Improve energy routing scheme for mobile ad hoc network Using variable range transmission

Samuel Bekele Tuffa

A Thesis Submitted to

The Department of Computer Science and Engineering
School of Electrical Engineering and Computing

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Computer Science and Engineering
Adama Science and Technology University

Aug, 2023
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Declaration

We declare that this thesis entitled "**Improve energy routing scheme for mobile ad hoc network Using variable range transmission**" is my work and has not been submitted to any university for a similar purpose. The references used in this proposal are duly recognized by proper citations.

____Samuel Bekele_______	________________________	________________
Name of student	Signature	Date

Recommendation of Advisors

I, the major advisor of this research proposal, hereby certify that I have closely advised the student while developing this proposal and read the draft thesis/dissertation proposal entitled "**Improve energy routing scheme for mobile ad hoc network Using variable range transmission**" prepared under my guidance by **Samuel Bekele**. Therefore, I recommend the submission of the proposal to the department for further review and evaluation.

__ Ketema Adere (PHD)	______________________	_______________
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Co-advisor/Co-supervisor	Signature	Date

Approval of Board of Examiners

we, the advisors of the thesis entitled "Improve energy routing scheme for mobile ad hoc network using variable range transmission" and developed by Samuel Bekele, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr.- Ketema Adere	______________________	______________________
Major Advisor	Signature	Date
______________________	______________________	______________________
Co-advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Samuel Bekele have read and evaluated the thesis entitled "Improve energy routing scheme for mobile ad hoc network using variable range transmission" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Computer Science and Engineering.

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Office of Postgraduate Studies,	Dean Signature	Date

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AODV	Ad hoc on demand Distance Vector
AODMV	Ad hoc On-demand Distance Multipath Vector
AOMDV	Ad hoc On-demand Multipath Distance Vector
AQOR	Ad hoc QoS On-demand Routing
CBRP	Cluster Based Routing protocol
DSDV	Destination-Sequenced Distance-Vector Routing
DSR	Dynamic Source Routing
DST	Distributed spanning trees-based routing.
FSR	Fisheye State Routing GSR - Global state routing
EEAOMDV	Energy Extend Ad hoc On-demand Multipath Distance Vector
MSR	Multipath Source Routing
OLSR	Optimized Link State Routing
OTCL	Object-oriented Tool Command Language
EAR	Energy Aware Routing
RREQ	Route Request
RREP	Route Reply
SMR	Split Multipath Routing
WRP	Wireless Routing Protocol
ZRP	Zone Routing Protocol

ABSTRACT

A MANET (Mobile Ad-hoc Network) is a self-sustained, multi-hop communication network where nodes interact directly or indirectly through intermediaries, making every node act as a mobile router that adheres to a routing protocol for route determination and maintenance. In the MANET ecosystem, every node relies on limited battery power, rendering efficient energy management a critical concern. Therefore, optimizing energy usage stands as a paramount challenge in the context of MANETs. When nodes possess awareness of both their energy levels and the recipient's location, it facilitates reduced energy consumption and augments throughput. In response to these challenges, this paper introduces an innovative approach to enhance energy efficiency in MANETs. We propose an Improved Energy Routing Scheme that leverages the concept of Variable Range Transmission (VRT) as a foundational element. The primary objective of this scheme is reduce the energy content used while maintaining robust and efficient routing within the network. Our proposed scheme incorporates the EEAOMDV (Energy-Efficient On Demand Multipath Distance Vector) routing protocol, which builds upon the principles of the traditional AOMDV protocol. EEAOMDV integrates VRT, enabling nodes to dynamically adjust their transmission ranges based on their remaining energy levels. This adaptive mechanism ensures the optimal utilization of energy resources, thereby enhancing overall network performance. A notable feature of EEAOMDV is its capability to improve packet delivery ratios by selectively forwarding data packets along multiple disjoint paths. This feature proves especially valuable in highly mobile and dynamic environments, ensuring reliable communication even in challenging conditions. Through extensive simulations conducted using a network simulator called NS2, we evaluate the performance of EEAOMDV and compare it with the traditional AOMDV protocol. Our results demonstrate that EEAOMDV consistently outperforms AOMDV in terms of packet delivery ratios, energy efficiency, and network longevity. This research contributes to ongoing efforts to maximize energy efficiency and routing in MANETs, addressing the evolving requirements of modern mobile communication systems and promoting sustainability in wireless networking.

Keywords: Mobile ad hoc networks, routing protocols, AOMDV, EEAOMDV, packet delivery ratio, energy consumption, network life

CHAPTER 1
INTRODUCTION

1.1 Background of the study

A Mobile Ad Hoc Networks (MANETs) have gained significant prominence due to their self-configuring, infrastructure-less nature, making them suitable for dynamic and rapidly changing environments. However, among the most pressing challenges in MANETs is efficient energy management, as nodes operate on limited battery power. Prolonging the network's lifetime while ensuring uninterrupted communication is of paramount importance (Marina, K., & Das, 2004),.

In pursuit of enhancing the energy efficiency of MANETs, researchers and engineers have been exploring various routing schemes. Among these schemes, a particularly promising approach is the incorporation of Variable Range Transmission (VRT). VRT is an innovative concept that seeks to optimize energy consumption by dynamically regulating the range of transmission of nodes based on network conditions. This technique can significantly impact the overall performance and longevity of MANETs (Murthy, R., & Manoj, 2004).

In this investigation, we delve into the development and analysis of an improved energy routing scheme for MANETs, with a primary focus on leveraging Variable Range Transmission. We aim to address the energy consumption challenges while simultaneously ensuring the robustness and reliability of communication within the network. This research endeavors to provide valuable insights into the potential benefits of VRT-based routing in MANETs and its role in advancing the state-of-the-art in energy-efficient network design

In the realm of Mobile Ad Hoc Networks (MANETs), routing protocols are essential in establishing efficient communication pathways among mobile nodes. Two widely studied and deployed routing protocols within MANETs are the Ad Hoc On Demand Distance Vector (AODV) and the Ad Hoc On Demand Multipath Distance Vector (AOMDV). These protocols have been instrumental in enabling seamless data exchange among nodes in dynamic and self-configuring network environments.

However, as the demand for MANETs continues to grow across diverse applications, there is an increasing need to improve performance and adaptability of these routing protocols to varying network conditions. One promising avenue for achieving this optimization is the integration of Variable Range Transmission (VRT) techniques.

Variable Range Transmission involves dynamically regulating the transmitting distance of range of nodes based on real-time network parameters and requirements. By implementing VRT within AODV and AOMDV, it becomes possible to fine-tune the routing decisions and adapt to the ever-changing dynamics of mobile ad hoc networks. This, in turn, can lead to improved network efficiency, reduced energy consumption, and enhanced overall network performance.

In this investigation, we start an investigation of the synergistic potential of combining AODV and AOMDV routing protocols with Variable Range Transmission. Our objective is to investigate how VRT can enhance the routing capabilities of AODV and AOMDV in MANETs, with a focus on optimizing route discovery, resource utilization, and overall network robustness. Through empirical analysis and experimentation, we aim to shed light on the benefits and challenges of this integration and provide valuable insights into the future of routing protocols in MANETs.

1.2 Motivation

The Ad hoc networks have the ability to establishing communication and connectivity without relying on pre-existing infrastructure. This makes them highly suitable for scenarios where traditional network infrastructure is absent, damaged, or impractical to deploy, such as in disaster-stricken areas, remote locations, or ad hoc military deployments. Ad hoc networks are highly flexible and adaptive to changing network topologies and node mobility. Nodes can easily join or leave the network, and the network dynamically adjusts to accommodate node movements. This flexibility makes ad hoc networks ideal for mobile applications, vehicular networks, and scenarios where nodes are constantly on the move. Ad hoc networks may be created fast and deployed in situations requiring immediate communication and coordination. They enable on-the-fly network formation, allowing nodes to connect and communicate without requiring manual configuration or pre-planning. This makes ad hoc networks valuable in emergency response scenarios and temporary event setups. Ad hoc networks are able scale effectively, as the addition of new nodes does not require extensive infrastructure upgrades. Nodes inside ad hoc network self-organize and collaborate to maintain network connectivity, allowing the network to grow or shrink dynamically based on the number of participating nodes. This scalability is particularly advantageous in large-scale deployments or dynamic environments. Ad hoc networks exhibit inherent fault tolerance and resilience. Due to the multi-hop nature of communication, if a node or a link fails, alternative routes can be quickly established to maintain connectivity. This fault tolerance ensures robustness and reliability, making ad hoc networks suitable for critical applications where network disruptions can have severe consequences. Ad hoc networks may a cost-effective solution compared to traditional infrastructure-based networks. By eliminating the need for costly infrastructure deployment, ad-hoc networks able to provide communication capabilities in resource-constrained environments. They also minimize reliance on centralized equipment and maintenance, reducing operational costs. Ad hoc networks facilitate collaborative applications where nodes cooperate to perform distributed tasks. Examples include distributed sensing WI-FI sensor networks, cooperative data forwarding, collaborative localization, and collaborative processing. Ad hoc networks enable distributed intelligence and collaborative decision-making among nodes.

1.3 A Description of the Issue

MANETs are formed dynamically by an autonomous system a group of mobile nodes are connected through wireless links without using existing network infrastructure or centralized administration, the purposes of the mobile ad hoc networks are proper utilization of network resources to gain maximum throughput, reduce packet delivery delay and prolonged network lifetime.

The finite amount of battery energy has a significant impact on a mobile node’s lifespan. Since these mobile nodes are getting smaller and smaller every day, it is important to make sure that the limited battery is used as efficiently as possible (Islam, 2014). Developing routing protocols for MANETs has been a challenging task because of its dynamic topology, bandwidth constrained wireless links and resource (David C.Wyld,, Nagamalai,, & Dhinaharan, Jan Zizka, 2012) . the nodes/mobile hosts are dynamic and move around freely on encompassing the area that permits the network to cover the entire region. As mentioned earlier, the nodes rely on their neighbors for multi-hop communications over the spread region. Communication involves data transmission between one-hop and multi-hop neighbors that was accomplished using routing and transmission protocol.

The confronted MANETs weakness was the absence of a central controller and its self-directed character. They have a significant effect on the daily process of node contact and networking. Scaling the nodes in the network was also wearisome because of built-in mobility which causes repeated connection breakage and data loss. The energy resources of actively participating nodes get depleted faster than other nodes, which in some cases, may lead to partitioning of the network, thus decreasing the lifetime of the network. For this reason, reducing energy consumption is a crucial problem in ad hoc wireless networks. Other important questions are: How can a node find an energy-efficient route to the destination? What are the implications of adjusting the transmission powers of data and control packets? How can multiple transmissions take place simultaneously in the same vicinity? We address these questions in the subsequent sections (David C.Wyld,, Nagamalai,, & Dhinaharan, Jan Zizka, 2012) . The three major ways of increasing the life of a node are efficient battery management, transmission power management and system power management. In this paper, a scheme has been proposed to minimize the energy consumption at the nodes, thus maximizing the network lifetime. Transmission power control approach is used to modifying the power levels at node. Common power levels are used during Route Discovery. New power levels are calculated between every pair of nodes based on distance.

1.4 Research Question Base on the problems stated in

The description of the issue section of this research tries to answer the following questions.

1. How to maximize the network lifetime of Ad hoc network?
2. What method adjusts the power levels at node?
3. How to implement the proposed variable range transmission?

1.5 Objective of the Study

General Objective

The primary goal of the study is to design reducing the energy consumption is a wireless ad hoc network by using variable transmission range.

Specific Objective

To reach the general objective; the researcher defines the following specific objectives:

- Review literature and related works in performance improvement of power efficient
- Examine the status of variable transmission range and mechanism,
- Design efficient power algorithm and implement in variable transmission range,
- To simulate, packet delivery ratio, energy consumption, and network lifetime.,
- To analyze and compare default and proposed algorithms.

1.6 Significant of the study

To Extending the lifespan of the network is a significant achievement, especially in scenarios where nodes have limited energy resources. By optimizing energy consumption through variable range transmission, the network can operate for more extended periods without needing frequent battery replacements or recharging, making it more practical for various applications, such as military communications, disaster recovery, or environmental monitoring.

1.7 Contribute

I study's routing scheme may also contribute to improved network reliability. MANETs are often deployed in dynamic and challenging environments where nodes may move, fail, or experience interference. By adapting transmission range based on distance, the routing scheme can potentially reduce packet loss, enhance connectivity, and maintain network stability even in the face of changing conditions.

1.8 Expected outcome of the study

The expected outcome of this study is the improvement of performance in ad hoc networks.
Also, a modified version of power efficiency algorithm will be produced.

1.9 Delimitation scope

Scope

This paper focuses on how to exclude what the size of the proposed EEAOMDV (Energy-Efficient On Demand Multipath Distance Vector) routing protocol extends to the domain of mobile Ad Hoc Networks (MANETs). The protocol aims to enhance packet delivery ratio, reduce energy consumption, and extend the network lifetime in MANETs. It specifically focuses on improving the effectiveness of the existing AOMDV (Ad Hoc On Demand Multipath Distance Vector) protocol by incorporating variable range transmission and power control mechanisms.

The protocol addresses the challenges faced in dynamic and highly mobile environments, where efficient routing is crucial for reliable communication. By dynamically adjusting transmission ranges based on residual energy levels, the protocol optimizes energy utilization and promotes better resource management. It also employs multipath routing to enhance packet delivery ratio and reliability.

1.10 Limitations

Due to some constraints, this study has the following limitations:

- Due to the absence of physical Open Flow devices, this research employs virtual counterparts, namely switches and controllers.
- In this work only implemented the performance of EEAOMDV is evaluated and in contrast to AOMDV protocol.
- This work evaluates packet delivery ratio, energy consumption, and network lifetime.

1.11 Research Method

This section shows how advanced system solutions are designed and implemented and how to analyze research based on previously conducted research and currently available technology. At this stage of the study, all mechanics of every step and procedure will clearly be defined based on the identified problem domain and characteristics. So, in this step, I have demonstrated a method of approach, a flowchart of the design system, the proposed system test and evaluation mechanism, comparison default and the proposed algorithm in action, and defined the tools we used in every step. The tasks mentioned above in the research show some quick steps that I get around to the strategy of this research.

- Collected the relevant resource accurately by analyzing published articles, research papers, a dedicated forum about the problem I identified, and visiting official sites of the technology to look around specifications, methodology, technology stack, conventions, and archetype. After all of these, some available experts and community members the community discussion to discuss the best possible ideas around.
- The crucial primary step was to define the identified problem to be solved clearly.
- After that, I identified the parameters for designing the proposed solution.

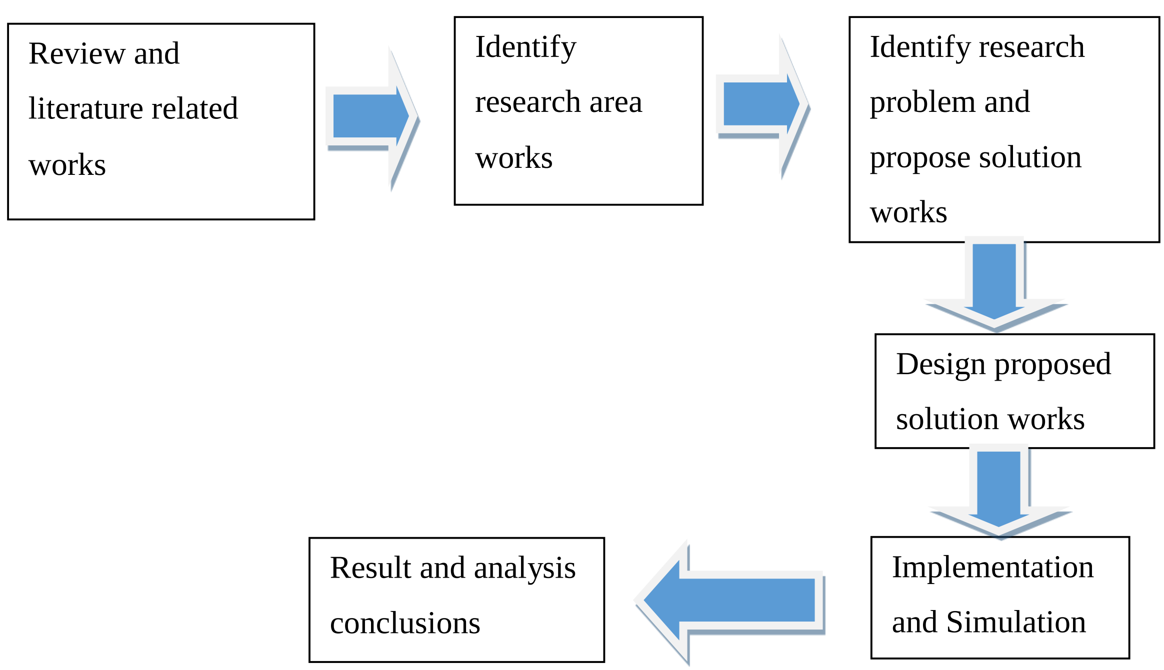

Figure 1: Research Methodology

- Then I implement the proposed solution.

Finally, I prepared for the conduct of the experiment using different mechanisms that suited the problem I identified and documented the result I obtained from the analysis. Analyze the result to check what is wrong or whether the intended task works or not and look in detail at my conclusion for my algorithm. My algorithm may trigger another issue that needs a solution for the future. We clearly show this without any hesitation to fellow researchers and reviewers in an ethical Mannet

CHAPTER 2
LITRATURE REVIEW

2.1 Introduction

The MANET's mobile nodes network are operated on their battery energy and objectives of the routing protocols should include higher data delivery ratio keeping the energy consumption rate at minimum level. The successful packet delivery rate mostly depends on the lifetime of the nodes, in other words on residual energy of the nodes. To make the network more well-located, routing protocol should operate in an efficient way, so that it can avoid early termination of the mobile nodes and expand the network lifespan significantly.

MANET performs the routing function for establishing communication among different nodes. As a result, nodes along these routes tend to "die" soon because of the battery energy exhaustion (M.Malek, K.Dantu, & M.pedram, 2003). With the mobility feature, the nodes can maintain and restructure of the network topology (Latchoumi, T.P. Jayakumar,, latha, p.,, & Janakiraman,s, 2016). Communication involves data transmission between one-hop and a multi-hop neighbor that was accomplished using routing and transmission protocol. The nodes, which encompass a wide region, are dependent on their neighbors for data transmission and receiving (Li, 2018).

