Optimizing Routing in MANETs with Energy Conservation

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ABSTRACT

Context: In Wireless Networks, *MANETs can dynamically create a network without relying on a central hub or infrastructure. These features will be helpful for scenarios such as disaster relief or military operations. However, the absence of a central authority presents challenges concerning security and routing, affecting the network's stability and capabilities.*
Approach: A *proposed scheme incorporates the consideration of the power factor when selecting routes to handle the challenges efficiently. These are integrated with the widely used AODV routing protocol and simulated using the NS-2 simulator*. We evaluate the simulated results to determine the impact of the proposed scheme on the network.
Findings: The simulation outcomes demonstrate that the suggested approach significantly improves network performance concerning power consumption and stability. *Including the power factor in route selection positively influences the network's capacity to maintain efficient communication and reduce the energy consumed.*
Type of paper: *Review based Analysis.*
Keywords: Power Factor, MANETs, AODV, ENERGY.

1. INTRODUCTION :

Wireless networks are rapidly advancing, enabling users to access information and services through electronic media. This technology provides fast and affordable internet connectivity to people worldwide without requiring a license. One variation of wireless networks in the third layer, the network layer, is Ad Hoc networks. In such networks, nodes exhibit dynamicity and mobility, leading to rapid changes in network topology. In this network, every node will serve as both a host and a router; however, the dynamic nature of these nodes will result in frequent changes in the network's topology. Ad hoc networks have numerous potential applications and are particularly valuable in various fields. These networks are beneficial in battlefield operations, disaster recovery efforts (e.g., earthquake, flood, and fire), emergency missions, home networking, conferences, and conventions where information sharing is crucial. In military communications, data acquisition and virtual classroom applications in hostile environments are suitable for setting up contacts in exhibitions, coordinating defines or attack strategies on the battlefield, and facilitating information sharing among airport terminal workers.
Issues in the field of MANETS are as follows:
(a) Congestion Control
(b) Dynamic Topology
(c) Frequent Path Breakage
(d) Link Stability
(e) Mobility
(f) Power Management
(g) QOS (Quality of Service)
(f) Reliability
(g) Routing
(h) Security

(1) Restricted bandwidth and power resources: Mobile devices within ad hoc networks typically possess limited capabilities, such as battery power and wireless bandwidth. These limitations can pose challenges when accommodating more nodes or handling high traffic volumes.
(2) Dynamic network topology: The positions and connections of devices undergo frequent changes, creating difficulties in establishing stable routes for efficient data transmission.
(3) Security concerns: Ad hoc networks lack a fixed infrastructure, making them more susceptible to security attacks, including spoofing and jamming. Protecting the network and the transmitted data becomes more challenging in such scenarios.
(4) Quality of Service (QoS): Ad hoc networks provide a different level of QoS than infrastructure-based networks, making it challenging to support real-time applications like audio and video streaming.
(5) Complex routing: Routing is intricate due to mobile routers with minimal power for processing, memory, and battery life.
(6) Scalability limitations: When the number of nodes increases, ad-hoc networks face constraints on scalability due to the overhead involved in managing and maintaining the network.

The Paper follows the structure below: The Literature review examines the previous work, while Section 3 elaborates on the proposed algorithm. Section 4 conducts the performance evaluation using NS-2, and the concluding section presents the final remarks.

2. LITERATURE REVIEW :

The AODV (Ad-hoc On-demand Distance Vector) routing protocol will be created explicitly for mobile ad-hoc networks (MANETs) to operate reactively, establishing the route between the nodes only if required. Recently, researchers have examined various aspects of the AODV protocol, including its performance, security, and robustness. Some investigations have focused on assessing the impact of different network conditions, such as node mobility and density, on AODV's performance. Numerous methods exist to enhance AODV's security by mitigating routing attacks or incorporating cryptographic techniques.

In a study by (Gouda et al., 2013) [28], a new routing protocol inspired by AODV integrates machine learning algorithms to improve the PDR and minimize the E2E delay. The outcomes indicated that their innovative approach surpassed the performance of the traditional AODV protocol. Similarly, (Bhattacharyya et al., 2018) [21], the novel AODV incorporates a direction-based routing mechanism, leveraging direction information to improve routing performance. The study highlighted the superior performance of the proposed protocol compared to AODV, considering metrics such as E2E delay, PDR, and control overhead.

