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Improving Dynamic Routing Protocol with Energy-aware Mechanism in Mobile Ad Hoc Network

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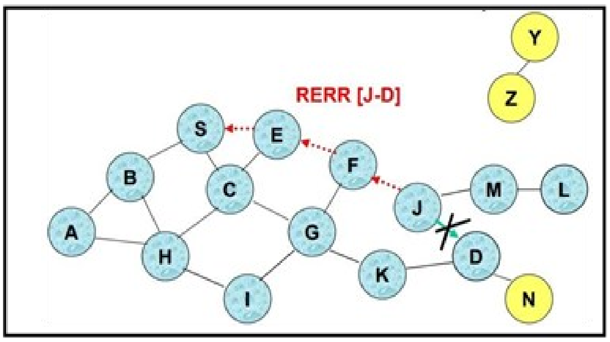
ABSTRACT



A Mobile Ad hoc Network (MANET) is designed for specific communication needs, where nodes dynamically interact. In a MANET, mobile nodes self-configure and frequently adapt to changes in topology due to their ability to move freely. Each node operates as a router, forwarding data to other designated nodes within the network. Since these mobile nodes rely on battery power, energy management becomes critical. This paper addresses the challenges of routing in MANETs by improving the Dynamic Source Routing (DSR) protocol. The proposed enhancement, termed energy-aware DSR, aims to mitigate and reduce packet loss and improve the packet delivery ratio, which often suffers due to node energy depletion. Simulations conducted with the NS-3.26 tool across varying node counts demonstrate that the energy-aware DSR protocol significantly outperforms the traditional DSR in terms of efficiency and reliability.

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1. INTRODUCTION

There are two primary types of networks: wired and wireless. A wired network connects devices to one another using physical cables, where the communication medium for transferring data is the wire. In contrast, a wireless network relies on air as the communication medium [1]-[6]. Wireless networks can be further classified into infrastructure-based and infrastructure-less networks. In an infrastructure-based wireless network, a central network to which hosts connect via a base station provides traditional network services such as address assignment and routing. Conversely, infrastructure-less networks, commonly known as ad hoc networks, do not rely on a fixed infrastructure. In these networks, the hosts themselves must provide essential network services, including routing, address assignment, and DNS-like name translation.

An ad hoc network is a specific type of wireless network that consists of at least two devices linked through wireless communication. Wireless networks offer significant advantages in various applications, including environmental monitoring, traffic management, military operations, and healthcare [7]-[10]. There are several types of ad hoc networks, such as Vehicular Ad hoc Networks (VANET), Mobile Ad hoc Networks (MANET), and Wireless Sensor Networks (WSN). This study focuses primarily on MANETs. A MANET is a collection of mobile nodes that communicate with each other via radio waves, without any centralized control or pre-existing infrastructure. These networks are self-organizing, self-managing, and adaptive, with communication established through multi-hop routing. Nodes can join or leave the network as needed, with mobile nodes capable of moving freely and randomly.

Due to their dynamic nature, the topology of MANETs frequently changes, necessitating the development of secure routing protocols. The self-configuring capability of nodes in mobile ad hoc networks allows for urgent communication without relying on fixed infrastructure. This feature makes MANETs particularly valuable in situations where immediate connectivity is required, as they can be established anytime and anywhere [11]-[13].

To guide the algorithm's development, several research questions were formulated. Performance evaluation shows a 6.2% improvement in the average packet delivery ratio compared to the standard DSR protocol, indicating its effectiveness in reducing packet loss due to energy depletion. Although the algorithm takes time to calculate node energy, it requires less time than rebroadcasting Route Request (RREQ) messages and setting up delivery paths. Moreover, the energy-aware DSR protocol exhibits lower packet loss than existing routing protocols.

2. MATERIAL AND METHODS

Researchers define an evaluation method to assess the artifact's performance. The experimental method is one such approach, utilized to measure the effectiveness of the artifact through simulation. Experimental research is a well-established technique for validating artifacts by manipulating variables and categorizing the relationships between them. All experiments and results must be reproducible. In the field of computer science (CS), this method is applied across various domains, including artificial neural networks, automated theorem proving, natural language processing, and performance analysis. Using quantitative analysis, researchers can examine the artifact's performance [14]-[17]. The methods and tools employed in this study support and validate the legitimacy of the developed algorithm.

2.1. Simulation Method

The simulation method involves designing a model of a real system and conducting experiments to assess its performance or to gain insights into the system. In this study, simulation is used to evaluate the performance of the artifact, particularly for phenomena that are challenging to understand or measure in real-world settings. Simulation allows for the emulation of real systems, providing functionality for isolated events [18]-[20].