2.2 Wireless networks

A Wireless network (S-B. Lee, 2000) can be mentioned to as the interconnection of a network device where the devices in the network communicate to one another with the help of a wireless channel. These wireless nodes have the capability to exchange information with each other either with the help of a wireless infrastructure based or through infrastructure-less. Wireless networks that can easily exchange messages with one other without the use of the underlying infrastructure are referred to infrastructure-less networks. One of the valuable examples of a network with no infrastructure is MANETs.

2.3 Mobile Ad Hoc Networks

With the rapid growth in mobile and telecommunication technology, there is a great augmentation of personal communication devices such as laptops, mobiles and Personal Digital Assistants (PDAs). These devices get easy access to network via wireless interfaces. Unlike in infrastructure network, with a mobile ad hoc network there is no central authority such as gateways/access points which control communication session (C. E. Perkins, 2003). Instead of that in order to exchange information, the members of an ad hoc network by themselves are intelligent enough to relay the packet from originating to ending. Routing decisions on such networks are highly dependent on the channel availability and the nodes within range.

2.3.1 Types of Mobile Wireless Networks

There are three main types of mobile networks as mentioned in (A. Duran and C.-C. Shen ". W., 2004).

- Infrastructure Networks
- Ad-hoc Networks
- Hybrid Networks

A) Infrastructure Network

Mobile ad hoc networks (MANETs) are considered by their infrastructure-less nature, meaning they do not rely on a fixed infrastructure like routers or access points. Instead, MANETs are formed by a gathering of mobile devices or nodes that communicate directly with each other to establish network connectivity and enable data transmission.

In a MANET, each node performs both host and router functions, allowing packets to be forwarded through multiple hops until they reach their intended destination. This multi-hop communication enables nodes to converse with one another even if they are not within direct wireless range.

Figure 2: infrastructure of Network

B) Ad hoc networks

Ad hoc networks are the type of wireless networks without fixed infrastructure. Ad-hoc network types are important for the architecture where the deployment of an infrastructure is either not cost effective or is not feasible. One of the crucial features which make ad hoc network differ from infrastructure is that the functionality normally performed by infrastructure network components, such as routers, switches, and access points can be achieved by the regular nodes which are participating in the network. There is an assumption within ad hoc networks that the nodes which are participating in the networks are mobile and they have limited resources such as energy, bandwidth, storage etc. Routing systems for ad hoc networks there are several design goals and some of the typical design goals (Dmitri A. Moltchanov, 2009) are:

Minimal control overhead: Control messaging consumes processing a resource like bandwidth, and battery power to both transmit and receive a message. Hence, reducing control messaging is also one of the mechanisms which helps to conserve battery power.

Multi-hop routing capability: In ad hoc mobile networks, sender and receiver node may not fall under the same transmission range. Because the range of wireless transmission mobile nodes is often limited. Hence, to make the communication between source and destination, the routing protocol must able multi-hop communication by providing routes between sources and destinations.

Dynamic topology maintenance: Once a route is constructed, it is likely that some link in the route will fail due to the movement of the nodes. For a sender to communicate with a receiver, a viable routing path must be maintained. Since path breakages are common for ad hoc networks, failed link must be maintained quickly with a minimum of associated overhead.

Loop prevention: During the route discover process, when the source node along the path chooses the next hop to the target node is also a node that occurred earlier in the route loops in routing protocol occur. In mobile ad-hoc networks, routing loops significantly wastes resources and are detrimental to the network. Since packet processing and transmission is expensive in terms of energy and bandwidth, the loops must be removed at all times.

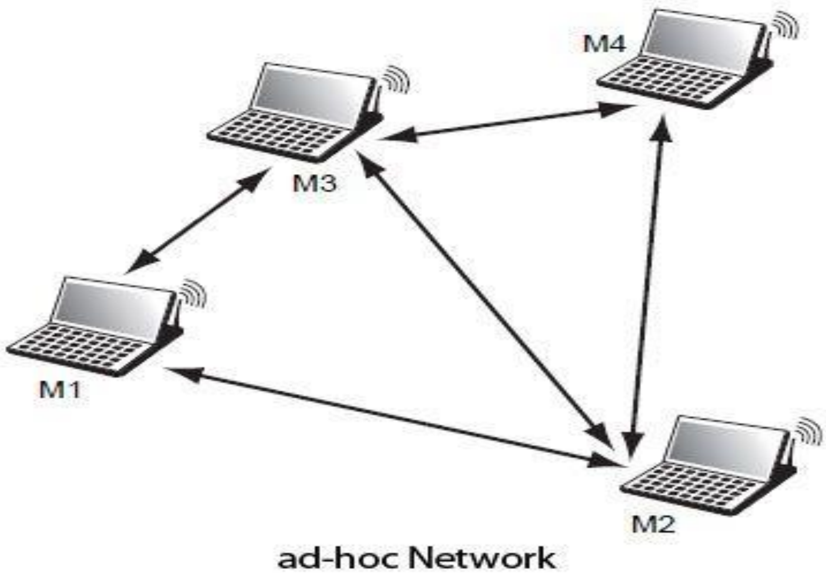

Figure 3: Ad hoc Network

C) Hybrid Networks

Hybrid networks combine a number of different types of networks or network technologies that are integrated to provide enhanced connectivity, coverage, or functionality. Hybrid networks leverage the strengths of each network type to overcome limitations and offer a more robust and versatile communication infrastructure. Hybrid networks offer flexibility, improved coverage, increased reliability, and optimized resource utilization by leveraging the strengths of different network types. The integration of multiple networks or technologies allows for better connectivity and enhanced services, addressing the specific requirements of different deployment scenarios (Dilli, 2011).

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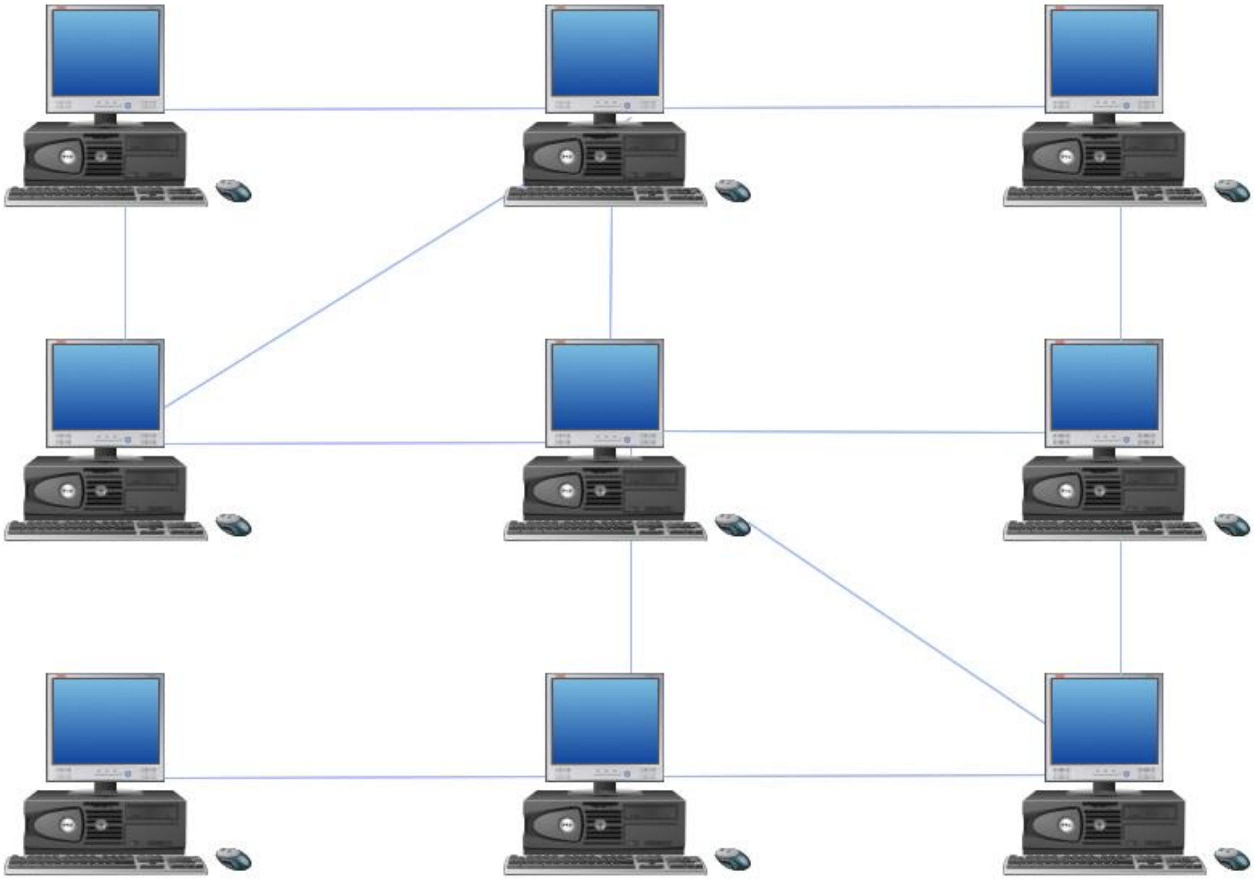

Figure 4: Hybrid Network

2.3.2 Characteristics of a MANET

MANET is characterized by some specific features as mentioned in (S. K. Sarkar, 2007).Mobile ad hoc networks (MANETs) possess several distinctive characteristics that set them apart from traditional wired or infrastructure-based networks. These characteristics arise due to the dynamic and self-configuring nature of MANETs. Here are some key characteristics of MANETs:

Infrastructure-less: MANETs operate without relying on a pre-existing fixed infrastructure such as routers, access points, or centralized servers. Instead, each node in a MANET function as a host as well as router, enabling direct communication between nodes.

Dynamic Topology: MANETs experience frequent changes in network topology due to the mobility of nodes. Nodes can either participate in or withdraw from network, move around, or change their connections, leading to a highly dynamic network structure. MANETs' routing protocols must be adaptable to these topology changes.

Distributed Control: MANETs employ distributed control mechanisms, as there is no central authority or centralized control over the network. Each node participates in the routing process and collaboratively establishes routes with other nodes.

Multi-hop Communication: MANETs support multi-hop communication, where data packets are relayed through multiple intermediate nodes to reach their destination. Since nodes may not be within direct wireless range of each other, multi-hop communication enables end-to-end connectivity.

Limited Resources: Nodes in MANETs often have limited resources, such as processing power, memory, energy (battery life), and bandwidth. Efficient resource management and optimization techniques are essential to prolong network lifetime and maximize resource utilization.

Node Mobility: Nodes in a MANET are mobile and can change their positions independently. This mobility introduces additional challenges, including route disruptions, link instability, and the need for adaptive routing protocols to accommodate node movement.

Self-Configuration: MANETs are self-configuring, meaning nodes can autonomously establish connections and form ad hoc networks on the fly. Nodes utilize discovery mechanisms to identify neighboring nodes and dynamically create communication links.

Scalability: MANETs can scale to accommodate varying numbers of nodes. They can support small-scale networks with a few nodes or large-scale deployments with hundreds or thousands of nodes. The network's routing and control protocols must be scalable to efficiently handle the increasing network size.

Limited Security: MANETs face security challenges due to their open and dynamic nature. Not absence of centralized authority and the lack of physical boundaries make MANETs susceptible to various security threats, including eavesdropping, unauthorized access, routing attacks, and malicious node behavior.

Ad Hoc Connectivity: MANETs are particularly suitable for scenarios where traditional infrastructure is not available or impractical, such as emergency or disaster situations, military operations, remote areas, or temporary deployments. MANETs allow for quick and ad hoc network formation, enabling instant communication and collaboration among nodes

2.3.3 Design Issues

Designing MANET involves addressing several key design issues to ensure efficient and reliable network operation. These design issues include:

Routing Protocol Selection: Selecting suitable routing protocols are crucial for MANETs. The choice depending on variables like network size, node mobility, scalability requirements, resource constraints, and QoS (Quality of Service) considerations.

Mobility Management: Since nodes in MANETs are mobile, mobility management is essential to handle node movements effectively. This includes mechanisms for tracking node positions, updating routing information, handling route failures due to mobility, and minimizing disruption during handoffs.

Energy Efficiency: MANETs often operate with limited energy resources, particularly when it comes to battery-powered nodes. Designing energy-efficient protocols and mechanisms is crucial to extend the network's lifetime. This involves techniques such as node sleep scheduling, power-aware routing, and energy-aware data aggregation.

Quality of Service (QoS): QoS support is essential in MANETs for applications with specific performance requirements. Designing QoS mechanisms involves managing issues such as bandwidth allocation, delay control, reliability, and prioritization of different types of traffic.

Security: MANETs are vulnerable to various security threats due to their dynamic and open nature. Designing robust security mechanisms is essential to protect the network against attacks such as unauthorized access, data tampering, eavesdropping, and routing attacks. This includes authentication, encryption, intrusion detection, and secure routing protocols.

Scalability: MANETs should be scalable to accommodate varying network sizes. The design should consider the ability in order to manage several nodes, efficiently manage routing tables, control overhead, and ensure scalability without compromising performance.

Multicast and Broadcast Support: Supporting communication via multicast and broadcast is important for many applications in MANETs. Designing efficient multicast and broadcast protocols is necessary to minimize overhead, handle node dynamics, and ensure reliable and timely delivery of multicast and broadcast messages.

Quality of Experience (QoE): In addition to QoS, considering the end-user experience is crucial. Designing for QoE involves taking into account factors such as application-specific requirements, user interactions, perceived performance, and user satisfaction.

Network supervision and management: Efficient network management and monitoring mechanisms are needed to detect and resolve network issues, monitor performance metrics, gather network statistics, and provide diagnostics and troubleshooting capabilities.

Interoperability and Interworking: MANETs may need to interoperate with other networks, such as cellular networks or the internet. Designing mechanisms for interworking and seamless integration with other network types is important to ensure connectivity and communication across different network domains.

2.3.4 Applications of MANET

MANET consists of mobile wireless nodes and independent of any pre-existed network infrastructure. Throughout communication, nodes can move anyplace dynamically without any restriction. This non-restricted mobility and easy deployment of nodes makes MANET highly popular and more suitable for real-time application scenarios.

MANETs find applications in various scenarios where traditional wired or infrastructure-based networks are unavailable, impractical, or inadequate. MANETs are particularly well-suited for dynamic and mobile environments, offering self-configuring and decentralized communication capabilities. Here are some common applications of MANETs:

Emergency and Disaster Response: MANETs play a crucial role in emergency and disaster situations where existing communication infrastructure may be damaged or unavailable. First responders and emergency personnel can quickly form ad hoc networks to establish communication and coordinate their efforts in rescue operations, disaster management, and relief efforts.

A Military Action: MANETs are extensively used in a military action where traditional communication infrastructure may be absent or vulnerable to disruption. Ad hoc networks can be set up by military personnel to create reliable and secure communication between soldiers, vehicles, and command posts on the battlefield.

Intelligent Transportation Systems (ITS): MANETs are employed in VANETs (vehicular ad hoc networks) to enable communication and information exchange among vehicles, road infrastructure, and traffic management systems. VANETs facilitate applications such as real-time traffic monitoring, collision avoidance, traffic signal optimization, and vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication.

Remote and Rural Areas: MANETs are deployed in remote or rural areas with limited or no communication infrastructure. They enable connectivity and communication for communities in underserved locations, supporting applications like community networking, telemedicine, rural education, and information dissemination.

Outdoor Events and Gatherings: MANETs are useful for providing temporary network connectivity in outdoor events, festivals, concerts, or sports gatherings. Ad hoc networks can be formed by participants to exchange information, plan activities, and offer public services without the need for conventional infrastructure.

Sensor Networks and Internet of Things (Iota): MANETs are integrated with WSNs (wireless sensor networks) to create dynamic and self-configuring networks of sensors for various applications such as environmental monitoring, smart agriculture, industrial automation, and asset tracking. MANETs enable sensor nodes to communicate and relay data to central processing or monitoring stations.

Mobile Social Networking: Without relying on centralized social media platforms or internet access, people may create ad hoc networks to share resources, trade information, and interact socially thanks to MANETs.

Ad hoc Collaboration and File Sharing: MANETs enable ad hoc collaboration and file sharing among users in close proximity. Users can form temporary networks to collaborate on tasks, share files, and exchange data without requiring an internet connection.

Urban Sensing and Smart Cities: MANETs support urban sensing applications, where mobile devices and sensors collect data about the urban environment, including air quality, noise levels, traffic patterns, and infrastructure monitoring. MANETs enable data aggregation, routing, and transmission for real-time monitoring and analysis in smart city environments.

Mobile Gaming and Entertainment: Application for multiplayer mobile gaming and entertainment are possible with MANETs. For real-time gaming, interactive entertainment, or location-based augmented reality experiences, users can create ad hoc networks.

2.4 MANET Routing Protocols

Routers are among the necessities of networking for delivering information from one host to the other host. Routing algorithm plays an important role in MANET during communication. In MANET all nodes act as routers, servers, hosts and access points. Routing could be a basic operation of the MANET (Dr. Ranjan Bose, 2001). The target of a MANET routing protocol is to support the propagation of knowledge from a sender to any or all the receivers whereas attempting to use the accessible information measure with efficiency within the presence of frequent nodes movement in the network. However, selecting energy efficient routing could be a tough and challenging task. In recent years, numerous routing procedures have implemented for MANETs. Those protocols have distinguishing features and use totally different mechanisms (M. Kumar, 2016) . MANET routing protocols could be broadly classified into three main groups based on the routing information update mechanism. They could be Reactive (On-demand), Proactive (Table-driven) and Hybrid. Those categories of routing protocols will facilitate nodes to determine which way to route packets from the source to the destination in MANET.

2.4.1 Properties of Ad-Hoc Routing Protocols

Different characteristics of ad hoc routing protocols govern their behavior, usefulness and applicability for MANETs (mobile ad hoc networks). These properties help in evaluating and comparing different routing protocols based on specific requirements and network characteristics. Here are some ad hoc routing methods' typical characteristics:

Routing Strategy: Ad hoc routing protocols employ different routing strategies, such as reactive (on-demand), proactive (table-driven), or hybrid approaches. Reactive protocols establish routes on-demand when needed, proactive protocols maintain up-to-date routing information proactively, and hybrid protocols combine aspects reactive as well as proactive strategies.