Regarding on-demand protocols, there are two main methods: Discovering and Maintaining the route. In the discovering phase, source nodes send messages to find the best and shortest path to the destination, which can use much energy. The route maintenance method responds dynamically to any changes in the availability of hops in the network topology, and implementation varies across different algorithms. In basic on-demand protocols like AODV and DSR (Patil M et al., 2015) [19], both processes are not capable under heavy network loads due to increased node mobility caused by packet transmission delays concern MAC (Medium et al.) contention. Mobility disrupts established routes, and their repair further drains battery power. Additionally, flooding RREQ and RREP messages depletes the energy resources of participating nodes. Even base stations that receive these broadcast messages use very little energy.

AODV and DSR are two routing protocols commonly employed in ad-hoc networks. Whenever there is a requirement, AODV establishes routes between nodes only when required. Whenever any node wants to transfer a packet to another node without a set route, it transmits the RREQ packet in all the outgoing paths. The RREQ propagates through the network, and upon reaching a node that has a possible or existing route to the destination or is the destination itself, a route reply (RREP) packet is sent back to the source, thereby creating a route for packet transmission. Similarly, DSR is also a reactive protocol, similar to AODV, but it utilizes source routing methods rather than maintaining routing tables. In the DSR protocol, each packet contains the possible route from its source to the

destination based on the hops' availability. The next hop for packet forwarding is determined based on the source route within the packet. AODV is generally easier to implement and has lower network overhead, while DSR allows for more flexible and efficient route discovery without relying on periodic broadcasts for routing information maintenance.
AODV and DSR do not consider metrics that depend on power, such as the network nodes' lifetime or energy dissipation by participating nodes. For solving this issue, power will be considered when making routing decisions in an ad hoc network.

Pushparaj R et al. (2014). Patil M et al. (2015) and Chawda K et al. (2015) [18, 19, 22] developed Energy2AODV, an energy-efficient AODV that incorporates the Expand Ring Search (ERS) technique for route discovery, effectively reducing energy consumption by avoiding duplicate rebroadcasting of RREQ packets. They carried out the research using AODV as the base protocol. (Krung M et al., 2002) [33] Enhances the capability of AODV by utilizing power-based path selection. When a link breaks in an AODV-enabled network, a RERR message is triggered. The node-detecting link break broadcasts the RERR message to its neighbors, who propagate it further until all nodes with a route through the broken link must get notified. After receiving the RERR message, the route discovery process initiates to check another possible route to the destination based on available neighboring nods. This protocol calculates the number of hops covered by the data packet and the number of remaining hops to be traveled. If the number of traveled hops exceeds the remaining hops, it enables an energy booster path; otherwise, it selects an alternate path. Under high network load, this protocol exhibits good performance. The authors (Tavosian et al., 2012) [4] applied network coding in the ANC scheme to improve AODV's energy consumption. The authors combined network coding with the AODV routing process, reducing energy consumption and data transmission. Additionally, they introduced a buffering mechanism in intermediate nodes to store incoming packets, combined them with the coding scheme, and forwarded the combination.

The authors (Huang et al., 2011) [5] modify the gossip algorithm implemented on AODV to address high congestion issues. They consider the remaining power of a node in the RREQ and then make the decisions using the gossiping probability. Sun, W., Zhang [6] modify AODV for unidirectional ad hoc networks by employing a backup strategy that computes multiple paths. (Thanthry, N. et al., 2006) [7] discussed the EM-AODV protocol that considers three parameters: battery level, bandwidth, and signal strength when making routing decisions. This protocol uses a multiple-route technique but selects the route based on the node's minimum affinity, available bandwidth, and maximum consumed battery power. Periodically, each node updates this information and chooses the route with the maximum residual battery unless it deems it unfit, in which case it discards it. (Gwalani, S. et al., 2003) [8] discussed AODV-PA (AODV with path accumulation) to enhance the effectiveness of the flooding mechanism by utilizing distributed routed information. The authors (Shibao et al., 2010) [10] presented HP-ERS-AODV, which predicts the latest location of the destination node by studying the patterns of wireless devices attached to humans. Utilizing time-to-live values reduces the re-transmission of request messages. The authors (Dargahi et al., 2008) [11] modified AODV and introduced SP-AODV, where they added a flag value to the RREQ packet. They also included two constants, MinTH and MaxTH, which control the value of a new field called the counter in the routing table. The counter value is incremented or decremented based on the constant values, indicating the estimated time for a node to reach the destination. Demir et al. (2007) [12] discuss an auction-based protocol for end-to-end routing to avoid wastage of the source's resources. Considering parameters like digital currency and current energy, implementing the Vickery auction increases the bid when the energy level decreases, and vice versa. However, selfish behavior does not guarantee favorable outcomes. (Sethi S et al., 2009) [13] IMAODV combines AODV and MAODV, which supports multicasting and reliability in a large network area. This protocol establishes bi-directional shared multicasting trees if the group members remain within the connected network. (Thanthry N et al., 2006) [7] proposed using the EM-AODV algorithm to increase the lifespan of networks. This algorithm considers the energy levels of nodes to optimize their usage.

