-aware routing protocol must meet various requirements to ensure effective and dependable communication within a network. These requirements encompass several key aspects. Firstly, the protocol should efficiently manage available bandwidth to optimize data traffic, adhering to specified QoS metrics like throughput and latency. Secondly, it must prioritize reliability, selecting routes with minimal packet loss and resilience to network failures. Thirdly, latency control is paramount, particularly for real-time applications, necessitating the selection of routes with minimal delay and jitter. Moreover, scalability is crucial to accommodate networks of varying sizes while maintaining efficiency and resource utilization. Additionally, adaptability to network dynamics, support for differentiated services, and energy efficiency are essential considerations. Security measures are also imperative to safeguard data transmission against potential threats. Furthermore, optimizing Quality-of-Experience (QoE) and adhering to industry standards ensure user satisfaction and interoperability. By meeting these requirements, a QoS-aware routing protocol can effectively facilitate reliable communication while addressing diverse application needs and network conditions.

3.1. Resource estimation

Ad hoc networks enable resource sharing among host nodes and their nearby counterparts. Given the dynamic nature of MANET architecture, accurately estimating resource availability becomes essential for enhancing Quality of Service (QoS) [29].

3.2. Route discovery

Route finding in MANETs can be facilitated through either reactive or proactive procedures [30]. In proactive mechanisms, routes are discovered and established with minimal delay, whereas reactive mechanisms prioritize reducing routing overhead despite higher route establishment times [31]. Achieving superior Quality of Service (QoS) entails conducting route discovery with lower overhead and delay. Figure 2 illustrates a discovered route in MANET.

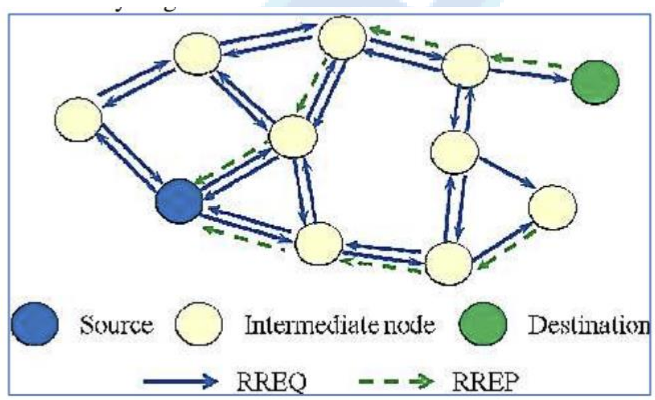

Fig. 2. discovering routes

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3.3. Resource reservation QoS

In dynamic topology, allocating resources to nodes poses a considerable challenge, especially in scenarios of resource scarcity. Besides addressing insufficiency, prioritizing resource allocation to nodes involved in transmission enhances the overall quality of service [32].

3.4. Route maintenance

The mobility of nodes in MANETs can result in occasional disconnection of identified data transmission routes [33]. To address this challenge, it is crucial to predict the movement of nodes and identify redundant routes for the same data transmission, ensuring route availability and enhancing Quality of Service (QoS). Figure 3 illustrates route maintenance in MANET.

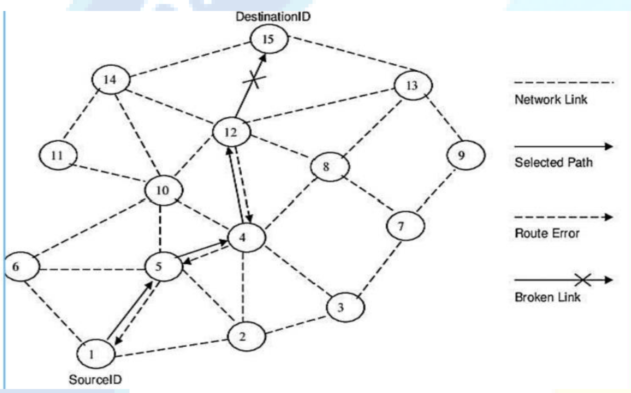

Fig. 3. Route maintenance

3.5. Route selection

In MANETs, routes from source to destination are chosen from multiple existing routes, taking into account factors such as bandwidth availability, route distance, and the number of hop counts [34]. Figure 7 illustrates the types of media that could be transmitted over MANETs' networks, along with considerations for Quality of Service (QoS).

4. Manet routing protocols

A network protocol, a set of systematic guidelines, governs the exchange of data among various devices within the same network [11]. Routing, data transfer, communication, and resource sharing all rely on network protocols. Figure 4 illustrates a mobile ad hoc network (MANET), which consists of an autonomous group of mobile users (nodes) interacting across wireless networks with limited bandwidth. Due to the mobility of nodes, the network topology can change rapidly and unpredictably over time. As the network is decentralized, nodes must organize and exchange information. Routing messages can be challenging in a decentralized environment where the topology is constantly changing [35]. Unlike in a static network, where the shortest path between two points based on a specified cost function is typically the best route, applying this concept in MANETs presents challenges.