Route Discovery and Maintenance: Routing protocols make use of methods for route management and discovery. Route discovery involves finding a route from the beginning until the end node, while route maintenance handles the detection and recovery from link or node failures to ensure continuous connectivity.

Routing Metrics: Routing protocols consider various metrics to determine the selection of routes. Metrics can include factors like hop count, link quality, residual energy, bandwidth, delay, congestion, or a combination of these. The choice of metrics depends on the specific requirements of the network and the application being served.

Scalability: Scalability is the capacity for a routing protocol to handle a growing number of nodes and increasing network size without significant degradation in performance. Scalable protocols employ mechanisms to control routing table size, minimize control overhead, and efficiently adapt to changes in network topology.

Mobility Support: MANETs are characterized by node mobility, and routing protocols should be able to handle dynamic topology changes. Protocols need to adapt to node movements, handle route disruptions, and quickly establish new routes when nodes may join or quit the network or when link qualities change due to mobility.

Overhead and Control Traffic: Routing protocols generate control traffic for route discovery, maintenance, and updating routing information. The overhead caused by control traffic should be kept minimal to conserve network resources, especially in networks with limited bandwidth or energy-constrained nodes.

Energy Efficiency: Energy efficiency is crucial in MANETs, where nodes are typically battery-powered and have limited energy resources. Energy-aware routing protocols aim to minimize energy consumption by optimizing route selection, reducing control message exchanges, or employing techniques like sleep scheduling or clustering to conserve energy.

Security: Security is essential in MANETs to protect against various threats, including unauthorized access, data integrity violations, eavesdropping, and malicious attacks. Secure routing protocols incorporate mechanisms for authentication, encryption, integrity checks, and detection of malicious behavior to ensure the integrity and confidentiality of communication.

QoS Support: QoS (Quality of Service) support is important for applications with specific performance requirements, such as real-time multimedia or mission-critical applications. QoS-aware routing protocols consider parameters like bandwidth, delay, jitter, or packet loss to establish routes that meet the required QoS criteria.

Adaptability: Ad hoc routing methods should be able to adapt to shifting network conditions, such as shifting traffic patterns, altering node density, or various network scenarios. Protocols should have the ability to dynamically adjust their behavior to optimize performance, accommodate network dynamics, and handle diverse application requirements.

2.4.2 Types of Routing Protocol

Traditional routing algorithms such as link-state and distance-vector do not scale in large mobile ad-hoc networks. This is due to the possibility that periodic or frequent route modifications in large networks could significantly reduce available bandwidth, intensify channel competition, and necessitate regular node power supply recharges. Several routing methods for MANETs have been developed to address the issues with the link-state and distance-vector algorithms. These ad-hoc router protocols are broken down into different three groups which are, proactive, reactive/on-demand and hybrid protocols (A. Duran and C.-C. Shen, 2004) .

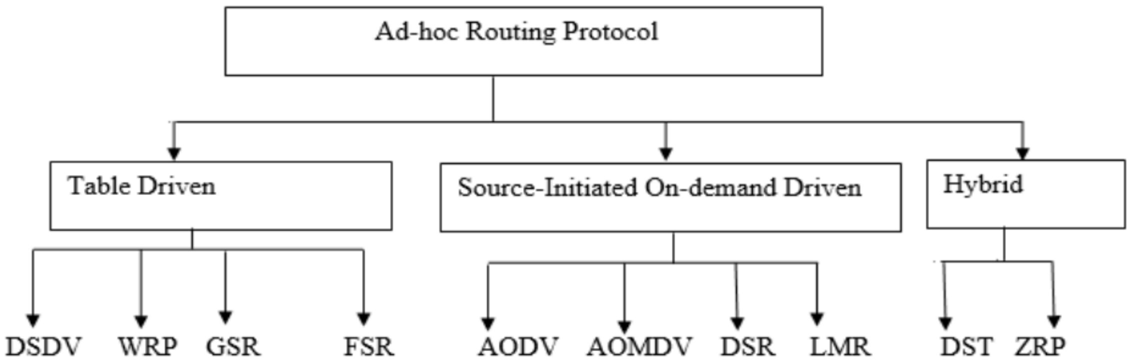

Figure 5: Types of Protocol for Ad Hoc Routing

In proactive protocols, the paths to all of the destination nodes are determined at the start up, and paths can be maintained. This can be achieved by using a periodic route update process. In on-demand protocols, the routes are initiated through the source node only when they are required. This can be achieved by using the path discovery process. The features being proactive and on-demand protocols are integrated into one for hybrid routing protocols. Every set of routing protocols includes a number of different routing techniques, for finding optimal route between source and destination and for routing the packet.

2.4.3 Proactive Routing protocol

These protocols are mostly based on shortest path algorithms. Although the proactive protocols do not have a delay in initial route discovery, they use a lot of bandwidth for recurrent topology changes. The proactive protocols are suitable for supporting a small number of mobile nodes in networks since they must update the node routing database whenever there is a topology change, which adds to the routing overhead (P. Singh, 2012) .There are a number of routing protocols fit under this category (M. Swathi, 2014).

Routing protocols that are proactive, sometimes called table-driven routing protocols, are designed to always maintain up-to-date routing information by continuously exchanging routing updates among network nodes. These protocols are proactive in nature because they proactively calculate and update routing tables, regardless of whether there is an immediate need to send data.

Here are some commonly used proactive routing protocols:

OLSR (Optimized Link State Routing): OLSR is an energetic routing protocol that uses a multipoint relaying (MPR) technique to reduce control message overhead. It creates a network topology, calculates the shortest paths, and distributes routing information to all nodes. OLSR is suitable for MANETs (mobile ad hoc networks) with high mobility and frequent topology changes.

Destination-Sequenced Distance Vector (DSDV): DSDV is a proactive a routing protocol that uses distance vector algorithm. Every node keeps an up-to-date routing table that contains the shortest path to all additional nodes in the network. DSDV uses sequence numbers to identify the freshness of routes also to avoid routing loops. It is suitable for small to medium-sized MANETs with relatively stable topologies.

Wireless Routing Protocol (WRP): proactive routing techniques, such as WRP is designed for wireless networks. It uses a distributed routing algorithm to maintain routing tables at each node. WRP supports both uncast and multicast routing and incorporates mechanisms to handle link failures and topology changes. It is suitable for both small-scale and large-scale wireless networks.

Fish-eye State Routing (FSR): proactive routing techniques, such as FSR that employs the concept of fisheye state routing to reduce control message overhead. The network is divided into multiple zones and exchanges routing information with higher frequency within the local zone and lower frequency in distant zones. FSR provides a scalable solution for MANETs with varying node densities.

Proactive routing protocols are known for their ability to provide faster route convergence and immediate access to up-to-date routing information. However, they may use more resources on the network due to the continuous exchange of routing updates and maintenance of routing tables. Proactive protocols are generally suitable for MANETs with relatively stable topologies, lower mobility, and less resource-constrained environments.

Routing protocols that are proactive, sometimes called table-driven routing protocols, offer several advantages and disadvantages. Let's explore them:

2.4.4 Advantages of Proactive Routing Protocols:

Low latency for data transmission: Proactive protocols maintain up-to-date routing information at all times. This allows for faster route acquisition and reduced latency in data transmission. Nodes have immediate access to precomputed routes, resulting in quicker delivery of packets.

Continuous connectivity: Proactive protocols ensure that routes are always available in the routing tables, even before data transmission is initiated. This continuous connectivity is beneficial for applications requiring real-time or consistent communication, such as voice and video streaming.

Proactive route discovery: As routing information is constantly updated, proactive protocols eliminate the need for on-demand route discovery processes. Routes are already established and readily available, minimizing the delay and overhead associated with reactive route discovery.

Better adaptability to network changes: Proactive protocols can quickly adapt to changes in network topology, such as node additions or removals. The routing tables are continuously updated, allowing nodes to reconfigure routes promptly and efficiently.

2.4.5 Disadvantages of Proactive Routing Protocols:

Increased control overhead: Proactive protocols require regular exchange of routing updates among network nodes to maintain up-to-date routing information. This results in increased control overhead and higher utilization of network resources, including bandwidth and processing power.

Higher storage requirements: Nodes in a proactive protocol need to store and maintain routing tables containing routing information for the entire network. This increases the storage requirements, especially in larger networks, which can be a limitation for resource-constrained devices.

Scalability challenges: Proactive protocols may face scalability challenges in large-scale networks due to the increased control overhead and storage requirements. As the network size grows, the amount of control traffic and memory consumption can become significant, impacting the general effectiveness of the protocol.

Suboptimal routes: Proactive protocols may suffer from suboptimal routing decisions. Routes are precomputed based on available routing information, which may not always reflect the most optimal paths in dynamic network conditions. This can result in inefficient route choices, increased latency, or higher resource utilization.

2.4.6 Reactive routing protocol

Reactive/on-demand routing protocol, the route taking you from source to destination pair is established when needed (on-demand). The path is maintained by a route maintenance process if the route fails after the path is established. Some of the examples are: “ad hoc on-demand distance vector routing” (AODV), “ad hoc on-demand Multipath distance vector routing” (AOMDV) , “dynamic source routing” (DSR) (Dr. Ranjan Bose, 2001), and “Cluster Based Routing protocol” (CBRP) (Jiang, 1999) , etc.

Ad hoc On-Demand Distance Vector (AODV): AODV is a frequently used reactive routing protocol that dynamically establishes routes in response to communication demands. It uses a combination of route discovery and route maintenance mechanisms to find and maintain routes between source and destination nodes. AODV employs sequence numbers to ensure loop-free and up-to-date routing information.

Dynamic Source Routing (DSR): DSR is another popular reactive routing protocol that relies on source routing. It enables source nodes to determine the complete path of a packet by including the list of intermediate nodes in the packet header. Whenever a route is not offered, the source starts the route-finding procedure by broadcasting a route request. Intermediate nodes with the requested route respond with a route reply, allowing the source to establish the desired path.

Temporally Ordered Routing Algorithm (TORA): Reactive routing protocol called TORA that utilizes a distributed algorithm to establish routes. It is designed to handle highly dynamic and rapidly changing network topologies. TORA uses a set of distributed control messages to manage route creation, maintenance, and deletion. It provides multiple routes to handle link failures and offers improved scalability.

Associativity-Based Routing (ABR): Reactive routing protocol ABR that focuses on reducing the overhead associated with route discovery. It utilizes the concept of associativity, where nodes maintain associations with their neighbors. These associations are used by a source node to start a route discovery process when it wishes to transfer data to a destination, which cuts down on the amount of broadcast control packets.

Backup Multipath Routing Protocol (BMPR): BMPR is also a reactive routing protocol that provides multiple backup routes in addition to the primary route. It aims to increase the dependability and tolerance for faults of communication in MANETs. When a route failure occurs, the protocol switches to one of the available backup routes to ensure continuous connectivity.

Each reactive routing protocol has its own advantages, limitations, and suitability for specific MANET scenarios. The choice of protocol depends on factors such as network size, mobility, scalability requirements, resource constraints, and the desired trade-off between control overhead and route establishment delay.

2.4.7 Reactive routing protocols offer several advantages in MANETs:

Reduced control overhead: Reactive protocols minimize control overhead by initiating route discovery processes only when needed. This reduces quantity of routing information exchange and conserves network resources.

Scalability: Reactive protocols are well-suited for large-scale MANETs as they do not require nodes to maintain routing information for the entire network. Routes are established on demand, enabling efficient resource utilization in networks with substantial nodes.

Flexibility in dynamic environments: Reactive protocols can adapt well to changes in network topology and connectivity. They are particularly suitable for networks with highly mobile nodes or frequent topology changes, as routes are dynamically discovered as required.

Support for ad hoc and temporary networks: Reactive protocols are ideal for ad hoc networks that are formed spontaneously or temporarily, such as disaster response scenarios or military operations. They allow nodes to establish routes on-the-fly without requiring prior configuration or setup.

2.4.8 limitations reactive routing protocols

Delay for route establishment: The initial route discovery process in reactive protocols introduces delay for establishing a communication connecting line between source and destination nodes. This delay can be significant, especially in scenarios where frequent route discoveries are needed.

Routing overhead during route discovery: Reactive protocols generate control overhead during the route discovery process. The flooding of RREQ packets can consume network resources, especially in large networks or in scenarios with high mobility.

Limited route availability during congestion: In congested networks with multiple concurrent communication requests, reactive protocols may experience difficulties in finding available routes, resulting in increased delay or failure in establishing routes.

2.4.9 Hierarchical Routing and Clustering

Hierarchical routing and Clustering are two approaches commonly used in MANETs (mobile ad hoc networks) to improve scalability, efficiency, and management of routing operations. Let's explore each concept in more detail:

Clustering: Clustering involves dividing the network into smaller groups or clusters, where each cluster is managed by a designated cluster head. The cluster head is responsible for coordinating the intra-cluster communication and managing the routing within the cluster. Here are some key points about clustering in MANETs:

Cluster Formation: The network nodes autonomously form clusters based on certain criteria such as proximity, connectivity, or specific clustering algorithms. Nodes can join or leave clusters dynamically as the network topology changes.

Cluster Head Selection: Each cluster selects a cluster head, which can be a fixed node or dynamically rotated among cluster members. The cluster head serves as a central point of contact and performs various tasks, such as maintaining cluster information, coordinating routing, and interacting with other cluster heads or the base station.

Inter-Cluster Routing: Cluster heads are responsible for inter-cluster routing, which involves exchanging routing information between clusters and forwarding data packets between different clusters. The cluster heads converse with one another to establish and maintain inter-cluster routes.

Benefits of Clustering: Clustering helps in reducing control overhead, improving network scalability, and enhancing the efficiency of routing operations. It reduces the number of control messages required for routing, optimizes resource utilization, and provides a hierarchical structure for network management.

Hierarchical Routing: Hierarchical routing is an approach where hierarchical organization underlies the network with multiple levels of nodes. The nodes are grouped into different levels based on their roles and responsibilities. Hierarchical routing offers the following features:

Hierarchy Formation: The network nodes are organized into a hierarchical structure, typically consisting of a higher-level backbone or infrastructure nodes and lower-level client or mobile nodes. The hierarchy can be formed based on factors such as node capabilities, power levels, location, or network roles.

Routing Zones: The network is divided into routing zones, where each zone has a zone leader or coordinator responsible for managing the routing within the zone. The zone leaders converse with one another to establish inter-zone routes and coordinate routing operations.

Inter-Zone Routing: Routing information is exchanged between zone leaders to establish inter-zone routes and facilitate communication between nodes in different zones. The hierarchical structure allows for efficient routing between zones and reduces the overall routing overhead.

Scalability and Efficiency: Hierarchical routing improves network scalability by reducing the routing complexity, as routing decisions are made at the zone level instead of individual nodes. It also improves the efficiency of routing operations by minimizing the control message overhead and optimizing the use of network resources.

Both hierarchical routing and clustering provide mechanisms to enhance the performance of routing protocols in MANETs, especially in large-scale networks. They offer scalability, reduced control overhead, improved resource utilization, and better management of routing operations. The choice between hierarchical routing and clustering depends on the specific characteristics of the network, such as mobility patterns, scalability requirements, node capabilities, and the desired trade-offs in terms of control overhead and routing efficiency. Some of the examples of hierarchical ad hoc routing protocols are: “zone routing protocol” (ZRP) (Zygmunt J. Haas, 2002) and “zone- based hierarchical link state” (ZHLS) routing protocol , “Distributed spanning trees based routing protocol” (DST) (M. Joa-Ng and I-Tai Lu, A peer-to-peer zone-based two-level link state routing for mobile ad hoc network, 1999).

2.4.10 Dynamic Routing Protocol

A dynamic routing protocol is a type of routing protocol used in computer networks, including MANETs (mobile ad hoc networks), that dynamically adjusts, and updates routing information based on network changes. Protocols for dynamic routing are intended to adapt to the changing network topology, link availability, and other factors to ensure efficient and reliable routing.

In dynamic routing protocols, network nodes exchange routing information with each other to build and maintain routing tables or databases. These protocols continuously monitor the network and update routing information in response to changes such as link failures, node additions or removals, and changes in network congestion.

There are two types of Dynamic Routing Protocols:

Distance Vector Protocols: Distance vector protocols, such as Routing Information Protocol (RIP) and Interior Gateway Routing Protocol (IGRP), calculate routes based on distance metrics. Every node keeps an up-to-date routing table that includes the distance (metric) to reach each network destination. The routing tables are periodically exchanged among neighboring nodes to update the distance metrics and determine the shortest paths. Distance vector protocols operate on the principle of iterative updates, where each node shares its routing table with its neighbors, and the process repeats until convergence is achieved.

Link State Protocols: Link state protocols, such as Open Shortest Path First (OSPF) and Intermediate System to Intermediate System (IS-IS), rely on the exchange of link state information. In link state protocols, each node collects information about its neighboring nodes, their links, and the overall network topology. This information is then flooded throughout the network, allowing each node to construct a complete and up-to-date map of the network. Using this topology information, link state protocols calculate the shortest paths to destination networks using algorithms like Dijkstra's algorithm.

2.4.11 Advantages of Dynamic Routing Protocols:

Adaptability: Dynamic routing protocols can quickly adapt to network changes, such as link failures or new nodes, by recalculating routes based on updated information. This enables efficient and reliable communication in dynamic environments.

Scalability: Dynamic routing protocols are suitable for large-scale networks as they distribute the routing computation across multiple nodes. They can handle network growth and changes without significant performance degradation.

Fault tolerance: Dynamic routing protocols can automatically detect and recover from link failures or node failures by recalculating routes along alternative paths.

Load balancing: Dynamic routing protocols can distribute network traffic across multiple paths, helping to balance the load and avoid congestion on specific links or nodes.

Disadvantages of Dynamic Routing Protocols:

Control overhead: Dynamic routing protocols require the exchange of routing information, which results in control overhead. The continuous updates and exchanges of routing tables can consume network bandwidth and processing resources.

Convergence time: Dynamic routing protocols need some time to converge and stabilize after network changes occur. During this convergence period, routing information may not be optimal, leading to temporary disruptions in communication.