To test the proposed protocol, constructing a large network with expensive network tools would be ideal; however, this is often impractical. Therefore, the simulation method is employed. The proposed algorithm requires mobile MANET devices, which are not readily available, making the NS-3.26 network simulation tool an appropriate choice. Simulation can facilitate complex processes that are difficult to replicate in laboratory settings, such as cosmic evolution. Various scientific fields, including astronomy, physics, and economics, as well as specialized areas like nonlinear systems, virtual reality, and artificial life, benefit from these methodologies.

Many studies have employed the NS-2 simulation tool to evaluate the effectiveness and efficiency of various algorithms, primarily due to its simplicity and compatibility [23]-[26]. However, this research utilizes the NS-3.26 simulation tool, which offers extensive libraries, comprehensive documentation, and greater compatibility with Mobile Ad hoc Networks (MANETs) compared to NS-2. One of the fundamental objectives in designing NS-3.26 was to enhance the realism of models, making them more closely aligned with the actual software implementations they represent.

Network simulation is essential for testing new protocols or modifications to existing ones within a controlled environment [27][28]. As networks of computing devices become larger and more complex, the demand for accurate and scalable network simulation technologies is critical. Despite the development of large-scale testbeds for network research, simulation remains vital for scalability (both in size and experimental speed), rapid prototyping, and educational purposes. Simulation-based studies allow for in-depth analysis at varying scales, data applications, and field conditions, resulting in reproducible and analyzable outcomes.

Among various network simulators, NS-3.26 stands out as a modular design tool that can connect to real networks. According to S. G. Gupta et al., NS-3.26 is distinct from its predecessor, NS-2, and is not compatible with it; thus, codes written for NS-2 cannot be executed in NS-3.26 [29][30]. This simulator uses C++ and Python, facilitating the integration of C++-based implementation codes. Its architecture mirrors that of Linux systems, featuring internal interfaces (network-to-device driver) and application interfaces (sockets) that align well with modern computer construction.

NS-3.26 has several characteristics and advantages. Firstly, it is not commercially supported, leading to limited resources for the long-term maintenance of its expanding codebase. Secondly, it offers ease of debugging and aligns better with current programming languages. Additionally, it emphasizes the use of standard input and output file formats, allowing for integration with external tools (such as Packet Tracer). Overall, NS-3.26 was designed to enhance the simulation experience and improve network modeling capabilities. Realism of the codes. Realism is about making the models closer to the implementation of the actual software implementations that they represent. Because of these characteristics and advantages, we used the NS-3.26 simulation tool for our work. Sample graphical animation of multiple nodes.

2.2. Proposed Algorithm

The Energy-aware algorithm is a modified version of the Dynamic Source Routing (DSR) proto-col. This proposed algorithm incorporates energy levels as a key parameter for selecting reliable routing paths. Each node calculates its remaining energy and stores this information in its routing cache can be seen in Figure 1.

In this modified approach, energy data is included in the Route Request (RREQ) message to facilitate the routing path selection process. Only nodes with sufficient energy participate in disseminating this infor-mation. Once the destination node receives the RREQ, it sends a Route Reply (RREP) back to the source node. After the source node receives the RREP, it can then send the actual data packet through the estab-lished route.