3. OBJECTIVES :

The research objectives of this scholarly Article are listed below:

(1) To Analyze energy usage in MANETs by studying node mobility, communication traffic, and protocol characteristics.
(2) To develop energy-efficient routing algorithms using computer networking and optimization principles.
(3) To evaluate trade-offs between energy conservation and network performance using simulation.
(4) To create energy-aware routing guidelines and communicate findings to network practitioners and researchers

4. PROPOSED APPROACH :

The primary objective aims to ensure energy efficiency and stability in the route. By seamlessly integrating, it modifies the AODV protocol. It specifically caters to different levels of data traffic and comprises two significant phases: the Route Request Phase (RREQ) and the RREP phase. In this modified version of AODV, every node updates its routing table with new power-related information. The node's battery status is categorized into various levels, with the critical battery status being the lowest or most precarious state, rendering the node ineligible for inclusion. On the other hand, the Active state indicates that the battery has a higher value than a specified threshold. When a new route is required, the system assesses the node's status and establishes the route accordingly.

Route Establishment: This algorithm facilitates the selection of an appropriate sequence of nodes via the path for the requesting party.

Session:

(1) Initially, Pi =0
(2) For each valid path Pi
(3) For each node Ni in Pi
(4) IF current battery status =Active state
(5) Then
(6) Include node in the path and broadcast RREQ to the intermediate nodes Ni.
(7) End IF
(8) At the source node S, Scan all RREPs
(9) RREP with the shortest active route and CURRENT Battery STATUS > MIN_ BATTERY is selected
(10) Forward data
(11) Else
(12) Exclude node from the path
(13) Then
(14) Sent RREQ to the selected node
(15) Then
(16) Forward the RREQ on the available active route
(17) Destination node D sends back RREP on the reverse path
(18) Source node S receives RREP
(19) Route is established
(20) The established route forwards data
(21) End For
(22) End For

4. SIMULATION SCENARIO :

We incorporated the above methodology into AODV by adding battery status to change its format. We conducted a simulation to study and analyze the operations of the M_AODV. The simulation used NS-2 (Dattana et al., 2019; Gouda et al., 2013) [15, 28]. During the simulation study, we considered the following metrics: E2E delay, throughput, PDR, and the sending and receiving of control packets.

Table 1: Simulation Scenario with Parameter Value

Simulation Parameters	Parameter Value
Simulator	NS-2.32
Simulation Area	700mts × 700mts

Mobile Nodes	25, 50,75,100
Pause Time	100
Packet Size	512kb
Protocols used for routing	AODV & Modi_AODV
Traffic Sources	CBR(UDP)
Simulation Time	500 Sec.
Performance Metrics	The proposed protocol was evaluated based on its impact on Packet Delivery Ratio, Throughput, Average End-to-End Delay, and Routing Load.