Complexity: Dynamic routing protocols are generally more complex to configure and manage in contrast to static routing protocols. They require a certain level of expertise and careful configuration to ensure proper operation.

Overall, dynamic routing protocols provide flexibility, adaptability, and fault tolerance in MANETs and other network environments. They are well-suited for networks with changing topology, mobility, and scalability requirements, where efficient and reliable routing is crucial.

2.4.12 Protocols for Multipath Routing in MANET

Protocols for Multipath Routing in MANETs (mobile ad hoc networks) are designed to establish and utilize multiple routes from source to destination nodes. These protocols aim to improve network performance, increase fault tolerance, and optimize resource utilization by distributing traffic across multiple paths. Here are some commonly used Protocols for Multipath Routing in MANETs:

Ad hoc On-Demand Multipath Distance Vector (AOMDV): AOMDV is an extension of the AODV routing protocol that allows for the creation of many routes from source to destination nodes. AOMDV selects and keeps several loop-free paths, which are used to distribute traffic and provide load balancing. It utilizes sequence numbers and route metrics to select the most appropriate paths and avoid routing loops.

Backup Multipath Routing Protocol (BMPR): The reactive routing technique known as BMPQ that establishes multiple backup paths in addition to the primary path. It aims to increase fault tolerance and reliability in MANETs. When a primary path fails, BMPR switches the data transmission to one of the available backup paths, ensuring continuous communication.

Multi-Path Ad hoc On-Demand Distance Vector (MP-AODV): MP-AODV is an extension of the AODV routing protocol that supports multipath routing. It enables the creation of several routes between sources and destinations nodes to provide load balancing and increased reliability. MP-AODV utilizes sequence numbers and hop counts to select and maintain multiple loop-free paths.

Secure Efficient Ad-hoc Distance Vector (SEAD): SEAD is a secure multipath routing protocol designed to provide secure and efficient communication in MANETs. It takes a variety of routes to distribute traffic, enhances security using cryptographic techniques, and ensures loop-free routing. SEAD considers both path length and residual energy of nodes in path selection.

Energy-Aware Multipath Routing Protocol (EAMRP): A multipath routing system called EAMRP takes energy efficiency into account while choosing a path. It aims to extend the network's lifetime by distributing traffic over energy-efficient paths and avoiding nodes with low residual energy. EAMRP takes into account factors for instance, hop count, connection quality and residual energy to select and maintain energy-efficient paths.

Multipath Source Routing Protocol (MSR): MSR is a source routing protocol that allows the origin node of specify multiple paths in the packet header (S. J. Lee and M. Gerla, 2001) . MSR is an extension of the on demand DSR. The source node determines and includes multiple paths in the packet, and intermediate nodes forward the packet along these paths. MSR provides flexibility in path selection and supports load balancing and fault tolerance.

Multipath routing protocols provide several benefits in MANETs, including improved network performance, load balancing, fault tolerance, and efficient resource utilization. They enable data to be transmitted through multiple paths, which can mitigate the effects of link failures, congestion, and node mobility. The choice of multipath routing protocol depends on the specific requirements of the network, such as desired level of fault tolerance, energy efficiency, security, and scalability.

2.4.13 Ad-hoc On-demand Multipath Distance Vector (AODV)

AODV (Ad-hoc On-demand Distance Vector) is a routing protocol designed for MANETs (mobile ad-hoc networks). This protocol responds to events that establishes routes on-demand when needed, rather than maintaining a constant routing table. AODV offers several features and mechanisms to enable efficient and dynamic routing in MANETs. Here are the key aspects of AODV:

Route Discovery: AODV utilizes route discovery to establish routes between a source and destination node. When a source node desire to communicate information to a destination node and has no route information, it starts the route-discovery procedure. A Route Request (RREQ) is broadcasts from the source packet, which propagates through the network until it reaches the final node or an intermediate node on a legitimate path there.

Route Reply and Route Maintenance: When a node receives a RREQ, it checks if the path is legal and leads there. If it does, it returns to the source with a Route Reply (RREP) packet, establishing the route. The RREP returns to the originating node, and intermediate nodes along the path establish reverse routes. Route maintenance mechanisms are employed to monitor the freshness and availability of the established routes. If a link or route fails, a RERR (Route Error) message is generated and propagated to affected nodes to initiate route repairs.

Hop Count: AODV utilizes hop count as a metric to determine the shortest path. Each node maintains the hop count information for its neighbors, allowing it to make informed routing decisions. AODV prefers paths with a lower hop count to minimize latency and reduce quantity of hops traversed.

Route Expiry and Deletion: AODV sets a route expiry timer for each route. If a route is not used within a specified time, it is considered stale and is deleted from the routing table. This mechanism helps keep the routing table updated and avoids the storage of outdated routes.

Sequence Numbers: AODV employs sequence numbers to ensure loop-free routing and to handle changes in network topology. Each node keeps a unique sequence number, and these numbers are used to identify the freshness of route information. Higher sequence numbers indicate more recent route updates.

Route Caching: AODV incorporates route caching to store recently used routes. When a node receives a RREP, it caches the route information for future use. If another node requests the same destination, the route can be directly retrieved from the cache, avoiding the need for route discovery.

AODV offers a balance between control overhead and route availability in MANETs. It minimizes the flooding of control packets by employing sequence numbers and maintaining route information only when needed. AODV is suitable for dynamic and mobile networks, where routes may change frequently due to node movements and link failures.

2.4.14 Ad-hoc On-demand Multipath Distance Vector (AOMDV)

Ad-hoc On-demand Multipath Distance Vector (AOMDV) has several paths protocol that extends the AODV (Ad hoc On-demand Distance Vector) protocol in MANETs (mobile ad-hoc networks). AOMDV enables the creation of many loop-free paths between a source and a destination node, providing benefits such as load balancing, fault tolerance, and improved network performance. Here are some key features and mechanisms of AOMDV:

On-Demand Route Discovery: AOMDV follows an on-demand route discovery mechanism similar to AODV. When a source node desire to communicate information to a destination node, but there isn’t valid route available in its routing table, it starts the route-discovery procedure by broadcasting a RREQ (route request) packet. The RREQ propagates through the network until it reaches the destination or a middle node with a recently-discovered path there.

Multiple Path Establishment: AOMDV permits the development of numerous loop-free routes connecting the source and destination nodes. The protocol keeping a set of disjoint paths by using sequence numbers and hop counts to avoid routing loops. Multiple paths provide load balancing, distribute traffic, and improve network performance.

Path Selection and Maintenance: AOMDV selects the multiple paths based on sequence numbers and hop counts. It chooses the paths using the fewest hops possible and the highest sequence numbers, ensuring loop-freedom and avoiding potential routing loops. Each path is assigned a different identifier to differentiate it from other paths.

Route Metrics: AOMDV considers route metrics, such as hop count, to determine the quality and efficiency of the paths. It prefers paths with shorter hop counts, as they generally have lower latency and consume fewer network resources.

Route Maintenance: AOMDV employs a route maintenance mechanism to monitor the freshness and availability of the established paths. If a path becomes invalid due to link failures or changes in network topology, the protocol triggers a RERR (route error) message to inform the affected nodes. The RERR message initiates a new route discovery process to establish alternative paths.

Route Expiry and Deletion: AOMDV sets a route expiry timer for each path to ensure timely route updates and prevent the storage of stale routes. If a path is not used within a specified time, it is deleted from the routing table.

AOMDV combines the benefits of on-demand routing with the advantages of multipath routing, providing improved performance and reliability in MANETs. It enables load balancing, fault tolerance against link failures, and efficient utilization of network resources. AOMDV is suitable for scenarios where multipath communication is desired, such as multimedia streaming, real-time applications, and networks with high traffic loads.

2.5 Transmission Power Control

In a MANET (Mobile Ad-hoc Network), TPC (Transmission Power Control) refers to the mechanism of regulating the transmitting capacity of wireless devices in order to optimize network performance and energy efficiency. TPC in MANETs takes into account the dynamic and self-organizing nature of the network, where nodes can move, join, either quit the network at any time. The primary goals of TPC in MANETs are as follows:

Power Optimization: TPC aims to optimize the transmission power levels of nodes in order to achieve reliable communication while minimizing energy consumption. By altering the gearbox power in accordance with the distance to neighboring nodes and the desired signal quality, TPC helps in maintaining efficient and low-power communication links within the MANET.

Interference Reduction: TPC plays a crucial role in mitigating interference in MANETs. By dynamically modifying the gearbox power, nodes can avoid unnecessary interference with other nearby nodes. This helps in improving the overall network capacity and reducing the effects of co-channel interference and hidden terminal problems.

Connectivity Maintenance: TPC helps in maintaining connectivity in MANETs, especially in scenarios where nodes may move or change their positions frequently. By varying the transmission power according on the distance between nodes, TPC ensures that nodes within the transmission range can establish and maintain communication links. This is particularly important for maintaining a connected network topology and enabling efficient routing.

Energy Efficiency: TPC in MANETs focuses on optimizing the amount of energy of wireless devices. By varying the gearbox power according to the communication requirements and network conditions, TPC helps in reducing unnecessary energy expenditure. This contributes to prolonging the cellular device battery life, improving network longevity, and enabling nodes to operate for longer durations.

The specific implementation of TPC in MANETs can vary depending on the routing protocol and the network environment. It may involve techniques such as received signal strength estimation, link quality measurements, or signal-to-noise ratio calculations. The TPC algorithm dynamically adjusts the transmission power levels based on these measurements and predefined thresholds to achieve the desired objectives.

Overall, Transmission Power Control in MANETs is an important mechanism for optimizing network performance, minimizing interference, maintaining connectivity, and improving energy efficiency. It helps in adapting the capacity of gearbox nodes to the changing network conditions and enhances the overall functionality and reliability of the MANET. However, if the communication range is limited, more hops are required for packets to arrive at the destination, but there is lower energy consumption per hop (J. Deng, 2004) .

2.5.1 Energy Conservation Approaches

Energy conservation approaches are techniques and strategies employed to minimize energy consumption in various systems, including wireless networks. In relation to MANETs (mobile ad-hoc networks), where energy efficiency is crucial due to limited battery resources, several energy conservation approaches can be adopted. Here are some common approaches:

Sleep Mode: Nodes in a MANET can periodically enter a sleep mode to conserve energy when they are not actively involved in communication. By turning off their radio or switching to a low-power state, nodes can reduce their energy consumption during idle periods.

Power Management: Power management techniques involve optimizing the power usage of network components, such as the radio interface, CPU, and other peripherals. This includes dynamically adjusting the transmission power, reducing processing power during idle times, and selectively activating hardware components as needed.

Duty Cycling: Duty cycling involves periodically turning on and off the radio interface of a node to conserve energy. Nodes switch between the active and sleeping states, enabling them to save energy during periods of inactivity while maintaining connectivity and responsiveness.

Routing Optimization: Efficient routing protocols and algorithms can be employed to find energy-efficient paths for data transmission. These protocols take into account the residual energy levels of nodes when selecting routes, aiming to balance the use of energy and prolong network lifetime.

Data Aggregation: Data aggregation techniques involve consolidating and compressing data packets at intermediate nodes before forwarding them to reduce the number of transmissions. This reduces the overall usage of energy in the network by minimizing redundant data transmissions.

Topology Control: Topology control mechanisms aim to regulate the density and connectivity of nodes in a MANET. Using the gearbox power’s adjustment and optimizing the node placement, topology control techniques can reduce energy consumption, avoid unnecessary node overlap, and improve network efficiency.

Quality of Service (QoS) Adaptation: QoS adaptation techniques dynamically adjust the transmission parameters such as data rate, modulation scheme, and depending on gearbox power network conditions and application requirements. This ensures efficient resource utilization and reduces energy consumption without compromising performance.

Energy Harvesting: Energy harvesting techniques involve capturing and utilizing energy from the environment, such as solar, wind, or kinetic energy, to power the nodes in the network. Energy harvesting mechanisms can supplement the limited battery power and extend the operational lifespan of nodes.

These approaches can be used individually or in combination to optimize energy consumption in MANETs. The choice and effectiveness of specific techniques depend on factors such as network size, mobility, traffic patterns, and application requirements. Energy conservation approaches play a significant part in enhancing the longevity and sustainability of wireless networks, enabling efficient operation and effective utilization of limited energy resources (M. Joa-Ng and I-Tai Lu, 1999) .

2.5.2 Power Control Approaches

Power control (M. Abbas and H. Mohamood, 2011) affects the system's performance level by opting for the lowest power level that can be used in order for an ad-hoc network to remain connected to the network and has been successfully used in mobile networks. It enables ad hoc networks to improve many key aspects, including interference distribution, power consumption, routing, throughput, clustering, connectivity, organization and backbone management (S. Basagni, 2004).

In an ad-hoc networks, the Power control is more important than in cellular networks as the nodes in an ad-hoc network communicate by sending data to neighboring nodes (M. C. Chuah and Q. Zhang, 2006).

The choice of power level is extremely important as it has an indirect impact on the system's physical layer, network layer and transport layer by determining the quality of received signal, transmission range and level of interference [48]. When looking at the concept of controlling power in ad-hoc networks, there are some key terms which must be defined (H. Wu and Y. Pan)[49]:

- The transmit power is "the output power of the signal transmitted by the transceiver of a sender".
- The received power is "the strength of the signal received at the receiver. The received power is typically smaller than the transmit power due to signal attenuation between the sender and the receiver".

• The transmission range is “a distance from a sender within which a node can receive and decode packets correctly. This is a function of the difference in signal attenuation and transmit power between the sender and receiver, and the signal noise around the receiver”.

• The carrier sense range, which is “a distance from a sender within which a node can sense the transmission, i.e., the signal can be received but the packet may not be decoded correctly. The carrier sense range is typically larger than the transmission range.

2.5.3 Effects of low and high transmission power control

The effects of low and high transmission power control in wireless communication systems can have significant impacts on various aspects of network performance. Here are the effects of low and high transmission power control:

Low Transmission Power Control:

Limited Coverage: Low transmission power limits the coverage area of a wireless device. The signal’s intensity is dropping with distance, and devices operating at low power may have a shorter communication range. This can result in reduced network coverage and limited connectivity.

Shorter Range: With low transmission power, the range at which devices can effectively converse with one another is reduced. This can lead to a greater extent of communication failures or packet loss, especially when devices are located far apart or encounter obstacles.

Energy Conservation: Low transmission power consumes less energy, which is beneficial for devices with limited battery resources, such as mobile devices or sensor nodes. By reducing power consumption, devices can prolong their battery life and improve energy efficiency.

Reduced Interference: Lower transmission power can help reduce interference with neighboring devices or networks. With a smaller coverage area, the chances of interfering with other devices operating within the same frequency range decrease, leading to improved overall network performance.

High Transmission Power Control:

Extended Coverage: High transmission power allows for an extended coverage area, enabling devices to communicate over longer distances. This can result in broader network coverage and improved connectivity, especially in large-scale deployments or environments with sparse device density.

Increased Range: With higher transmission power, devices can transmit signals over a greater range. This can help overcome obstacles or attenuating factors in the wireless environment, resulting in improved signal strength and reduced chances of communication failures.

Enhanced Signal Quality: High transmission power can improve signal quality, as it helps to overcome signal attenuation, path loss, and interference. This can lead to higher data rates, better reliability, and improved overall network performance.

Increased Energy Consumption: Transmitting at high power levels consumes more energy, which can impact the cellular device battery life and other energy-constrained devices. It is essential to consider power efficiency and energy conservation techniques to mitigate the impact of increased power consumption.

Potential Interference: Operating at high transmission power can increase the potential for interference with neighboring devices or networks. This can degrade the performance of nearby devices operating within the same frequency range and lead to decreased network capacity and degraded overall performance.

The selection of transmission power control levels depends on various factors, including the network environment, device capabilities, desired coverage, energy constraints, and interference considerations. Optimal power control strategies aim to strike a balance between coverage, signal quality, energy efficiency, and interference management to achieve effective and trustworthy wifi communication.

Low transmission power results in lower energy consumption, thereby extending the network's lifetime. As the density is lower, there is a low overhead in creating routing tables and less interference which, in turn, creates a higher capacity, and there is also a lower packet loss rate. However, as the network is sparse the network connectivity is reduced.

The network distance is larger due to a smaller number of links, and there is a larger amount of hops to the destination. The end-to-end latency is lower with high network loads.

In contrast, high transmission power involves higher energy consumption and a short network lifetime. There is also higher interference, decreasing the capacity and resulting in a higher packet loss rate. The network is dense and network connectivity is increased by adding more links. As there are more routing options, there is a higher overhead in creating routing tables. The network diameter is smaller as there are fewer node degrees, and there are also fewer hops. The end-to-end latency is lower with low network loads; higher loads results in delays due to interference.

2.5.4 Effects of common and variable transmission power

The effects of common and variable transmission power in wireless communication systems can have significant impacts on network performance and energy efficiency. Here are the effects of common and variable transmission power:

Common Transmission Power:

Uniform Signal Strength: Common transmission power implies that all devices in the network operate at the same power level. This results in a uniform signal strength across the network, which simplifies the communication process and reduces the complexity of power control algorithms.

Limited Adaptability: Common transmission power does not take into account the variations in channel conditions or the distances between devices. This lack of adaptability can result in suboptimal performance in terms of signal quality, network coverage, and energy consumption.

Potential Interference: When all devices transmit at the same power level, there is a higher likelihood of interference among neighboring devices or networks operating within the same frequency range. This interference can degrade performance over the whole network and reduce the capacity of the wireless medium.

Variable Transmission Power:

Adaptive Signal Strength: Variable transmission power allows devices to dynamically adjust their power levels based on the channel conditions, distances, and network requirements. This adaptability enables devices to optimize the signal strength according to their communication **needs, leading to improved signal quality and network performance.**

Extended Coverage: With variable transmission power, devices can adjust their power levels to reach devices located farther away. This can expand the region covered of the network and improve connectivity, particularly in scenarios with varying device densities or irregular network topologies.

Energy Efficiency: Variable transmission power enables devices to operate at lower power levels when communicating with nearby devices or when the channel conditions are favorable. This energy-efficient operation can significantly prolong the cellular device battery life and conserve energy in resource-constrained networks.