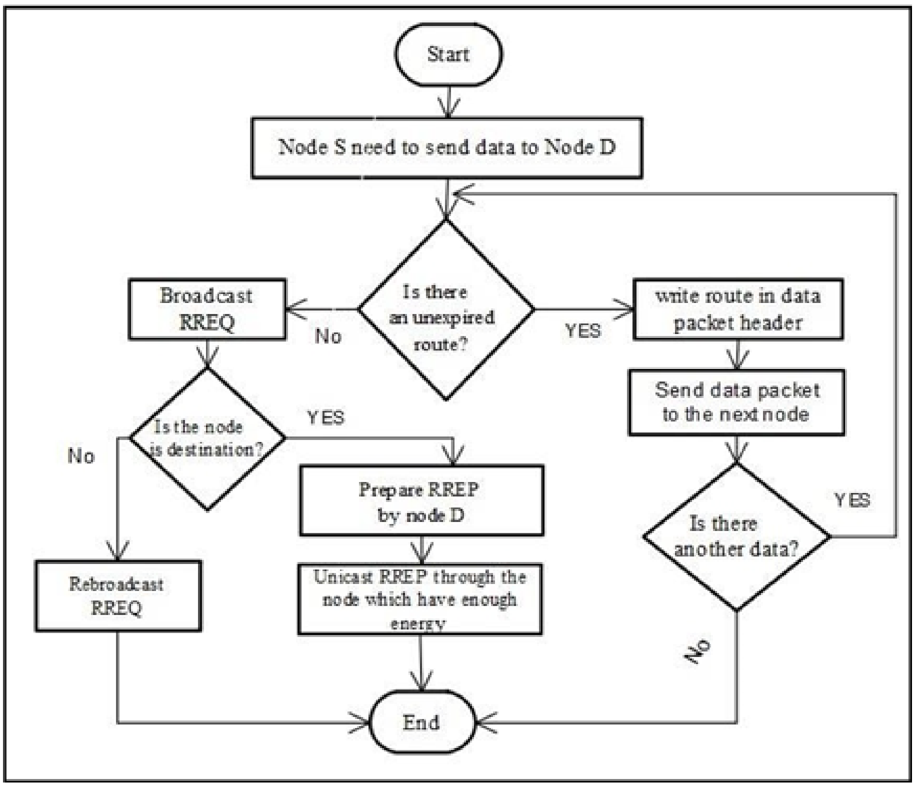

Figure 1. Flow of Activity to Discover a Routing Path

In this article, we design an energy-aware Dynamic Source Routing (DSR) protocol aimed at reducing packet loss and increasing the packet delivery ratio in MANETs. During the route discovery process, nodes with minimal energy are excluded from route selection. Each node calculates its remaining energy and stores this information in its route cache. It then checks if its remaining energy exceeds a predefined threshold.

If an intermediate node's remaining energy falls below this threshold during route discovery, the algorithm reconstructs the path before sending the actual packet. This calculation provides current energy values for nodes, enabling the selection of appropriate relay nodes. The following criteria are used to assess the remaining energy of a node; some are predefined, while others are derived from calculations. Threshold value: which is the maximum of the energy of nodes that can't process any activity. "Threshold Value" denotes it. The threshold value is initialized to analyze the effect of minimum energy on packet loss, delay, and packet delivery ratio.

Threshold Value: 1 Joule {1}

Node Request Period: The base time interval for route requests encompasses delays from queuing, interrupt processing, and transfer times, referred to as "m_requestPeriod." This value is obtained from the DSR module, which provides it directly.

m_requestPeriod = 40 milliseconds {2}.

Network Diameter: This metric indicates the maximum number of hops possible between any two nodes within the network, represented as "Net Diameter" and expressed as an integer. While the network diameter can be adjusted, the study focuses on its effects rather than changing it.

Net Diameter = 35 {3}.

Maximum Request Period Time: This is the maximum time interval allowed between route requests, labeled as "m_maxRequestPeriod," and is measured in seconds [21][22].

m_maxRequestPeriod = m_requestPeriod * Net Diameter {4}.

In the current Dynamic Source Routing (DSR) protocol, the source node S, which broadcasts a Route Request (RREQ) to all neighboring nodes, initiates the route discovery process. The source node evaluates the hop count to determine the optimal path and sets a time-to-live (TTL) value to resend the RREQ if a Route Reply (RREP) is not received within the specified time.

When an intermediate node receives the RREQ, it checks if the destination address matches its own. If it does not match, the node forwards the RREQ and stores the route information in its cache. If the node is the intended destination, it sends an RREP back to the source node S.

In the case of a link failure, a Route Error (RERR) message is generated to notify other nodes of the problem. For example, if communication between nodes J and D is disrupted, node J will send a route error message back to the source node along the reverse path can be seen in Figure 2.

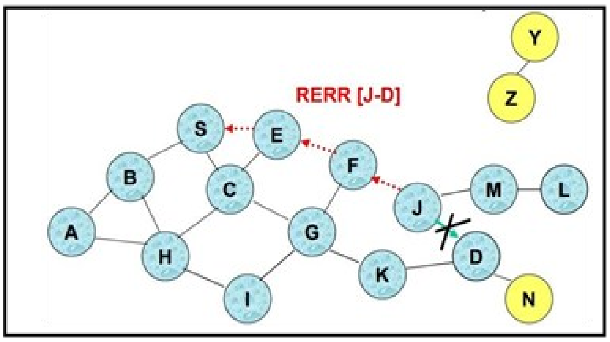

Figure 2. Propagation of rout error message

3. RESULTS AND DISCUSSION

3.1. Packet Delivery Ratio

The packet delivery ratio (PDR) is defined as the ratio of the total packets received by the destination node DDD without error to the total packets sent by the source node SSS. A total number of lost packets is used to calculate the total number of delivered packets (RX = TX – Total lost packets). The packet delivery ratio of our developed algorithm for a small number of nodes is better. When the number of nodes increases in the developed algorithm, PDR relatively decreases. Figure 3 shows the PDR result of the protocols when the number of nodes changed by keeping the other parameters constant. In our study, the packet delivery ratio of the developed algorithm shows better performance with a smaller number of nodes. However, as the number of nodes increases, the PDR tends to decrease. Figure 4 presents the PDR results of the protocols while varying the number of nodes, with all other parameters held constant.