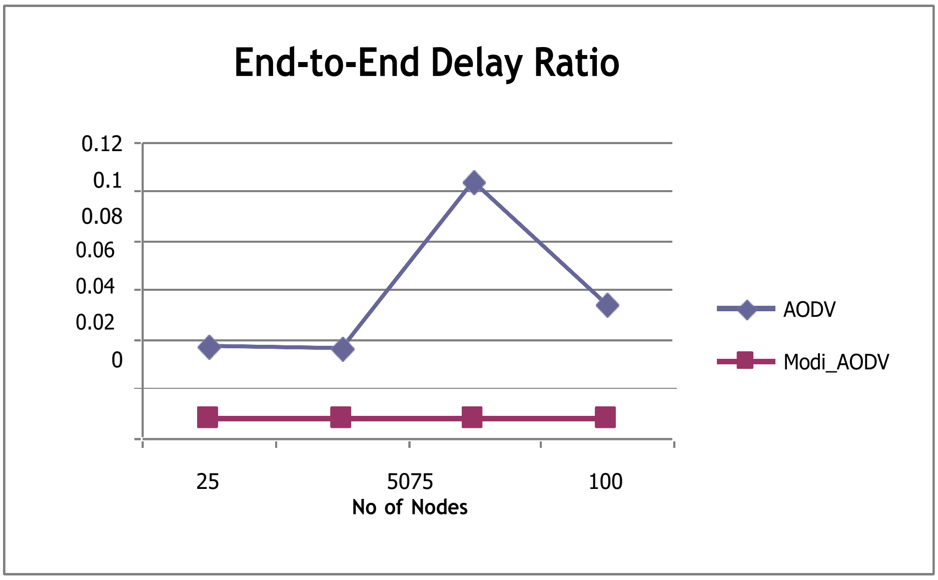

Fig. 1: End-to-End Delay comparison for different no of Nodes [100]

End-to-End Delay versus Number of Nodes: Primary performance measurement used to calculate the effectiveness of AODV are the E2E delay, representing the time required for a packet to transfer from source to destination. The network's size can significantly influence AODV's performance depending on the number of nodes. With an increased number of nodes, the required likelihood of congestion and collisions in the network rises, resulting in prolonged end-to-end delay. Furthermore, routing and control message overhead increase as the number of nodes increases, further contributing to delays. The growing network complexity due to increasing nodes impacts delays and path discovery time, potentially causing increased delays. However, more nodes in the network may present more communication options and enhance the probability of finding a viable path to the destination.

Consequently, a trade-off exists between the number of nodes and end-to-end delay for AODV. Figure 1 illustrates the efficiency of AODV and Modi_AODV concerning the end-to-end delay. When considering the existing AODV, the high end-to-end delay exhibits significant fluctuations. Conversely, Modi_AODV achieves a lower and more stable end-to-end delay ratio.

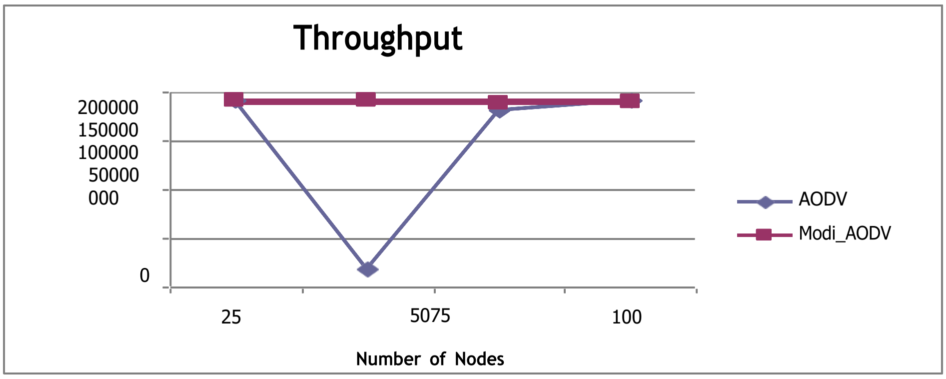

Fig. 2: Throughput using various No of Nodes [100]

Throughput versus Number of Nodes: Throughput is a quantifiable measure of the data volume transmitted across a network within a specific time frame, typically expressed in bits per second (bps). Within the AODV protocol, several factors can impact the throughput, including the number of nodes available in the network, the volume of traffic generated by these nodes, and their capabilities, such as their processing power and wireless interfaces. As the network's node count increases, so does the volume of generated traffic, potentially leading to congestion and reduced throughput. The number of nodes within the network will also directly influence the AODV protocol's efficiency. More nodes result in increased routing tables that must be maintained, causing heightened overhead and lengthier routing table lookup times. An elevated node count generally introduces overhead and complexity to the routing protocol, impacting overall network performance. It is vital to balance the desired level of throughput, overall performance, and the number of nodes present within the network to achieve optimal results. Figure 2 depicts the efficiency of AODV and Modi_AODV in terms of throughput. According to Krung M et al.'s study in 2002 [33], while the throughput remains relatively low at 50 nodes with AODV, it demonstrates better performance at 25, 75, and 100 nodes. In contrast, Modi_AODV exhibits superior and more stable performance.