Interference Mitigation: By dynamically adjusting power levels, variable transmission power can help mitigate interference with neighboring devices or networks. Devices can lower their power levels when there were strong neighboring signals to reduce interference, thereby improving overall network performance and spectral efficiency.

Complex Power Control: Implementing variable transmission power requires more sophisticated power control algorithms and mechanisms. The complexity of determining optimal power levels based on dynamic factors such as channel conditions, distances, and interference can increase the computational overhead and signaling the network's overhead.

The choice between common and variable transmission power depends on factors such as network topology, device mobility, channel conditions, energy constraints, and interference considerations. Variable transmission power provides more adaptability, energy efficiency, and potential for improved performance, but it also requires more sophisticated power control mechanisms. The selection should consider the specific requirements and characteristics of the wireless network to achieve optimal performance and energy efficiency.

2.5.5 Benefits of power control in ad-hoc networks

Transmission power control has some key benefits (S. Misra, 2009): controlling Power in ad-hoc networks offers several benefits that contribute to improved network performance, energy efficiency, and overall system reliability. Here are some of the key benefits of power control in ad-hoc networks:

Signal Quality Improvement: Power control enables devices to adjust their transmission power levels based on the channel conditions, distances, and signal quality requirements. By optimizing the signal strength, power control helps improve the quality of communication links, mitigates signal degradation due to path loss, and reduces the probability of bit errors and packet loss. This leads to higher data rates, enhanced reliability, and improved overall network performance.

Interference Mitigation: Power control allows devices to adjust their power levels to avoid or mitigate interference with neighboring devices or networks. By reducing transmission power when there were strong neighboring signals, power control helps minimize co-channel interference and enhances the spectral efficiency of the network. This leads to improved network capacity, reduced collisions, and better utilization of the wireless medium.

Energy Conservation: Power control techniques aim to optimize the power usage of devices in ad-hoc networks, leading to improved energy efficiency and prolonged network lifetime. By dynamically adjusting depending on the gearbox power the communication requirements and channel conditions, devices can operate at lower power levels when communicating with nearby devices or under favorable channel conditions. This helps conserve battery power and extends the operational lifespan of energy-constrained devices, such as mobile devices or sensor nodes.

Increased Network Capacity: Power control techniques enable devices to adapt their transmission power levels to the specific communication needs and distances. By optimizing power levels, power control reduces unnecessary power consumption and improves spatial reuse of the wireless spectrum. This leads to increased network capacity, as more devices can effectively communicate within the limited available spectrum without causing excessive interference.

Improved Connectivity: Power control plays a crucial role in maintaining connectivity in ad-hoc networks, especially in scenarios with varying distances and dynamic network topologies. By adjusting power levels, devices can compensate for variations in link quality, overcome signal attenuation, and establish reliable communication links. This helps maintain connectivity even in challenging wireless environments and enhances the overall robustness and resilience of the network.

Adaptive Operation: Power control enables devices to adapt their transmission power dynamically, allowing the network to respond to changes in channel conditions, node mobility, or network topology. This adaptability improves the network's ability to handle variations and fluctuations, ensuring efficient and reliable communication in dynamic ad-hoc network environments.

By leveraging power control techniques, ad-hoc networks may achieve better signal quality, reduced interference, improved energy efficiency, increased network capacity, enhanced connectivity, and adaptive operation. These benefits contribute to more robust, efficient, and trustworthy wireless communication in situation involving ad-hoc networks.

2.6 Power Management Approaches

Power management approaches in ad-hoc networks are crucial for optimizing energy usage, extending battery life, and improving overall network efficiency. Here are some power management approaches commonly used in ad-hoc networks:

Sleep Mode: Ad hoc network devices can enter sleep mode during idle periods or when not actively participating in network activities. Sleep mode conserves power by disabling non-essential components or operations while maintaining essential functionalities. Devices can periodically wake up from sleep mode to check for incoming data or participate in network activities.

Dynamic Power Adjustment: Ad hoc network devices can dynamically adjust their transmission power levels based on the communication requirements and network conditions. By optimizing power levels, devices can balance the signal strength and energy consumption, ensuring efficient communication while conserving energy. Power adjustment can be based on factors such as link quality, distance, interference, or network congestion.

Power-Aware Routing Protocols: Power-aware routing protocols consider the energy constraints of nodes when making routing decisions. These protocols take into account the residual energy levels of nodes and strive to balance your energy usage across the network. They route packets through energy-efficient paths and may employ techniques like load balancing or node clustering to distribute energy usage evenly.

Adaptive Power Control: Adaptive power control adjusts the transmission power levels based on the changing network topology and node mobility. Nodes can increase their power levels when they need to reach distant nodes or overcome signal attenuation due to mobility or obstacles. Conversely, they can lower their power levels when communicating with nearby nodes to conserve energy and reduce interference.

Traffic-Aware Power Management: Power management can be tailored based on the traffic characteristics in the ad hoc network. Nodes can adjust their power consumption based on the traffic load, prioritize certain types of traffic, or apply traffic scheduling mechanisms to optimize energy usage. For example, nodes can dynamically adjust their power levels based on the amount of incoming traffic or the urgency of the data being transmitted.

Energy Harvesting: Ad-hoc networks may leverage energy harvesting techniques to capture and utilize ambient energy sources to power network devices. Energy harvesting technologies, such as solar power, wind power, or kinetic energy, can supplement or replace battery power, reducing the dependency on traditional power sources and prolonging network operation.

Collaborative Power Management: Nodes in ad-hoc networks may collaborate and coordinate their power management strategies to optimize overall network performance. This can involve sharing power-related information, balancing energy consumption, and making joint decisions on power control or resource allocation. Collaboration among nodes can lead to better energy utilization and more efficient network operation.

The choice and implementation of power management approaches in ad hoc networks depend on factors such as network size, node capabilities, traffic patterns, energy constraints, and application requirements. Effective power management strategies aim to strike a balance between network performance, energy conservation, and resource utilization to maximize the lifespan and efficiency of the ad hoc network.

2.6.1 Energy Consumption

Energy consumption in ad-hoc wireless network is a critical aspect that directly impacts the network's performance, lifetime, and overall efficiency. Here are some factors that contribute to the amount of energy used by ad-hoc networks:

Transmission and Reception: The transmission and reception of data packets require energy. When nodes transmit data, they need to use power to amplify the signal and send it over the wireless medium. Similarly, when nodes receive data, they consume energy to process and decode the received signal. The energy used in transmission and reception depends on factors such as the distance between nodes, the data rate, and the modulation schemes used.

Routing Overhead: Methods for routing in ad hoc networks generate control packets to establish and maintain network routes. These control packets contribute to additional energy consumption as they are transmitted and processed by nodes. The frequency and size of control packets, Moreover, the routing protocol's efficiency, impact the energy overhead associated with routing operations.

Idle Listening: Ad-hoc network nodes often need to listen to the wireless medium to detect incoming transmissions or network changes. However, this idle listening consumes energy even when no actual data transmission is occurring. Minimizing idle listening time can help decrease the use of energy in the network.

Overhead of Network Maintenance: Ad hoc networks require ongoing network maintenance tasks such as neighbor discovery, route updates, and network synchronization. These tasks involve periodic communication and coordination among nodes, resulting in additional energy consumption. The frequency and efficiency of network maintenance activities impact the overall energy consumption.

Signal Interference and Collisions: Signal interference and collisions can occur in ad-hoc networks, especially when multiple nodes transmit simultaneously or when neighboring networks operate similar frequency range. Interference and collisions lead to retransmissions, increasing energy consumption. Efficient medium access control (MAC) protocols and collision avoidance mechanisms can help mitigate the energy impact of interference and collisions.

Mobility and Node Disconnections: In mobile ad-hoc networks, the movement of nodes can cause frequent topology changes and node disconnections. Nodes need to continuously adapt to these changes, update their routing information, and establish new connections. These dynamic operations consume energy due to the additional signaling and routing overhead involved.

Power Control: Power control mechanisms, such as adaptive transmission power or dynamic power scaling, can help optimize energy consumption using the gearbox power's adjustment levels based on distance, link quality, and network conditions. Efficient power control strategies can reduce unnecessary power consumption and extend node battery life.

Efficient energy management and preservation methods in ad-hoc networks aim to minimize energy consumption while maintaining acceptable performance levels. These techniques involve optimizing transmission power, reducing idle listening, implementing energy-aware routing protocols, and developing energy-efficient MAC protocols. By addressing these energy-consuming factors, ad-hoc networks may achieve improved energy efficiency, extended network lifetime, and enhanced overall network performance.

2.7 Power Aware Routing

Power-aware routing refers to routing procedures and techniques that consider the energy constraints of nodes in ad-hoc networks when making routing decisions. The primary objective of power-aware routing is to optimize energy consumption, prolong network lifetime, and ensure efficient utilization of energy resources.

Power-aware routing protocols take into account the remaining energy levels of nodes and aim to balance energy usage across the network. They strive to avoid routing paths that involve energy-depleted nodes, minimize long-distance transmissions, and promote energy-efficient communication.

Here are some key aspects and techniques commonly employed in power-aware routing:

Energy-Aware Metrics: Power-aware routing protocols use energy-aware metrics to evaluate the energy status of nodes and determine suitable routing paths. These metrics can consider factors such as lingering energy levels, energy consumption rates, or estimated energy needed for transmission.

Route Discovery: During the stage of finding a route, power-aware routing protocols aim to discover energy-efficient paths that consume less energy and avoid energy-depleted nodes. They may employ mechanisms like residual energy-based route selection or prefer routes with intermediate nodes having higher energy levels.

Route Maintenance: Power-aware routing protocols continuously monitor the energy levels of nodes along the established routes and take appropriate actions in case of significant energy depletion or node failures. They can initiate route repairs or route updates to avoid routing through nodes with low energy reserves.

Load Balancing: Power-aware routing protocols may incorporate load balancing techniques to distribute energy consumption across nodes in a balanced manner. This can involve redistributing traffic or rerouting data flows to balance the energy utilization and prevent the exhaustion of energy in a subset of nodes.

Sleep Modes: Power-aware routing protocols can integrate sleep mode mechanisms where nodes enter low-power states during periods of inactivity. This helps conserve energy by lowering the energy usage of idle nodes and extending their battery life.

Energy-Efficient Data Aggregation: Power-aware routing protocols can employ data aggregation techniques to reduce the amount of data transmission and minimize energy consumption. By aggregating data at intermediate nodes, redundant transmissions can be eliminated, leading to energy savings.

Energy-Aware Network Partitioning: In some cases, power-aware routing protocols may partition the network into clusters or sub-networks to optimize energy usage. Each cluster can have a cluster head responsible for coordinating the routing within the cluster and aggregating data. This hierarchical approach reduces energy consumption by limiting long-distance transmissions.

Power-conscious routing techniques aim to adapt to the dynamic energy conditions in ad-hoc networks and ensure efficient energy management. By considering energy constraints in the routing process, these protocols help extend network lifetime, improve overall network performance, and enhance the energy efficiency of ad-hoc networks (H. Huang, 2010) (R. Ramanathan and R. Rosales-Hain, 200)

2.8 Related Work

In the preceding chapters, we delved into the myriad challenges that MANETs (Mobile Ad-Hoc Networks) grapple with, encompassing bandwidth constraints, energy limitations, security concerns, and the ever-fluctuating network topology. To surmount these challenges, countless researchers have devoted extensive efforts to devise routing mechanisms that can bestow QoS (Quality of Service) upon network users.

Routing, being the cornerstone of network communication, assumes paramount importance in relation to MANETs. Nevertheless, it is an intricate endeavor due to the highly dynamic and decentralized nature of these networks. Notably, energy-efficient routing emerges as a pivotal design criterion for MANETs, given that mobile nodes predominantly rely on battery power, which is inherently constrained.

In the realm of MANETs, various methodologies have been explored to maximize network lifetime and augment energy efficiency. Diverse researchers have adopted a range of metrics or parameters to achieve energy-efficient communication, encompassing node energy consumption, residual energy levels, traffic density, and node locations. These parameters serve as pivotal factors in optimizing energy-efficient communication strategies within MANETs.

Numerous routing algorithms have been harnessed to extend the longevity of links and, consequently, the battery life of individual nodes. Routing metrics are instrumental in facilitating the selection of the most resilient and energy-efficient routes for communication. It is crucial to acknowledge that each routing protocol carries its own set of advantages and limitations.

In this section, we catalog a selection of energy-efficient schemes meticulously crafted by researchers in the field. These schemes have been meticulously designed to navigate the constraints imposed by battery power limitations. However, it is imperative to recognize that no single solution is universally ideal. Rather, each scheme bears have particular advantages and weaknesses, and the choice of which to employ hinges upon the specific demands and characteristics of the MANET in question.

Trivedi, Nayak and Mohan (Trivedi V. , Nayak, Padhan , & Mohan, 2021) introduced a GPS-Aided AODV routing protocol that enhances the traditional AODV routing by incorporating GPS-equipped nodes. This modification involves the integration of GPS-derived information into route requests, route replies, and routing tables.

While this algorithm excels in reducing overhead and route discovery time, it comes with a drawback: it leads to increased energy consumption within the network. This heightened energy usage ultimately shortens the overall network lifetime.

Veena Trivedi et al. (Trivedi V. , Nayak, Padhan, & Mohan, 2021),presented a genetic algorithm upgrade to AODV routing to identify the shortest path between sources and destinations. The direction algorithms for moving nodes is very complex, as the path size is increased the header size of data packet is also increased, in this paper this issue is solved by genetic algorithms but here no information is discussed about node energy and link load.

In a research project by Rashid and Ras (Rashid & Ras, 2020), they proposed a congestion avoidance technique for network management. This approach involves utilizing the backpropagation algorithm to compute congestion changes on every node within the network. Subsequently, the node with the lowest probability of congestion is chosen to establish the path from one place to another. this methodology is commonly referred to as Congestion Control AODV (CCAODV). Its primary objective is to prevent link disruptions within the MANET (Mobile Ad Hoc Network). Additionally, it incorporates incoming signal strength as a cross-layer design parameter. It's crucial to remember this approach does not take energy consumption into account.

Hosam El-Ocla, in a paper dated (El-Ocla, 2020), suggested a Multiple Routing system for Mobile Ad-Hoc Networks using a genetic algorithm. This protocol was compared to AOMDV (Ad-Hoc On-Demand Multipath Distance Vector) and another routing protocol called AOMDV-FFn that incorporates genetic algorithms (AOMDV-GA).

These protocols aim to optimize the method of choosing the route by maximizing fitness values, which consider factors such as route length, remaining energy, and minimizing data traffic, even when there was random data packet loss. In this context, a mechanism is introduced to enhance TCP Congestion Control for Random Loss (TCP CERL) within the FFn (presumably a component of AOMDV-FFn) to further optimize efficient routes.

Mohammad Nabati1 & Mohsen Maadani2 & Mohammad Ali Pourmina (Nabati1 , Maadani2, & Ali Pourmina1, 2021) a novel heterogeneous MANET routing protocol called “learning Automata and Genetic based Ad hoc On-Demand Distance Vector” (AGEN-AODV) is proposed . It uses the genetic algorithm to select the optimal route with a fitness function based on the traffic rate, stability, energy, and hope count metrics. AGEN-AODV introduces increased complexity due to its energy-awar. It may demand more resources, rendering it less suitable for nodes with limited processing capabilities or constrained resources features, potentially resulting in higher computational overhead and control message complexity.

Zhihui Lin; Jie Sun (Lin, Jie, & Sun, 2021) is proposed Based on Routing Protocol Link Stability in MANET, multi-path routing protocol focuses on achieving link stability using wireless networks considering factors such as mobility patterns and queue lengths. It aims to strike a balance between distance and routing lifetime but acknowledges that the use of multiple paths can lead to increased energy consumption due to frequent path changes. This research likely contributes to the field of wireless ad-hoc routing protocols or sensor networks, where link stability and energy efficiency are important considerations.

(Balasubramanie & Babu, 2020) the study explores a hybrid optimization approach that combines the 2-Opt algorithm, the ABC algorithm, and fuzzy rule-based node classification to select optimal paths inside a network. The goal is to improve the packet delivery rate and the detection of malicious nodes. However, the results suggest that the hybrid approach only offers limited improvements compared to using the ABC algorithm alone for rule selection. This research contributes to the field of network optimization and routing algorithms, particularly in relation to addressing end-to-end delay and malicious node detection in network communication.

(Al-Essa & Al-Suhai, 2022) this research has focused on the design and development of the MARA (Mobility-Aware Routing Algorithm) for MANETs (Mobile Ad Hoc Networks). MARA leverages mobile node decisions to make informed choices regarding the rebroadcasting or discarding of received broadcasted messages. Key parameters considered in this algorithm include the distance between nodes, residual energy levels of the nodes, and node speed. These factors are taken into account during both the route request and route reply processes to reduce the likelihood of link breakages and improve overall network performance.

Table 1: An Overview of Related Works

Authors and year of pub.	Title	Route selection & achievement	Limitation
Trivedi, Nayak, padhan & Mohan (2021)	Use of Genetic Algorithms to improve the performance of the AODV routing protocol for MANET.	The quickest path between sources and destinations	No consider node energy and link nod
Rashid, Mamoon; Ras, Dr Sachin Kumar Gupta and Aabid (2020)	An Innovative Congestion control Model for MANET's quality of service	calculates changes of congestion on each node in network	There is no consider residual energy
Hosam El-Ocl (2020)	Utilizing a genetic algorithm for multipath routing in Mobile Ad-Hoc Networks	efficient routes and find multiple routes from originating to ending	residual energy for long distance loss
Mohammad Nabati1 & Mohsen Maadani2 & Mohammad Ali Pourmina 2021	AGEN-AODV: an Intelligent Energy-Aware Routing Protocol for Heterogeneous Mobile Ad-Hoc Networks	It uses the genetic algorithm to select the optimal route with a fitness function based on the traffic rate, stability, energy, and hop-count	higher computational overhead and control message complexity
Zhihui Lin; Jie Sun (2021)	Using a link stability-based routing protocol	link stability in wireless networks and load balance	increased energy consumption due to frequent path changes
R. Logesh Babu &	Hybrid Artificial Bee Colony with 2-Opt Algorithm for Fuzzy	improves packet delivery rate and the	No conceder energy

P. Balasubramanie (2020)	Rule Selection in MANET	detection of malicious nodes	
(Al-Essa & Al-Suhai, 2022)	Mobility and Transmission Power of the MANET AODV Routing Protocol	These factors are taken into account during both the routing requests and responses processes to reduce the likelihood of link breakages	There is same overhead .