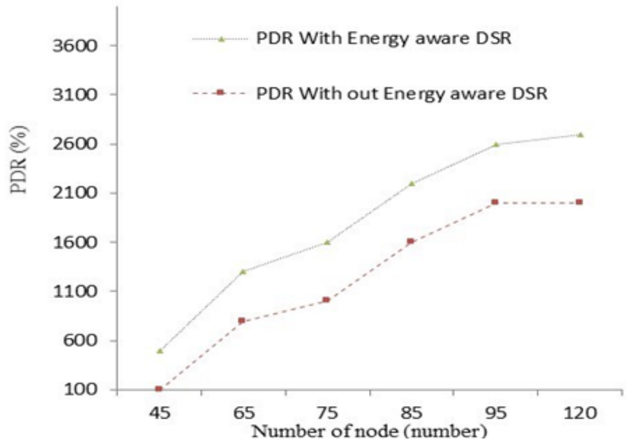

Figure 3. Graph illustrating the Average Packet Delivery Ratio with different numbers of nodes

3.2. Packet loss

Packet loss refers to the difference between the number of packets sent from the source and the number of packets successfully received at the destination. It refers to the number of packets that are lost because of various factors, including high queuing times within the network and resource limitations such as energy exhaustion of nodes.

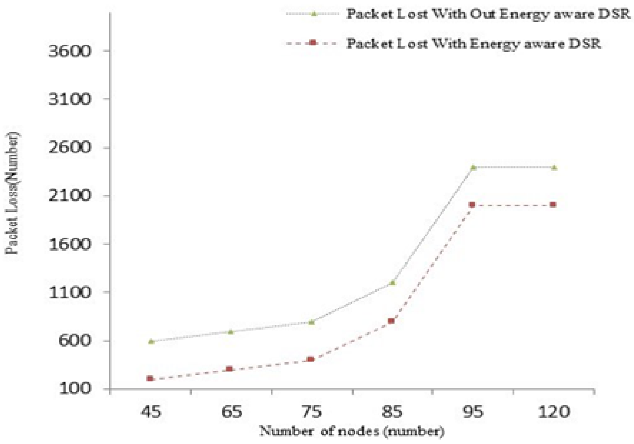

Figure 4. Packet loss graph with a varying number of nodes

3.3. Discussion

The objective of this article is to develop an energy-aware Dynamic Source Routing (DSR) protocol for Mobile Ad hoc Networks (MANETs). The effectiveness and efficiency of this algorithm are evaluated using specific performance metrics, including packet delivery ratio and packet loss. The primary aim is to reduce the number of packets dropped due to energy depletion.

To guide the development of the algorithm, several research questions were established. Evaluation of the algorithm's performance indicates that the average packet delivery ratio improves by 6.2% compared to the standard DSR protocol. This enhancement demonstrates the algorithm’s ability to reduce packet loss associated with energy depletion. While the algorithm requires time to compute the remaining energy of the nodes, this time is still less than that needed for rebroadcasting Route Request (RREQ) messages and constructing paths for packet delivery within the network. Additionally, the packet loss associated with the energy-aware DSR protocol is lower than that of existing routing protocols.

The implementation was tested with varying numbers of nodes, yielding superior results in packet delivery ratio compared to previous works [31]-[40]. Overall, this study demonstrates that it is possible to effectively reduce packet loss and enhance the packet delivery ratio in MANETs.

4. CONCLUSION

This article presents the development of an effective energy-aware Dynamic Source Routing (DSR) protocol aimed at enhancing performance metrics such as packet delivery ratio and packet loss in Mobile Ad hoc Networks (MANETs). The researchers posed key questions to guide their investigation and established objectives that were successfully met throughout the study. Our findings indicate that the energy-aware DSR protocol performs better than the existing routing protocols when evaluating packet delivery ratios and packet loss. However, both protocols face challenges in dense networks. As the number of nodes increases, packet loss and end-to-end delay rise, while the packet delivery ratio declines. This degradation is primarily attributed to the limited buffer size within the protocols.

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