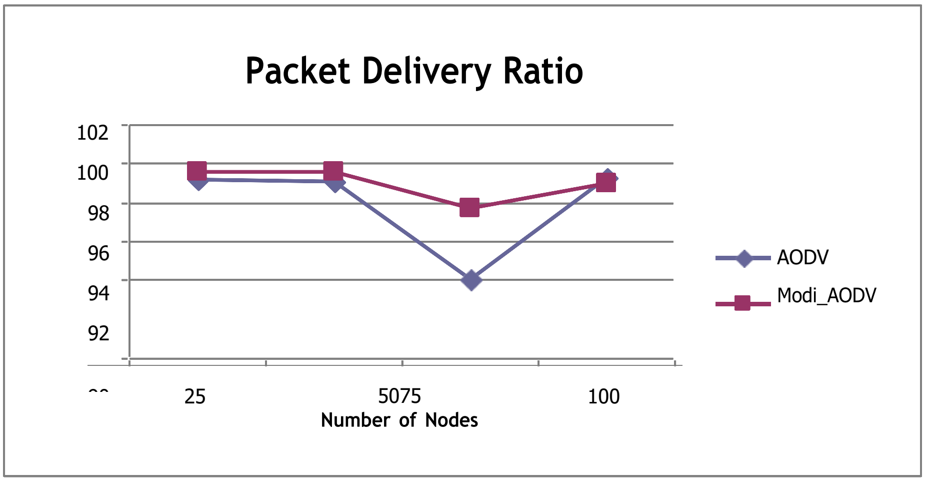

Fig. 3: Packet Delivery using different No of Nodes [100]

Packet delivery rate compared to the number of nodes: The packet delivery rate represents the percentage of packets reaching their intended destination. In contrast, the number of nodes denotes the total count of devices within the network. When the number of nodes changes, the network's complexity grows, potentially resulting in a lower packet delivery ratio. A higher node count increases the likelihood of packet collisions or interference, leading to lost or delayed packets. Additionally, more nodes lead to larger routing tables, causing increased overhead and delays. However, employing efficient routing protocols like AODV can reduce the influence of node quantity on the packet delivery rate, as they can swiftly and accurately find routes between nodes. Incorporating power control and frequency allocation techniques can lead to an improved packet delivery ratio in dense networks. However, it is essential to note that the number of nodes does not solely determine the packet delivery ratio; various factors like wireless channel conditions, mobility, power, and network bandwidth also cause AODV exhibits low and unstable packet delivery ratios, Modi_AODV demonstrate better and consistently stable performance. Significantly impact the network performance and packet delivery ratio. Figure 3 illustrates the comparison between AODV and Modi_AODV regarding the Packet Delivery Ratiometric. While AODV exhibits low and unstable packet delivery ratios, Modi_AODV demonstrates better and consistently stable performance.

In MANET, the discovery and establishment of routes between nodes rely on Route Request (RREQ) and Route Reply (RREP) packets. When a source node lacks a route to a destination, it initiates the process by broadcasting an RREQ packet containing relevant information like source and destination addresses, a unique broadcast ID, and the source node's current sequence number. The receiving nodes forward the RREQ packet unless the end node or the nodes already forwarded the same RREQ based on the broadcast ID and source address are reached. Once the end node or an intermediate node with a fresher route to the destination reaches, it sends back a Route Reply (RREP) packet to the source node. The RREP packet contains essential details such as the destination, source addresses, and the destination's current sequence number. The RREQ/RREP packets can set a hop count as a constraint, avoiding loops and limiting the broadcast domain's size to ensure that the packets do not exceed a specific hop count. Additionally, the time-to-live (TTL) field in the RREQ/RREP packets prevents further forwarding when its TTL value reaches zero.