CHAPTER 3
MATERIAL AND METHOD

3.1 Introduction

This part will go over the organizing process, simulation, analysis, and comparison of the tools I looked at. In order to decide which methodology to use for my preferred technique, I examined the historical overview and looked for the best-fit technology. I now have the best option and flexibility for design and development plan thanks to this. During the preliminary research stage, I reviewed the manuscript and identified the gap to gather pertinent information using the scientific research review technique. I gather information from a variety of sources in order to become well-versed. I used a quantitative research methodology and an inductive technique in my study. I usually heavily stress the current use case to work with this already completed study. Our research also includes a number of use cases. In this step, the main source of our use cases is a critical assessment of a scientific work. A different data source is employed in addition to the paper review.

3.2 Proposed Method

Due to the restricted energy resources that define Ad-Hoc Networks for Mobile, energy-efficient routing is crucial for increasing network lifetime. In order to reduce energy consumption during route establishment and maintenance, this research offers a modified AOMDV(EEAOMDV) protocol and compares it to the traditional AOMDV.

Variable Range Transmission in AOMDV:

The idea of variable range transmission, in which each node varies its transmission range on the basis on its degree of remaining energy. A predetermined energy threshold or calculation based on energy is used by the node to determine its transmission range. For instance, a transmission range may be larger or narrower depending on the residual energy level, with a higher residual energy level often corresponding to a larger transmission range.

Nodes with higher energy levels can communicate across greater distances thanks to the variable range transmission, whereas nodes with lower energy levels must limit their transmissions in order to save energy.

Modification in Route Discovery:

The method of discovering routes in AOMDV is modified to consider the variable range transmission.

Each time a source node initiates a route discovery, it includes its current transmission range information in the request packet. Intermediate nodes receiving the request packet check if their residual energy level allows them to forward the packet within the specified transmission range.

Nodes with insufficient energy to support the transmission range drop the request packet, reducing the routing overhead and conserving energy. Only nodes within the feasible transmission range participate in the route-finding process, leading to efficient route establishment.

Route Selection:

The route selection process remains similar to AOMDV, where multiple loop-free paths are discovered and maintained. However, the variable range transmission enables the selection of paths based on the residual energy of the nodes along the routes.

Paths with nodes having higher residual energy are preferred over paths with nodes having lower residual energy. This ensures that routes are selected based on both energy efficiency and the remaining energy capacity of the participating nodes.

Energy-Aware Route Updates:

Nodes periodically exchange control packets to update their neighbors about their energy levels. When a node receives an energy update from a neighbor, it alters the routing table to consider the energy-aware information during route selection.

End-to-End Communication:

The destination node receives the data packets and acknowledges their successful delivery towards the source node. If a packet is lost or not acknowledged within a certain timeout, the source node retransmits the packet.

3.2.1 Propose Modify AOMDV (EEAOMDV)

Normally, when a source node broadcasts an RREQ, more than one route will be discovered, and the data packets will be passed through these routes without knowing the quality of the routes. Only when necessary does the AOMDV routing protocol find the paths from the source to the destination node (on-demand). The AOMDV routing protocol carries out two operations to route the packet from source to destination. These two processes are route discovery and route maintenance. AOMDV uses hello messages to know its neighbors and to ensure symmetric links. At the time of route discovery of AOMDV routing protocol, Source node initiate route discovery process. When intermediate node receives a Route Request control message two casesare involved. The Route Request control packet is forwarded to the destination node if the intermediate node lacks a valid path to the destination. The intermediate node returns the RREP control packets in the absence of a valid route. If the RREQ message is received at intermediate nodes more than once during route discovery methods, the duplicate copies are eliminated. By employing the Broadcast id-Source-id, this is possible. The AOMDV protocol determines the best path by counting the number of hops and subsequent hops to each destination. The AOMDV routing protocol accepts several alternative paths to the target node, ensuring loop-free routes. The list of upcoming hops and the announced hop count are reset when the path advertisement for a destination node is received. Each intermediate node discards duplicate RREQs, and each RREQ coming through a different neighbor to the source establishes a node-disjoint path, in order to find node disjoint paths. Any two RREQs in the AOMDV routing protocol control messages that arrive at the destination node via a different neighbor node.The destination node only responds to RREQs control packets that enter through various neighbor nodes in order to obtain several link-disjoint pathways. AOMDV has the benefit of allowing intermediary nodes to respond to route requests while still selecting disjoint routes. The destination node acknowledges numerous RREQ control messages, though, as it is a multipath routing protocol. It does not take into account the energy required to choose a path. In order to enhance the lifespan of networks, the proposed protocol here takes both residual energy and node transmission power into account while choosing paths.

Every node that receives RREQ packets chooses whether to take part in the broadcasting of RREQ packets depending on the two metrics, namely required energy and residual energy, as indicated in the flowchart in figure 6. The optimal path can be chosen by calculating the route cost factor for each potential path after the route has been discovered. The path with the lowest route cost function can then be selected. The initial source node checks its routing table to see if there is a valid route in it before sending data in the proposed EE-MAODV protocol for multipath route selection. Otherwise, it starts the route discovery process if it doesn't have a valid route in its route table. Here, we use an energy-efficient routing algorithm to choose the optimum path without experiencing link breakage because of low power. Every time a source node broadcasts an RREQ message to one of its neighbors, it first determines the amount of energy needed to travel there and compares it to the node's remaining energy. If a node's residual energy is more than its needed energy, an RREQ message will be broadcast. Then verify whether or not the node receiving RREQ is the destination node. If not, the node transmits RREQ to its neighbors in the same manner as in the earlier steps. following the destinationOtherwise, it starts the route discovery process if it doesn't have a valid route in its route table. Here, we use an energy-efficient routing algorithm to choose the optimum path without experiencing link breakage because of low power. Every time a source node broadcasts an RREQ message to one of its neighbors, it first determines the amount of energy needed to travel there and compares it to the node's remaining energy. If a node's residual energy is more than its needed energy, an RREQ message will be broadcast. Then verify whether or not the node receiving RREQ is the destination node. If not, the node transmits RREQ to its neighbors in the same manner as in the earlier steps. following the destinationOtherwise, it starts the route discovery process if it doesn't have a valid route in its route table. Here, we use an energy-efficient routing algorithm to choose the optimum path without experiencing link breakage because of low power. Every time a source node broadcasts an RREQ message to one of its neighbors, it first determines the amount of energy needed to travel there and compares it to the node's remaining energy. If a node's residual energy is more than its needed energy, an RREQ message will be broadcast. Then verify whether or not the node receiving RREQ is the destination node. If not, the node transmits RREQ to its neighbors in the same manner as in the earlier steps. following the destinationnode receives RREQ it replies RREP towards the source node using nodes that broadcast RREQ. Then the source node calculates route cost factor for every path and orders the path based on their route cost function value. And select the three best possible paths that have less route cost function value than others. The RREP packet will then be transmitted by the destination node through the chosen pathways to the source node. Finally, source nodes take the first best possible path as the main path and store the left two path on its route table as an alternative path and send the data through the first path to the destination node.

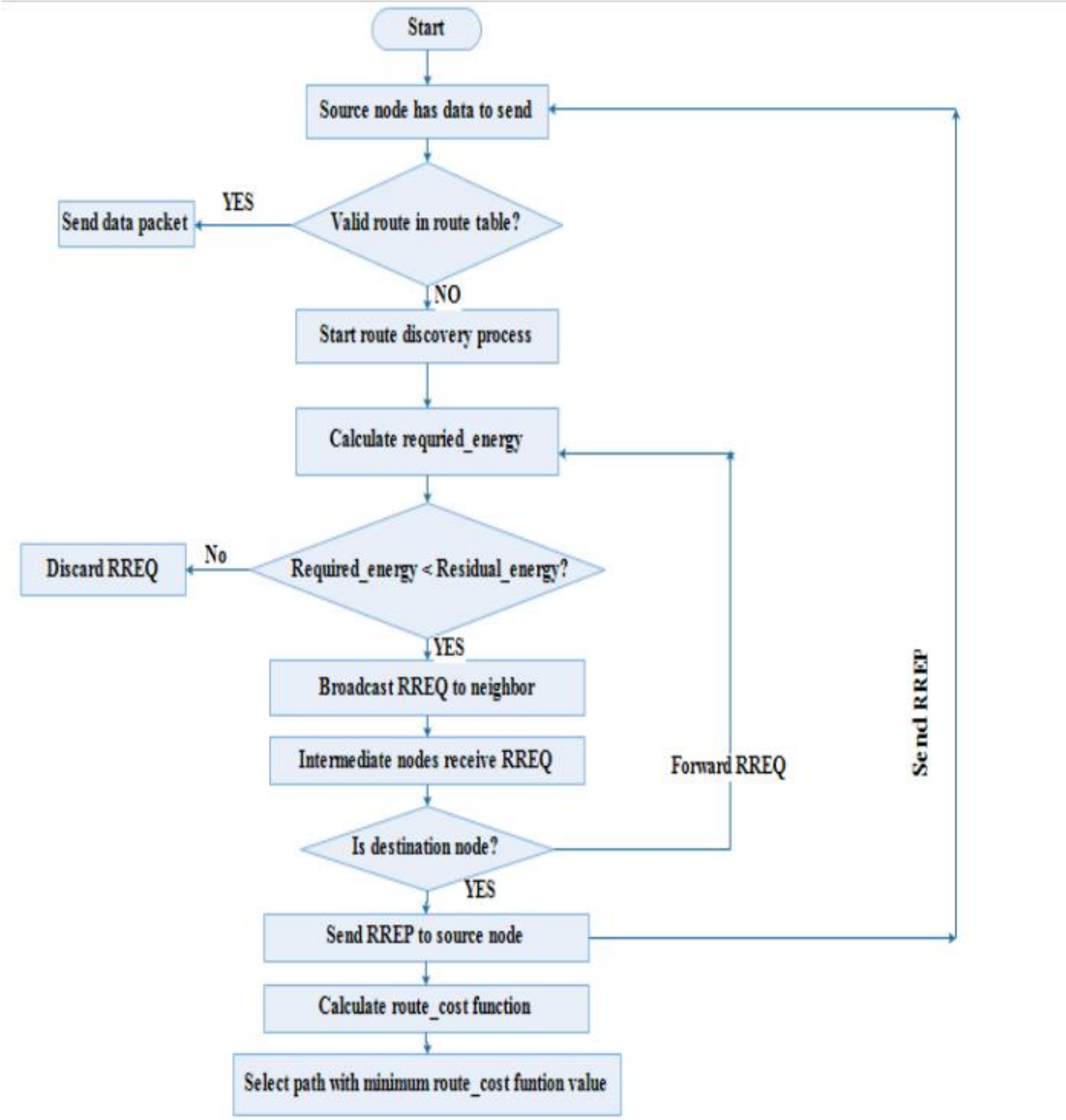

Figure 6: Flow Chart

3.3 Description of fundamental energy parameters

The proposed EE-AODMV protocol uses three parameters to discover and select an energy efficient path from the source to the destination. Specifically required energy, residual energy, and route cost function. In the following section, we will discuss in detail how each parameter is used one by one.

To incorporate residual energy considerations in the for variable-range transmission with respect to residual energy, you can modify the existing formulas by introducing a factor that represents the residual energy level. Here's an example of how the formulas can be adjusted:

Energy for Variable-Range Transmission:

The required energy for variable-range transmission can be estimated using the following modified formula:

Energy transmission = Eelec * n * L * E_residual * (d / R) ^2 where:

The energy needed to operate the transmitter or receiver circuitry for each bit is known as elec.

n is the number of bits being transmitted.

L is the number of hops or packets required to reach the destination.

E_residual is a factor representing the residual energy level of the transmitting node.

d is the distance between the transmitting and receiving nodes.

R is the maximum transmission range of the node.

The formula incorporates the residual energy factor (E_residual) and also adjusts the energy based on the ratio of the actual distance (d) to the maximum transmission range (R). This adjustment accounts for the energy dissipation that occurs when transmitting over longer distances.

It's crucial to remember that this formula is a simplified representation and that actual energy consumption during variable-range transmission can be affected by various factors, including the wireless channel conditions, transmission power control, fading effects, and modulation schemes. Therefore, a more accurate energy model may require considering additional parameters and incorporating specific wireless channel characteristics relevant to the network scenario.

Additionally, the residual energy factor (E residual) can be determined based on the energy model used in the network simulation or measurement data from the actual hardware implementation. The value of (E residual) can vary over time as the node consumes energy, and it should be periodically updated to reflect the remaining energy level accurately.

Required energy: - refers to the quantity of energy needed to perform a specific task or operation in a system. In the context using wireless ad-hoc networks, the required energy can vary depending on the nature of the task or operation being performed by the network nodes. Some examples of required energy in different scenarios are: It's crucial to remember that the required energy can vary significantly depending on the specific network protocol, algorithm, and implementation details. Optimizing the utilization of required energy is a fundamental aspect of energy-aware design and resource management in ad-hoc wireless networks.

Residual energy: - refers to the remaining energy level of a node or device in a wireless network. It represents the energy content that is still available for performing network operations, such as transmitting and receiving data or participating in routing protocols.

Nodes in a network can periodically update and exchange information about their residual energy levels. This information can be utilized by various algorithms and protocols to make energy-aware decisions, such as route selection, load balancing, or power management. Considering residual energy enables the network to dynamically adapt its operations and optimize energy consumption, thus improving network performance and extending the network's overall lifetime.

3.4 Proposed EEAOMDV Algorithm

The basic task of the proposed algorithm is to discover and select an energy efficient multiple paths and choose one path for data packet transmission and take others as a reserve when RERR occur to immediately recover from error to increase energy efficiency. Hence, the principal steps EE AOMDV that is being proposed algorithm are compute (a) required energy of each node, (b) residual energy of each node, (c) calculate route cost function, finally (d) selection of the best possible paths.

1. Establishing the route between the source and the destination.

2. Every node along the route computes its required energy to reach the next node in the path when it receives RREQ message before it broadcast RREQ packet to its neighbor node. A node calculates the required energy to reach its neighbor based on the number of packets to be transmitted, and the energy required to transmit a single packet. A node U computes the required energy to reach the next-hop node V on the path as follows:

$$Required\ energy= (N * ETx)$$

N= number of packets to be transmitted

ETx = energy required to transmit

3. Every node along the route computes its residual energy (RE). By using the following equation:

- Residual energy=E Initial-Energy consumed

Energy consumed(i) =E r(ni) +E S(ni) +E f(ni)

Where RE is residual energy, Eci for energy consumed, E initial for initial energy, Er for energy consumed for receiving, Es energy consumed for sending, Ef energy consumed for forwarding.

4. Every node checks its (Residual-energy and required energy).
5. If (Residual-energy > Required-energy)
6. Broadcast RREQ to its neighbor until it reaches the destination node.
7. The Destination node will respond to the source node's RREP in the opposite sequence.
8. If multiple paths have fulfilled the condition, then calculate route cost function of the path.
9. Select paths those have minimum route cost function value

3.4.1 Proposed Route discovery algorithm for Improved AOMDV

To propose a route discovery algorithm for the improved AOMDV (Ad hoc On-Demand Multipath Distance Vector) protocol with residual energy considerations, you can incorporate energy-aware mechanisms into the existing AOMDV route discovery process. Here's a high-level outline of the algorithm:

Route Request (RREQ) Phase: While establishing a route from a source node to a destination node and include the residual energy level of the source node in the RREQ packet. Broadcast the RREQ packet to the neighboring nodes, Intermediate nodes receiving the RREQ check their residual energy levels and forward the RREQ packet if the residual energy is above a threshold, else drop the packet.

Route Reply (RREP) Phase:

Upon receiving the RREQ packet, the destination node generates a RREP (Route Reply) packet:

Include the residual energy level of the destination node in the RREP packet.

Unicast the RREP packet returning to the original node.

Intermediate nodes receiving the RREP update their routing tables with the information from the RREP packet.

Route Selection: The source node receives multiple RREP packets and evaluates the received RREPs based on metrics like hop count, residual energy, link quality, etc. Assign a weight to each metric based on network requirements and preferences and calculate a composite metric score for each RREP using the assigned weights, Select the highest-scoring RREP as the primary route and consider additional RREPs with reasonably close scores as backup routes.

Multipath Establishment: If multiple routes are selected, establish and maintain multiple paths between the source and destination nodes. Update the routing tables to include all selected routes and their corresponding residual energy levels.

Route Maintenance: Periodically monitor the residual energy levels of the active routes. If a route's residual energy falls below a threshold or becomes unusable then initiate a route repair process by sending a Route Error (RERR) packet.

Update the routing tables accordingly until trigger the route-finding procedure again to find alternative paths.

Energy-Constrained Route Discovery: During the route discovery process, consider the residual energy levels of intermediate nodes. Nodes with lower residual energy may prioritize routes with higher residual energy while forwarding RREQ packets. This ensures that energy-constrained nodes avoid heavy routing responsibilities.

Energy-Aware Path Load Balancing: Distribute traffic across multiple paths based on their residual energy levels. Avoid overloading paths or nodes with critically low energy levels.

These proposed modifications enhance the AOMDV route discovery algorithm by incorporating residual energy considerations. The specific implementation details, such as the exact metrics used, energy thresholds, and weights assigned, will depend on the energy model, network characteristics, and optimization goals of the improved AOMDV protocol.

The key idea of this protocol is to ignore nodes with less battery power in order to exclude them from participating in route establishment and to find the path with nodal residual energy a route discovery process. Once a new route with highest lifetime, it is reselected to forward rest data packets.

To achieve the proposed goal: the first step is finding all possible number of paths by applying threshold value-based scheme and the second step is applying residual energy and maximum average bandwidth-based scheme for selecting the efficient path from multiple alternative paths. In this algorithm, nodes have information of their neighbor nodes such as the position neighboring nodes, and ID of neighbor nodes. The route-finding procedure starts whenever the sources node desires to transmit data to the destination node. First, it takes information from their table to calculate nodes required energy before they broadcast route request packet to their neighbor node. Nodes will broadcast RREQ to their neighbor node if the required energy of a node to reach the next node in the path is less than its residual energy. Otherwise, RREQ packet will be discarded. The destination node will return the RREP (route reply) pack to source nodes through the path that through the path that broadcasts the RREQ packet.