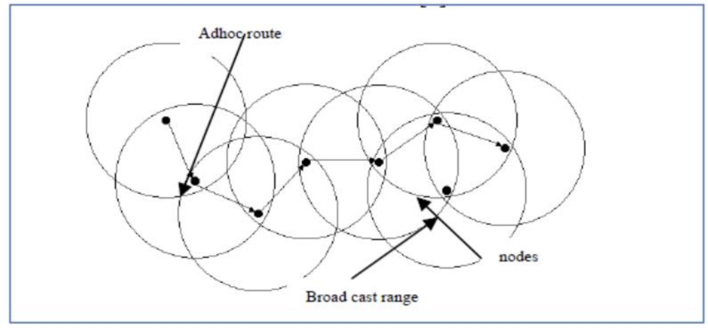

Fig. 4. Example of mobility in an Ad-hoc Network.

Routing in MANET networks is managed through reactive and proactive routing protocols. Among the reactive routing protocols, Dynamic Source Routing (DSR) and Ad Hoc On-Demand Distance Vector (AODV) are frequently utilized [21] [1]. The proactive routing protocol family also includes Ad Hoc On-Demand Distance Vector (AODV). Figure 5 illustrates various routing techniques based on topology.

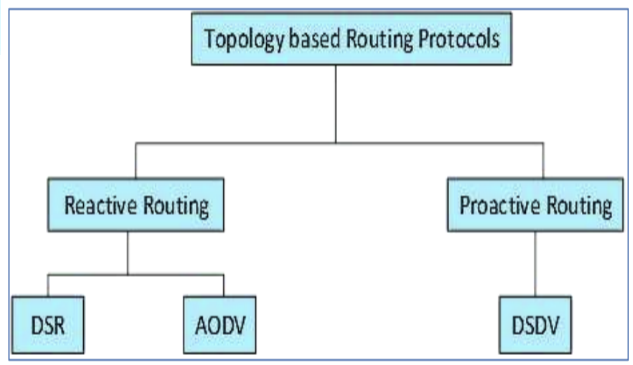

Fig. 5. Topology-based routing protocols.

While proactive routing protocols excel in reducing bandwidth utilization and achieving faster convergence times, reactive routing techniques are essential for managing dynamic network topologies [36]. However, it's worth noting that the AODV and DSR topology-based routing protocols consume more CPU, memory, bandwidth, and battery power compared to the DSDV routing protocol.

5. Dynamic source routing (DSR)

The route packets take within a MANET, from source to destination, is governed by a routing method known as TDSR. This method enables nodes to locate a source route over several network hops to any desired destination node [40]. The DSR routing protocol comprises two main aspects: route discovery and route maintenance.

When transmitting packets using the DSR protocol, mobile hosts first check their route cache to determine if they already have a route to the desired destination [38]. If a route to the destination exists in the cache, the packet is sent directly to the host. However, if the host node lacks a route or if the existing route is inactive, it initiates the route discovery procedure by sending a route request packet. This packet includes the destination addresses, the mobile source host, and a special identifying number [40]. Each node in the network receives the packet and uses the DSR routing protocol to determine if a route to the destination exists [35]. If not, it forwards the packet, adding its address to the route entry and utilizing its routing links.

When the request reaches the destination, and an unclaimed route to the destination is present in the intermediate node's cache, the route of a packet is established. Figure 6 illustrates the delivery of a packet using the DSR routing across the MANET network.

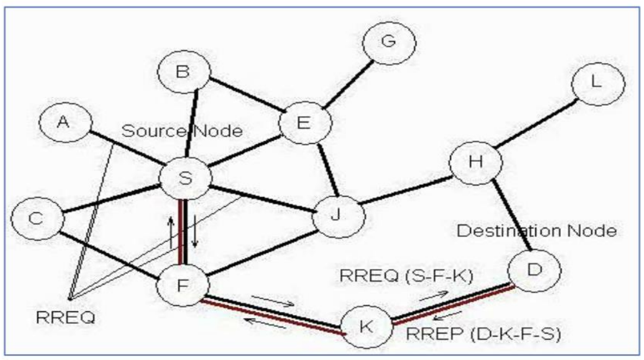

Fig. 6. DSR broadcast RREQ.