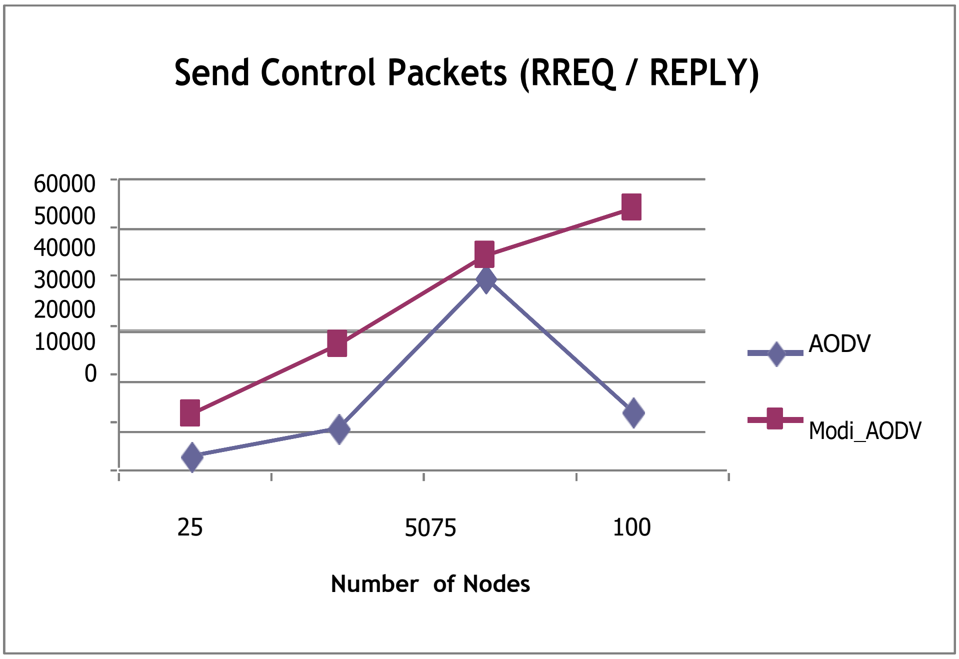

Fig. 4: Send Control Packets (RREQ/ REPLY) using various Numbers of Nodes [100]

Figure 4 demonstrates a performance comparison between AODV and Modi_AODV regarding the number of Control Packets transmitted. The graph illustrates that in Modi_AODV, the sent Control packets increase with the increment of the nodes.

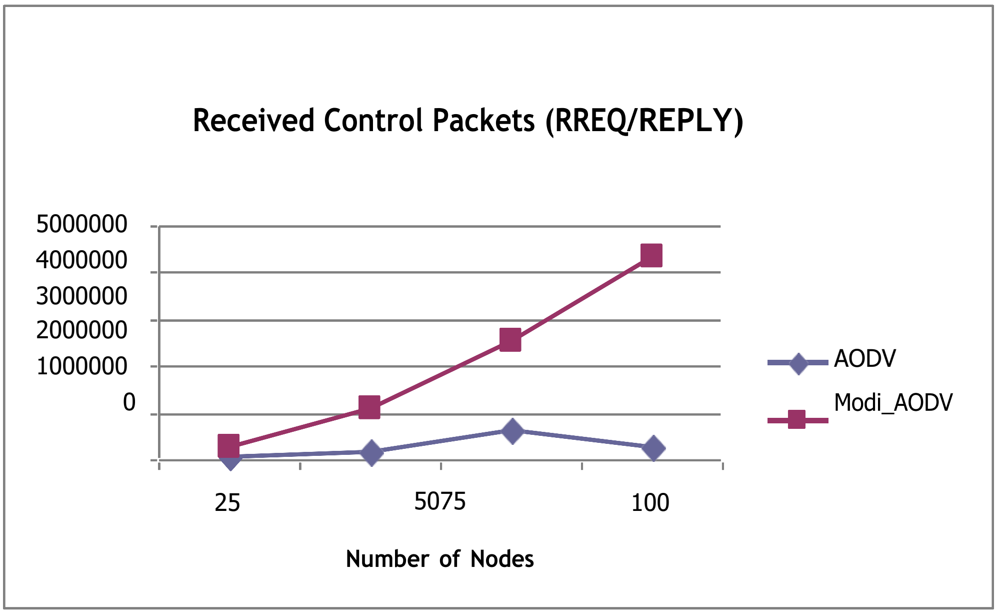

Fig. 5: Received Control Packets (RREQ/ REPLY) using various Numbers of Nodes [100]

In a wireless ad-hoc network, Received Control Packets (RREQ/REPLY) are crucial in establishing and maintaining routes between nodes. When a node needs to discover a route to a destination but lacks one, it initiates a Route Request (RREQ) packet containing the destination node's address and a unique identifier. Subsequently, when another node receives an RREQ packet, it checks whether it is the destination node itself or already possesses a route to the destination in its routing table. If it turns out to be the destination, a Route Reply (RREP) packet will sent back to the source node. Alternatively, if the receiving node has an existing route to the destination, it sends a unicast RREP to the node that initiated the RREQ. As the network expands and the number of nodes grows, the volume of broadcasted RREQ and unicast RREP packets also increases accordingly. It can lead to higher network traffic, potential congestion, and longer route discovery delays. To mitigate optimization techniques like rate-limiting the broadcast of RREQ packets and using more efficient routing metrics can be applied. As the node count increases, the transmission and reception of control packets through AODV also increase. However, this relationship is only sometimes linear, as various factors, such as network density, mobility, and interference, influence AODV's performance. Figure 5 presents the performance comparison between AODV and Modi_AODV regarding Received Control Packets. In the case of Modi_AODV, similar to Send Control packets, the count of Received Control packets is higher than AODV.