Modify AOMDV(EEAOMDV)

```
# Variable Initialization
set infinity
set energyThreshold 0.3  ; Energy threshold for transmission range adjustment
set initialRange 150     ; Initial transmission range
set maxRange 200         ; Maximum transmission range
# Node Initialization
for {set i 0} {$i < $val(nn)} {incr i} {
   $ns_ node-config -energyModel "EnergyModel" \
                -initialEnergy 100 \
                -idlePower 0.01 \
                -txPower 0.02 \
                -rxPower 0.02 \
                -sleepPower 0.001
}
# Route Discovery
proc RouteDiscovery {src dst} {
   global ns_ energyThreshold initialRange maxRange
   set node $src
   set range $initialRange
   # Check if the source node has enough energy to initiate the route discovery
   if {[$node energy] >= $energyThreshold} {
```

```
        $node set radius $range
        $node send [NewAgent/TCP] $range
        $node advance 1
    } else {
        puts "Source node does not have enough energy for route discovery."
    }
}
# Route Maintenance
proc RouteMaintenance {node} {
    global ns_ energyThreshold
    if {[$node energy] < $energyThreshold} {
        puts "Node [$node id] has low energy. Removing routes and triggering route repair."
        $node clear-routes
        # Trigger route repair process
        RouteDiscovery [$node id] [getDestination]
    }
}
# Data Forwarding
proc DataForwarding {node pkt} {
    global ns_
    if {[$node energy] >= 0} {
        # Forward packet to the next hop
        set nextHop [$ns_ get-next-hop $node [$pkt get-dst]]
        if {$nextHop != ""} {
            $ns_ attach-agent $node [NewAgent/TCP]
            [$ns_ agent $node] send $nextHop [$pkt size] [$ns_ agent $node]
            $ns_ detach-agent $node
        } else {
```

```
            puts "No route available for packet forwarding."
        }
    } else {
        puts "Node [$node id] has no energy. Packet dropped."
    }
}
# Energy-Aware Route Updates
proc EnergyUpdate {node} {
    global ns_
    # Update routing table with energy information from neighbors
    foreach neighbor [$node neighbors] {
        set neighborEnergy [$neighbor energy]
        set neighborId [$neighbor id]
        $ns_ rt-update $node $neighborId $neighborEnergy
    }
}
# End-to-End Communication
proc EndToEndCommunication {src dst dataSize} {
    global ns_
    # Create and send data packet from source to destination
    set pkt [$ns_ get-pkt-size $dataSize]
    $pkt set-src $src
    $pkt set-dst $dst
    # Start the data forwarding process
    DataForwarding $src $pkt
}
# Simulation Parameters
set val(nn) 50
```

```
set val(x) 500
set val(y) 500
set val(stop) 250.0
# Create a network topology
set ns_ [new Simulator]
set tracefd [open out.tr w]
$ns_ trace-all $tracefd
# Create nodes
for {set i 0} {$i < $val(nn)} {incr i} {
   set node($i) [$ns_ node]
   $node($i) set X_ [expr rand()*$val(x)]
   $node($i) set Y_ [expr rand()*$val(y)]
}
# Configure energy model, initial energy, and transmission range for each node
foreach node $ns_ nodes {
   $node set energyModel "EnergyModel"
   $node set initialEnergy 100
   $node set radius $initialRange
}
# Define node movements, energy updates, and communication events
$ns_ at 0.1 "$node(0) setdest 100 100 5"
$ns_ at 0.2 "EnergyUpdate $node(0)"
$ns_ at 1.0 "RouteDiscovery $node(0) $node(50)"
$ns_ at 2.0 "EndToEndCommunication $node(0) $node(50) 100"
# Run the simulation
$ns_ run
```

3.4.2 Route Selection Process of the Proposed Algorithm

As we have mentioned above the forwarder node discovery process of the existing MAODV is modified by considering required energy and residual energy, to avoid the problem of route failure due to low energy of the path's nodes and to reduce unnecessary flooding control messages to discover route. To be selected as a forward node from the source to the destination each node required energy should have to be less than its residual energy. After applying these two parameters different alternative routes may be available among those routes, we can select some of them by calculating the route cost function of the path. The least-expensive route cost function can be selected as an optimal path from the source to the destination. It could be calculated by using the following formula: -

Route cost function = Required energy / Residual energy

Where Required energy is the summation of each node's required energy in the path and Residual energy is the summation of residual energy of each node in the path. After calculating the route cost function of each path compare the value of all available paths and select the path which has less route cost function than others.

3.5 NS2 Architecture

NS2 is an object-oriented Tool Command Language (OTcl) translator that receives Tol script as input and outputs trace files. Image 7. The NS2's basic architecture is displayed below. Users of NS2 have access to the executable command ns, which accepts a Tcl simulation scripting file as an input argument. The Tcl script is supplied by users as an input argument for the NS2 executable command ns. The output is displayed graphically, such as in a plot graph, using a simulation trace file that has been prepared. C++ and the object-oriented Tool Command language are the two main languages used in NS2 (OTcl).OTcl puts up simulation by assembling and configuring the objects as well as setting up discrete events, whilst C++ offers the internal mechanism of the simulation objects. It might specify factors and events to facilitate interaction. NS2 comes with a ton of built-in C++ objects. It is advised to set up a simulation utilizing a Tcl simulation script and these C++ objects. Advanced users, however, find these objects lacking. They must create their own C++ objects and assemble them using an OTcl configuration interface (Hasan, 2014).

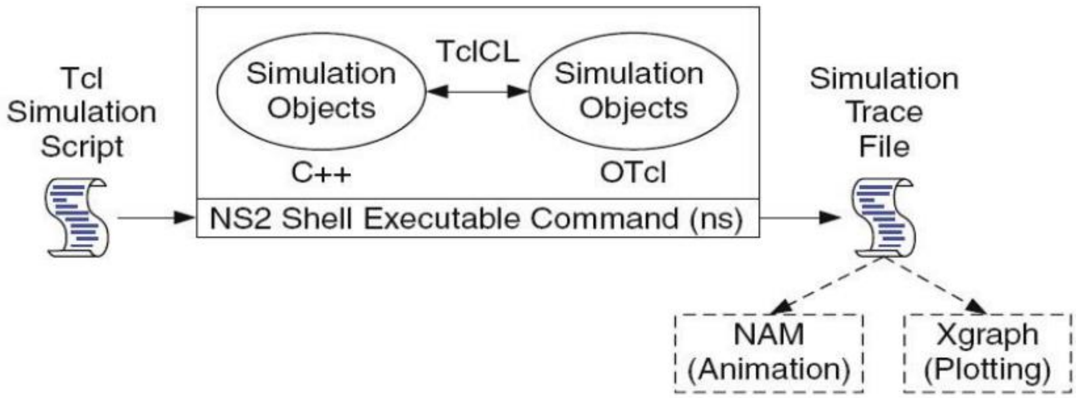

Figure 7: (NS2) Structure

NS2 outputs the outcomes of the simulation as either text-based or animation-based findings. Tools like NAM (Network AniMator) and XGraph were used to interactively and graphically understand these types of data. Users can extract a pertinent subset of text-based data and modify it into a more plausible presentation to investigate a certain network behavior [35].

3.5.1 NS2 Simulation Steps

Performing simulations using NS2 typically involves the following steps:

Step1: Network Topology Design: Define the network topology by specifying the number of nodes, their locations, and their interconnections. This can be done using NS2 script files or topology generation tools.

Step2: Protocol Configuration: Select the network protocols to be used in the simulation and configure their parameters. This includes setting routing protocols, transport protocols, application-level protocols, and any other relevant protocols based on your simulation objectives. Traffic Generation: Define the traffic patterns and sources in your network. Specify the type of traffic (e.g., CBR, VBR, FTP, etc.), traffic rates, and other relevant parameters such as packet size or inter-arrival times.

Step3: Event Scheduling: NS2 is event-driven, so you need to schedule events such as packet transmissions, route updates, and node movements using the NS2 simulation scheduler. This can be done using events and timers in your NS2 script.

Step4: Simulation Execution: Run the NS2 simulation by executing the NS2 script file. NS2 will simulate the network behavior according to the defined topology, protocols, traffic patterns, and events. The simulation will generate trace files containing detailed information about the simulation run.

Step5: Result Analysis: Analyze the output and trace files generated by the simulation to evaluate the performance of your network protocols and measure key metrics such as throughput, delay, packet loss, and energy consumption. Use appropriate tools or scripts to extract and analyze the data of interest.

Step6: Visualization: If desired, use NAM (Network Animator) or other visualization tools to visually observe the simulation results. NAM can provide graphical representations of the network topology, node movements, and packet flows, allowing for easier interpretation and visualization of the simulation behavior.

Step7: Experimentation and Iteration: Based on the analysis of the simulation results, you may need to refine your network design, protocol parameters, or traffic patterns and rerun the simulation to further investigate and optimize the performance of your network protocols.

It's significant to memo that NS2 simulations are typically performed by creating and modifying Tcl script files that define the simulation scenario, network parameters, and event scheduling. These script files are then executed within the NS2 environment to simulate and analyze the network behavior.

The specific details and intricacies of each step may vary depending on your specific simulation requirements, research objectives, and the protocols being studied. NS2 documentation, online resources, and examples can provide further guidance and help you navigate the simulation process.

3.5.2 Why NS2 is suitable for Mobile Ad-hoc Networks.

NS2 (Network Simulator 2) is considered suitable for Mobile Ad-hoc Networks (MANETs) due to several reasons:

Simulation Flexibility: NS2 provides a flexible and customizable simulation environment, allowing researchers to model and simulate various aspects of MANETs. It offers a wide-range of network protocols, mobility models, and traffic patterns that can be tailored to specific MANET scenarios.

Protocol Support: NS2 supports a diverse set of routing protocols specifically designed for MANETs, including proactive (e.g., OLSR, DSDV), reactive (e.g., AODV, DSR), and hybrid (e.g., ZRP) protocols. These protocols can be easily implemented and evaluated within NS2, enabling researchers to compare their performance under different conditions.

Mobility Modeling: MANETs involve nodes that can move freely, leading to dynamic network topologies. NS2 supports various mobility models, such as random waypoint, random walk, and group mobility, allowing researchers to simulate node movements and study the impact of mobility on MANET behavior.

Energy-Awareness: NS2 provides features and extensions to model and simulate energy-awareness in MANETs. Researchers can incorporate energy consumption models, power control algorithms, and energy-efficient routing protocols into their simulations to analyze the energy efficiency of MANET designs.

Trace and Performance Analysis: NS2 generates detailed trace files during simulations, which capture information about packet transmissions, routing decisions, energy levels, and other network events. These trace files can be analyzed using various tools to evaluate the performance metrics of MANET protocols, such as throughput, latency, packet loss, and energy consumption.

Visualization: NS2 includes the Network Animator (NAM) tool, which provides graphical visualization of the simulated network. NAM allows researchers to visually observe the behavior of the MANET, including node movements, link formations, and packet flows, facilitating better understanding and analysis of the simulation results.

Extensibility and Community Support: NS2 is an open source simulator with a large community of users and developers. It provides the flexibility to extend and modify the simulator to incorporate new protocols, algorithms, and models. Researchers can leverage the community support and available resources to enhance NS2 for MANET-related research.

Overall, flexibility, protocol support, mobility modeling capabilities, energy-awareness features, trace analysis, visualization tools, and extensibility make NS2 a suitable choice for simulating and evaluating Mobile Ad-hoc Networks. It enables researchers to study the behavior, performance, and optimization of MANET protocols and designs in a controlled and customizable simulation environment.

3.6 Network Simulator 2.35 (NS 2.35)

Provides the implements different protocols for simulation or research. Also created new protocols and all internal protocols can be changed as per user requirements. In Networks Simulator 2.35, mobile node has been designed to move a three-dimensional topology means X, Y and Z dimension. On the other hand, the Z dimension is not used. The mobile node is assumed to move always on horizontal environment with Z equal to 0. The node mobility scenarios are handled in two ways, in the first way, nodes' speeds, starting and ending positions are selected at random. At a prearranged time, the node would start moving from its original position to its destination at the defined speed. In the mobility scenario is normally stored in a separate file. In the second way, nodes starting positions are generated originally; the destination and speed are dynamically reorganized in a random way for the duration of the simulation. Networks simulator 2.35 also provides network traffic patterns like Cbr (constant bit rate).

Also, Networks Simulator-2.35 provides the utility for data analysis using the Xgraph and Gnuplot. In the complete version, the node class is better by adding more supporting features such as facility to move inside a topology, facility to send and receive packets over a wireless channel.

3.6.1 Networks Simulator 2 provides some advantages.

NS2 uses more packages and optional software. Tools like Xgraph and network animator (NAM) are used to represent the graphical view of the data or results. The NAM provides the visualization of networks such as how it transfers the data, how to send data and so on. Networks simulator are used two main part kernel and libraries. Networks simulator 2 model provides the Split-level programming for building the networks scenario. C++ language provides the simulation behavior while the simulation scenario is based on tool command language (TCL).

3.6.2 Networks Simulator 2 has some limitation.

Network simulator 2 is used for simulating network scenarios but it has some limitations. NS 2 does not provide the CIDR (Classless Inter-Domain Routing) and Sub netting. NS2 cannot support Variable Bit Rate (VBR) but it provides the Constant Bit Rate (CBR). Present VBR is used for audio or video streaming and encoding in the real network environment. NS2 does not support processing delays but supports different delays such as propagation, queuing and transmission. Networks Simulator has limited functions are used when created the scenario of large network. In large network hundreds of nodes to simulate and NS2 cannot give the results of that much large simulation. It means the greater number of nodes the slow the simulation.

3.7 Required Hardware and Software Tools

This section is focused on hardware and software environment. The required software and hardware are listed below.

Table 2: Hardware Requirement

Hardware	Specification
CPU	Intel(R) Core (TM) i3-3110M CPU @ 2.40GHz
RAM	8 GB
Storage	1 TB HDD
Operating System	Ubuntu 64-bit

Table 1: Software Requirement

Tools and Technologies	Name	Description
Variable transmission range	Energy	Java based open-source Open Flow/ Variable transmission range
Simulator	NS2	NS2 stands for Network Simulator Version 2. It is an open-source event-driven simulator designed specifically for research in computer communication networks.

CHAPTER 4
RESULT AND DISCUSSIONS

4.1 Introduction

This chapter describes the implementation details and experimental results of the proposed design for an efficient routing algorithm for the routing protocol. Different experiments were performed to verify the efficiency of the proposed algorithm. Sections 4.2 and 4.3 present the proposed system's implementation and experimental setup. Section 4.4 simulation scenario. Section 4.5 presents the test results of the systems. Finally, discussions are made in the last sections of this chapter.

4.2 Implementation Setup

The simulation setup and various parameters selected to simulate the routing protocols are briefly described in this chapter. It gives an assessment of the EE AOMDV and AOMDV protocol's performance using NS2.35. The performance of the MANET protocols is assessed in this chapter using the same performance criteria and input settings.

Simulations are carried out using NS2 version 2.35 on the Linux platform, it is barfly explain on chapter 3.5

The programming libraries provide for the researcher to tune the network elements, and parameters. NS-2 also provides well data analysis features like an Xgraph, Gnu plot.

4.3 Simulation Parameters

The simulation parameters for the proposed protocol has been shown in Table 4.1. By using the NS-2 simulator to access the achievement of the proposed protocol.

Table 2: Simulation Parameter

Parameter	Value
Simulator	NS2(2.35)
Packet size	512 bytes
Traffic Model	TCP
Mobility model	Melty
Simulation area	800*800
Routing protocol	EE AOMDV
Number of Nodes	20,30,40,50
Initial Energy of Node	100J
Radio- Propagation Model	Propagation/Tworayground
Antenna Model	Antenna/Omniantenna
Transmission range	200m
Simulation time	250sec

4.4 Simulation scenario

To improve the effectiveness and fairness of our review, the simulation scenario is run by deploying 20, 30, 40, and 50 nodes in an 800*800-square-foot area. 512 bytes make up the packet size. Each node has a wireless link for communication, which is formed using the EEAOMDV routing protocol. There are 100 joules of starting energy in each node. A sample screenshot of a communication between 40 nodes is displayed in the picture below.