6. Related Works

Numerous studies have attempted to simulate or analyze reactive and proactive protocols in ad-hoc environments. However, the complexity of protocols like DSR, DSDV, and AODV poses challenges for analytical approaches, as these protocols can be configured in various ways to achieve high performance in different scenarios. One such study by Mohammad Naserian (2017) introduces a new mathematical framework for quantifying the overhead of reactive routing protocols like DSR and AODV in wireless ad hoc networks with randomly located nodes. The analysis is validated through simulations, providing insights into the scalability properties of routing protocols.

In another work by Amith Khandakar et al. (year), a systematic method is presented to evaluate three popular routing protocols, namely DSR, AODV, and DSDV, based on performance metrics such as Packet Delivery Fraction (PDF), End-to-End Delay, and Normalized Routing Load. Their study outlines a step-by-step approach for conducting such evaluations, offering valuable guidance for future research endeavors.

Additionally, a study conducted by J. Broch (1998) assesses the performance of multiple routing protocols, including AODV, DSR, OLSR, and DSDV, focusing on Packet Delivery Ratio (PDR) and routing overhead. Through experimentation, they found that the Temporally Ordered Routing Algorithm exhibited the worst performance in terms of routing overhead, while AODV outperformed DSR in this aspect. However, other performance metrics of AODV and DSR were found to be similar across different mobility rates.

Furthermore, Akshay Shankar (2016) analyzed the performance of well-known MANETs routing protocols under high mobility scenarios and varying density levels. Their evaluation considered metrics such as Average End-to-End Delay, Normalized Routing Load (NRL), Packet Delivery Fraction (PDF), and Throughput. Simulation results indicated that AODV demonstrated better performance compared to DSR and DSDV in these scenarios.

Several studies have compared the performance of various routing protocols in ad hoc networks, focusing on metrics such as packet delivery ratio (PDR), throughput, end-to-end delay, and routing overhead. For instance, (Samir R. Das, 2014) conducted performance studies comparing the reactive routing protocols AODV and DSR across different network loads, mobility levels, and network sizes. They observed that DSR outperformed AODV in smaller networks with lower loads and mobility but not in larger networks with higher loads and mobility.

Another study by (A. A. Chavana, 2016) analyzed AODV and DSDV in terms of routing overhead, packet delivery ratio, throughput, and end-to-end delay, concluding that AODV performs better than DSDV in most metrics. Additionally, (Ahmed Al-Maashri, 2006) evaluated the performance of AODV, DSR, and OLSR under self-similar traffic conditions, finding that DSR performed better in terms of various QoS metrics at speeds less than 10 m/s.

Similarly, (Bhavyesh Divecha, 2014) compared AODV and DSR routing protocols across varying node densities and hop counts, with DSR consistently outperforming DSDV in different scenarios. (V. Rajeshkumar, 2015) presented a performance comparison of reactive and proactive protocols, including AODV, DSR, and DSDV, based on metrics such as throughput, control overhead, packet delivery ratio, and average end-to-end delay.

Furthermore, (Sandeep Sharma, 2017) compared AODV, DSR, and DSDV using metrics such as packet delivery ratio, routing overhead, and remaining energy, while (Fahad Taha AL-Dhief, 2017) evaluated the performance of DSR, AODV, and DSDV in terms of packet delivery ratio, average throughput, average end-to-end delay, and packet loss ratio.

Other studies, such as those by (Ankita Sharma, 2014), (Akshay Shankar, 2016), (Nilesh Chandra, 2015), (Asma Tuteja, 2010), (Gulati, 2014), and (Kumar, 2016), have also contributed valuable insights into the performance of various routing protocols in different scenarios. Overall, these studies provide important observations and recommendations for improving the performance of routing protocols in ad hoc networks.

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7. Conclusion

Routing protocols play a crucial role in establishing data paths from source to destination within mobile networks. These networks, such as wireless ad hoc networks (VANETs) or mobile ad hoc networks (MANETs), are characterized by their informal connectivity and lack of fixed infrastructure. MANETs, specifically, leverage self-organizing and self-managing capabilities, allowing nodes to communicate without reliance on a predefined infrastructure. In MANETs, each node serves both as a host and a router, facilitating decentralized communication. Routing protocols in MANETs can be categorized as proactive or reactive. Proactive protocols, exemplified by Destination-Sequenced Distance Vector Routing (DSDV), continuously maintain routing tables to establish routes proactively, potentially leading to longer convergence times but lower bandwidth consumption. In contrast, reactive protocols, such as Dynamic Source Routing (DSR) and Ad Hoc On-Demand Distance Vector (AODV), establish routes only when necessary, reducing routing overhead but potentially resulting in higher route establishment delays. Optimizing routing in MANETs often involves multi-objective optimization to balance factors like delay, packet loss, and packet delivery ratio (PDR). Metaheuristic algorithms are commonly employed to search for optimal routing paths across various scenarios and protocols, including DSR, AODV, and DSDV, aiming to improve network performance and efficiency.

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