5. SWOT ANALYSIS :

In the context of "Optimizing Routing in MANETs with Energy Conservation," researchers employ SWOT analysis to comprehensively assess existing routing protocols' strengths and weaknesses concerning energy conservation, identify opportunities for innovation in routing strategies, analyze potential threats and challenges that may hinder successful implementation, compare different routing solutions, and determine the viability and potential impact of the research [35-36].

Strengths:
(1) Addresses a significant problem in MANETs.
(2) Incorporates energy conservation techniques into routing protocols, reducing energy consumption
(3) Utilizes simulations for evaluating the algorithm, enabling controlled testing across different scenarios.
(4) Results validated through real-world experiments or deployment on a testbed.
(5) Holds potential for enhancing performance and energy efficiency in MANETs, expanding their practicality for various applications.

Weaknesses:
(1) Implementation of the algorithm may necessitate substantial modifications to existing routing protocols, posing challenges and time constraints.
(2) Effectiveness of the proposed algorithm may vary in different scenarios, requiring further optimization and refinement.
(3) Simulations may not fully represent real-world network behavior, limiting the generalizability of results.

Opportunities:
(1) Possibility to further enhance and optimize the proposed algorithm for improved performance and energy efficiency.
(2) Research findings can guide the development of new routing protocols that integrate energy conservation techniques.
(3) The application of the algorithm is too diverse domains with critical energy efficiency concerns, such as IoT networks or WSNs.

Threats:
(1) Potential competition from other research teams developing more effective or efficient algorithms.
(2) Limited adoption of the proposed algorithm due to resistance from industry or regulatory bodies.
(3) Cost and complexity associated with implementing the algorithm may hinder specific organizations or applications.

The analysis identifies the strengths of the novel routing protocols in conserving energy and enhancing network performance in MANETs. Moreover, considering technological advancements and research prospects, the SWOT analysis uncovers opportunities for further innovation and improvements in energy-efficient routing for MANETs. Lastly, the analysis addresses potential threats that could hinder the implementation and adoption of the proposed strategies, allowing researchers to develop strategies to mitigate risks and ensure the research's overall viability and impact.

6. RECOMMENDATIONS :

(1) Future researchers should extend the investigation into the performance of the Modi_AODV protocol through real-world experimentation and larger-scale simulations to validate its effectiveness under diverse and dynamic network conditions.
(2) Researchers should investigate the protocol's scalability by analyzing its performance with varying node densities and exploring its adaptability through dynamic parameter adjustments.
(3) Metrics such as energy consumption per successful data transmission should be considered when creating energy efficiency standards for a more comprehensive analysis.
(4) A thorough assessment of security implications and comparisons with other contemporary energy-efficient routing protocols would contribute to a more comprehensive understanding of the protocol's strengths and limitations.
(5) Providing practical implementation insights and guides for network administrators can foster broader adoption.
(6) Discussing the long-term sustainability of energy-efficient protocols within evolving networking landscapes can shed light on their enduring relevance.

7. CONCLUSION :

Based on the evaluation of throughput, PDR, and E2E delay, it is evident that Modi_AODV outperforms AODV regarding network performance. The optimization techniques applied in Modi_AODV, which include utilizing node location information to reduce control overhead and enhance routing efficiency, have led to significant improvements. This enhanced protocol demonstrates lower E2E delay, higher throughput, and a superior PDR, showcasing its overall greater efficiency in mobile ad-hoc networks. The findings indicate that the modifications made in Modi_AODV compared to the original AODV algorithm have contributed to these performance enhancements. The route discovery process is streamlined by leveraging a path stability mechanism, leading to increased network efficiency. It is worth noting that the efficiency of a routing protocol is contingent upon the unique network conditions and attributes, which can differ based on the situation.

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