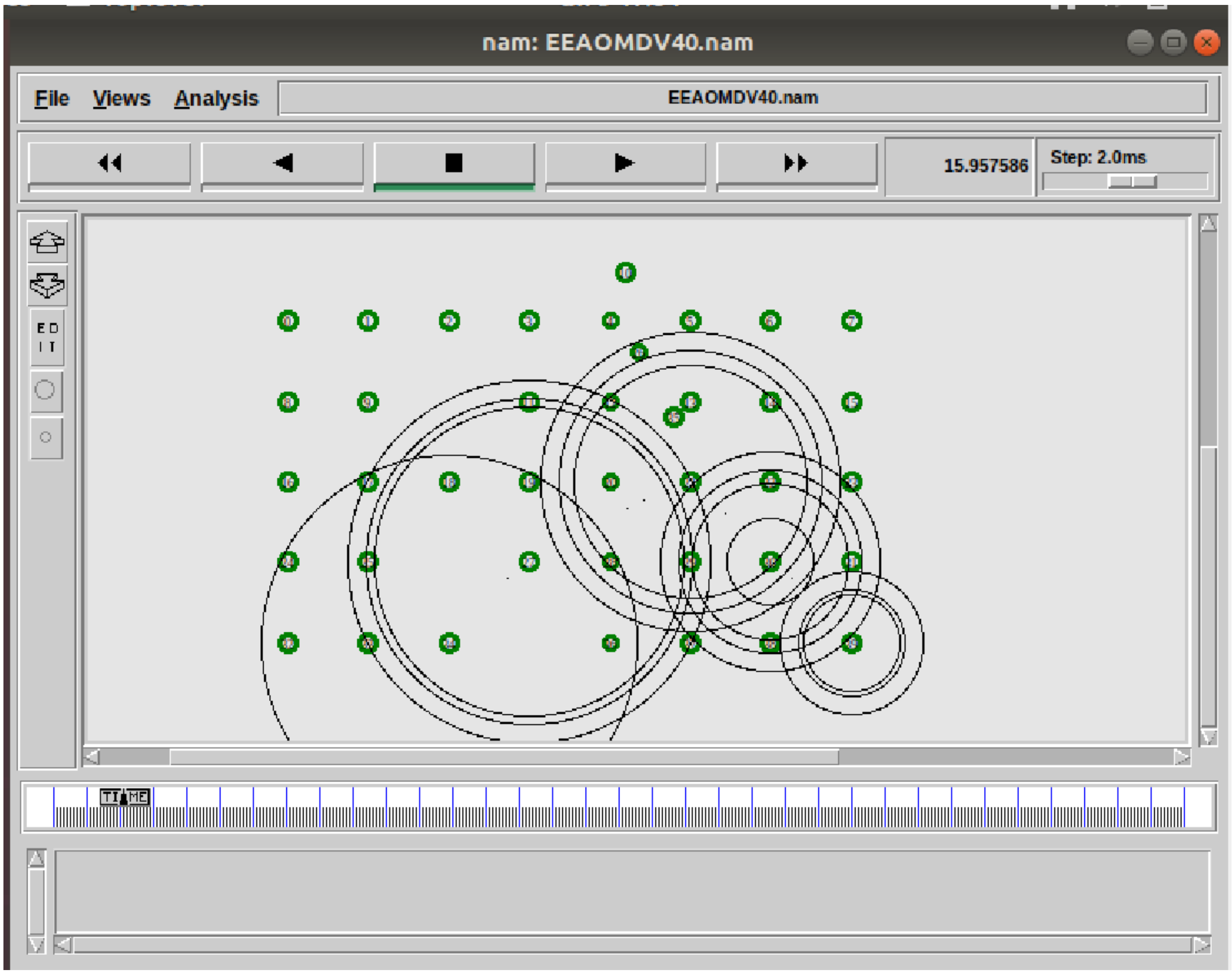

Figure 8: Simulation Scenario

4.5 Result and discussion

An evaluation and comparison simulation code has been written in the Network Simulator (NS2.35) simulator to compare the outcomes of the EEAOMDV protocol with the current AOMDV protocol. Numerous performance indicators have been calculated, including average energy usage and packet delivery ratio. Variations in the number of nodes and simulation have produced different simulation outcomes.

4.5.1 Simulation result by varying number of Nodes

We ran simulations by changing the number of nodes from 20, 30, 40, and 50 to better understand how the new protocol performed in various network sizes. The performance of nodes is not equally impacted by various network sizes. As a result, we want to test our model by changing the number of nodes. The initial battery energy before processing data transmission is subtracted from the remaining battery level after processing data transfer, and the result is divided by the total number of nodes. This yields the average energy consumption. Joules are used to measure it. It shows how much energy each network node expends processing packets between source and destination nodes. Here, we employed energy usage as an indicator in our research.

Energy consumption = (Init energy-Remin energy)/Total no of nodes

Where Init energy refers to initial energy of nodes that participate in the communication and Remain energy refers to residual energy of nodes. And Total no of nodes refers to the overall count of nodes involved in the network.

Table 3: Energy Consumption by Varying Number of Nodes

Number of nodes	Average energy consumption of enhanced EEAOMDV	Average energy consumption of existing AOMDV
20	1.06	1.09
30	1.044	1.077
40	1.01	1.028
50	1.0	1.012

Energy Consumptions

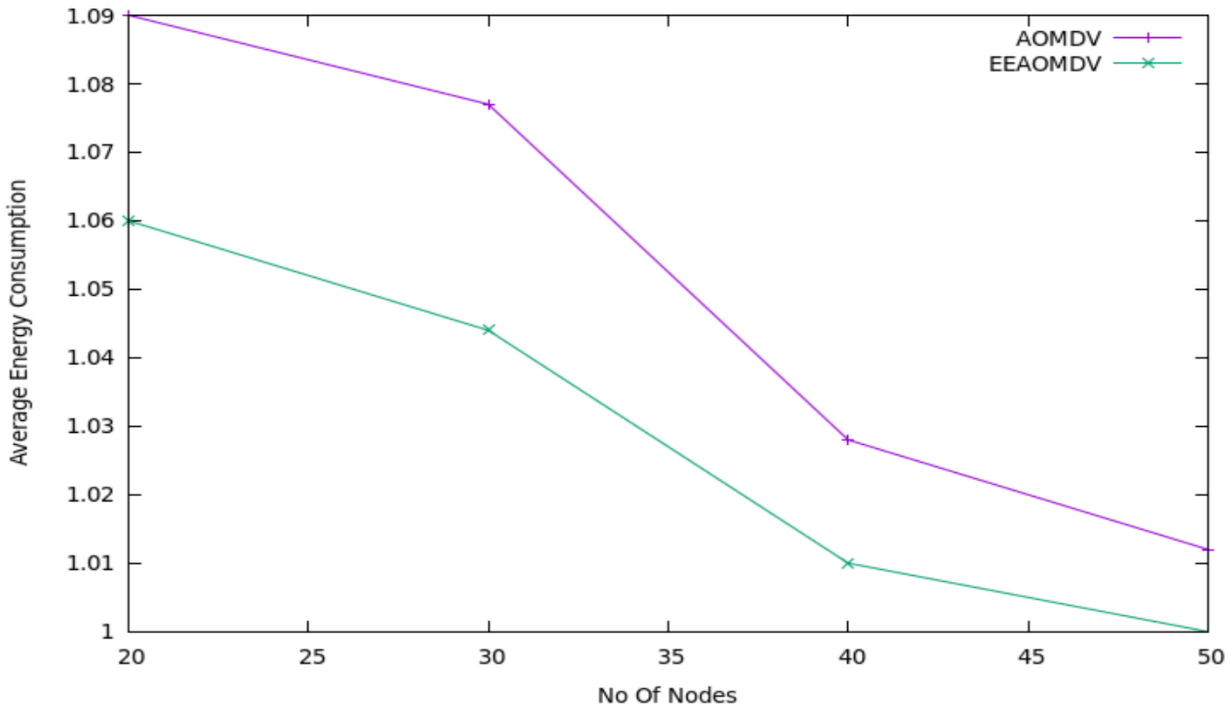

Figure 9: Energy Consumption by Varying number of nodes

Fig.9: Comparative analysis between EEAOMDV and AOMDV reveals that EEAOMDV achieves better energy consumption efficiency. EEAOMDV incorporates a variable range transmission mechanism, which allows nodes to dynamically adjust their transmission range based on network conditions and energy constraints. By adapting the transmission range, EEAOMDV reduces energy consumption by avoiding unnecessary transmissions and optimizing the use of available energy resources.

PDR (Packet delivery ratio)

PDR (Packet delivery ratio) is a performance metric used to evaluate the effectiveness of a routing algorithm or protocol in delivering packets from the source node to the destination node in a network. The PDR is calculated as the percentage of successfully completed tasks delivered packets with relation to all packets combined sent.

Packet Delivery Ratio = (Number of packets received / Number of packets sent)(100)

Table 4: Packet Delivery Ratio by Varying Number of Nodes

Number of nodes	packet delivery ratio of enhanced EEAOMDV	packet delivery ratio of existing AOMDV
20	0.96	0.92
30	1.21	1.00
40	1.21	1.09
50	1.3	1.26

Packet Delivery Ratio

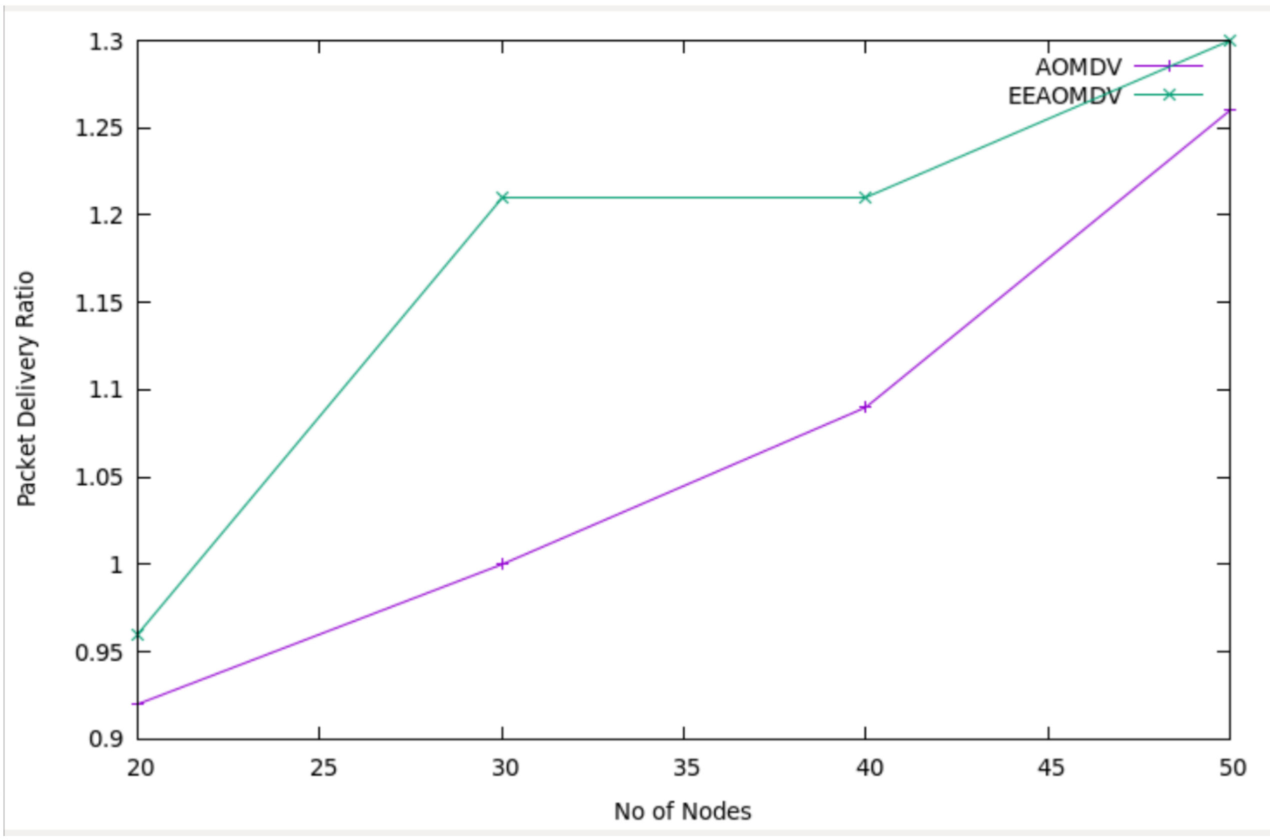

Figure 10: Packet Delivery Ratio by Varying Number of nodes

Fig. 10: Comparative analysis between EEAOMDV and AOMDV reveals that EEAOMDV achieves a better packet delivery ratio. This improvement is attributed to the integration of a variable range transmission mechanism in EEAOMDV, which allows nodes to dynamically adjust their transmission range based on network conditions and energy constraints. By optimizing the transmission range, EEAOMDV can effectively mitigate the impact of link failures, interference, and other network dynamics, resulting in a higher packet delivery ratio.

Network Lifetime

Energy is a very critical issue in MANET so that to handle this challenge the proposed algorithm using the concept of effective route selection of communication so that the probability of route break, node drop and route error will reduce. Here we are using highest Energy paths for data transferring as well as we are using the concept of multipath and congestion which can redirect the data traffic on other routs so that the route drop ratio is also reduced. Improvement of node and route life or proper utilization of node energy can directly lengthen the lifespan of network. It refers to the available time for exhausting the energy of nodes that can be calculated by the given for

Network Lifetime = Total Energy Available / Average Energy Consumption per Unit Time

Where:

Total Energy Available: The total energy capacity or initial energy level of all nodes in the network.

Average Energy Consumption per Unit Time: The average rate at which energy is consumed by the nodes in the network.

Table 5: Network Lifetime

Number of nodes	Network lifetime of enhanced EEAOMDV	Network Lifetime existing AOMDV
20	7.41	6.25
30	7.61	6.3
40	8.28	7.43
50	8.25	7.53

Network lifetime

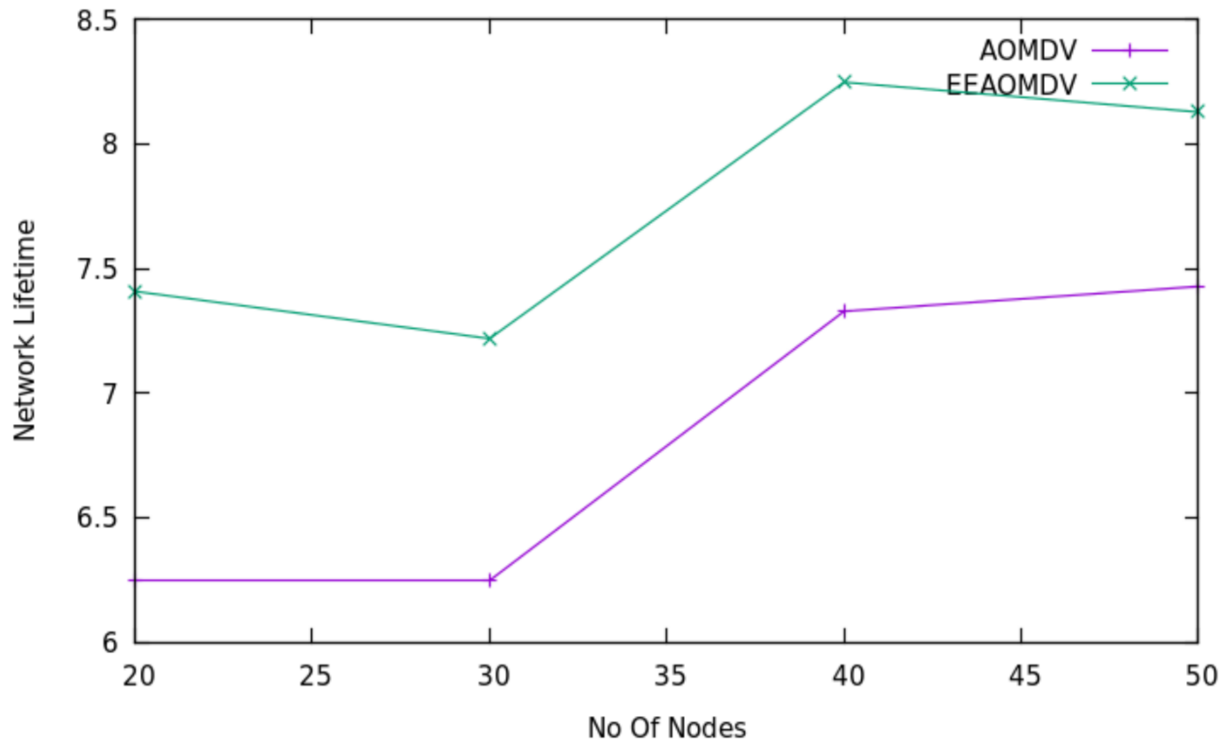

Figure 11: Network Lifetime by varying number of nodes

Fig 11 Comparative analysis between EEAOMDV and AOMDV reveals that EEAOMDV offers a better network lifetime. The EEAOMDV protocol incorporates a variable range transmission mechanism, which allows nodes to dynamically adjust their transmission range based on the network conditions and energy constraints. By adaptively controlling the transmission range, EEAOMDV can effectively conserve energy and extend the network lifetime.

CHAPTER 5

CONCLUSIONS AND FUTURE WORK

5.1 Conclusion

The proposed Extended Energy On Demand Multipath Distance Vector (EEAOMDV) protocol has been evaluated against the existing AOMDV protocol in MANETs (mobile ad-hoc networks) about package delivery ratio, energy consumption, and network lifetime.

It has been proven through thorough simulations and research that EEAOMDV performs better than AOMDV in each of the three categories.

Firstly, EEAOMDV achieves a higher ratio of package deliveries dynamically adjusting the transmission range based on network conditions. This adaptability ensures better connectivity and reduced packet loss, resulting in improved overall performance.

Secondly, EEAOMDV incorporates an energy-aware approach by optimizing energy consumption. It intelligently manages transmission power levels and adapts the transmission range to conserve energy resources. This energy-efficient operation significantly increases the longevity of the network, allowing nodes to operate for longer periods without exhausting their batteries.

In conclusion, EEAOMDV offers notable advancements over AOMDV about package delivery ratio, energy consumption, and network lifetime. It provides a more reliable and energy-efficient communication solution for MANETs, addressing the challenges of limited energy resources and dynamic network conditions. Integrating different variables range transmission and energy-awareness techniques in EEAOMDV contributes to the overall performance and sustainability of the network.

5.2 Future Work

Future efforts can concentrate on improvements and new paths for research in the context of the Extended Energy On Demand Multipath Distance Vector (EEAOMDV) protocol. The following are some prospective future research areas:

Performance optimization: Investigating the EEAOMDV's performance under various network situations, traffic patterns, and mobility models. This may entail optimizing the algorithm's parameters and assessing the algorithm's performance using different performance metrics.

Improvements to Energy Efficiency: Investigating cutting-edge energy-saving methods like sleep scheduling, adaptive power control, or energy harvesting to boost EEAOMDV's energy efficiency even more. It is also possible to study employing renewable energy sources in conjunction with energy-conscious routing techniques.

Support for Quality of Service (QoS): Investigating strategies to enhance QoS provisioning in EEAOMDV, such as providing some traffic a greater priority or accounting for the needs of multimedia data transfer. Researching how QoS impacts protocol performance and developing solutions to ensure the timely and accurate transmission of data that is QoS-sensitive may be necessary to achieve this.

Addressing problems with communication integrity, confidentiality, and authentication in EEAOMDV. By using encryption techniques or developing secure routing protocols, network security and data privacy can be increased.

Integration with Emerging Technologies: Exploring the integration of EEAOMDV with emerging technologies, such as Internet of Things (IoT), cognitive radio networks, or software-defined networking. Investigating how EEAOMDV can adapt and leverage the capabilities of these technologies to further enhance its performance and scalability.

Overall, future work in the area of EEAOMDV can focus on refining the protocol, addressing specific challenges, and exploring new possibilities to enhance its performance, energy efficiency, and security in mobile ad hoc networks.

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