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Integration and Performance Evaluation of Proposed Protocol in MANET

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***Abstract*— This study compares the efficiency of an introduced routing protocol versus current protocols (AODV, DSR, DSDV) in measuring how efficient the new algorithm might be in MANET environments through simulations. Scalability and adaptability with this experimental research design are probed using two scenarios involving distinct node densities: 50 nodes, 70 nodes, 90 nodes, and 110 nodes; with node speeds at 15 m/s, 30 m/s, 45 m/s, and 60 m/s. The average end-to-end latency, energy consumption, packet delivery ratio (PDR), normalized routing load (NRL), and throughput are the five metrics used to measure performance in this area. Since the PDR drops as the number of nodes and their mobility speeds rise, while NRL, latency, and energy consumption all go up, this points to problems with maintaining network performance in such cases. The proposed protocol outperformed AODV, DSR, and DSDV on all aspects, such as higher PDR, lower NRL, less delay, better throughput, and less energy usage. Statistical analysis verified the statistical significance of the improvements at $p < 0.05$. According to the results, the proposed protocol forms a potential answer for future MANET applications in the context of providing high advantages for the optimization of MANET performance, particularly in highly dense and mobile environments.**

***Index Terms*—MANET, Routing Protocols, Performance Metrics, Destination-Sequenced Distance-Vector (DSDV), Dynamic Source Routing (DSR), Ad-hoc On-Demand Distance Vector (AODV).**

I. Introduction

Networks of temporary wireless mobile hosts operating independently of fixed infrastructure and centralized management are known as mobile ad hoc networks. The characteristics that characterize a mobile ad hoc network are its wireless connectivity, dynamic topology, dispersed functioning, and simplicity of implementation. The system can function alone or connect to an existing network through gateways. Instead of having stationary routers, nodes in an ad hoc network are free to roam and form connections as needed. These networks rely on routers to establish and maintain connections to other nodes. The transmission power and location of mobile nodes determine the topology of an ad hoc network, and these factors might alter over time. When the efficiency or practicality of wired or mobile networks are compromised, ad hoc networks step in.

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The following are some examples: virtual classrooms, biological detection, tracking rare animals, space research, undersea operations, and infrastructure devastated by an earthquake. Data packets can be efficiently distributed across MNs using ad hoc routing techniques, even in the absence of a predetermined topology or centralized control. The rapid topological changes in mobile ad hoc networks make routing a challenging task.

A. Routing in MANET

MANET routing is challenging due to its dynamic nature, frequent topology changes, and multi-hop communication. Nodes frequently communicate routing control information, which leads to overhead. MANET routing protocols are either reactive, proactive, or hybrid.

- AODV: reactive discovery of routes and maintainer; routes are used and found only when needed, maintaining each node's information table in the route cache, and idle routes will be deleted after sometime.
- DSDV: Bellman-Ford-based proactive protocol: Nodes maintain tables of routing with next hop and hop count for reachable destinations. Routing tables are broadcast periodically to update all nodes to maintain communication in dynamic situations.
- DSR: A call-by demand protocol Dynamic Source Routing employs packet headers that provide a source route; as paths are discovered nodes update the caches. That protocol tends to make routes easier to maintain and forbids table exchange.

B. Objectives of the study

- To assess and contrast the suggested MANET protocol's performance with that of AODV, DSR, and DSDV.
- To examine flexibility and scalability over a range of mobility speeds and node densities.

II. LITERATURE REVIEW

Sathyaraj, P., & Rukmani Devi, D. (2021) suggested RSRA as a method for Manet secure routing in real-time. We go over the strategy of route-finding intermediary nodes, Internet of Things devices, and their trustworthiness. The initial step of this method is to identify every possible route from one point to another. Each mobile node's reliability is determined by a number of elements, including its location, mobility speed, energy, quantity of transmissions, and neighbor list. They can trust IoT devices because they are network-supported. They track the support for Internet of Things devices (DS) and mobile nodes' secure routes (MSRS). Using these two parameters, the technique determines data forwarding support (DFS) by tally of all IoT devices along the path. In order to enhance Manet's QoS, the DFS measure chose one specific path. Methods for developing quality of service are introduced and routing in Manet is examined. The routing process, however, considers modern IoT devices. They talk about how to measure the trust of Internet of Things devices and how to engage them in Manet routing. Various safe routing protocols for Internet of Things devices were detailed by Manet. Many qualities of service metrics are difficult for them to enhance.

Alnabhan, et al. (2017) focused on the appearance and functioning of categories. MANETs use mobile nodes to create a short-lived wireless network. To communicate, every MANET node needs to know how to route. Route optimization is critical for MANET pathways because they are multi-hop and fragile. Protocols for routing data based on topology and position are available.

An obstacle to improving MANET QoS is the efficacy of these protocols in extremely dynamic and crowded environments. Both sets of metrics were evaluated in a performance review, including end-to-end latency, packet delivery ratio, and routing overhead. In busy, ever-changing environments, position-based protocols appear to be more effective than topology-based ones. They recommended position-based methods for the future that are efficient.

Hamdi, et al. (2020) displayed two theoretical models and predicted performance quality of service metrics. Ad hoc wireless networks have recently captured the attention of consumer and academic communities across the globe. A large-scale sensing task is accomplished by coordinating the efforts of several small autonomous networking, connection, and sensing units that use little power and computational resources. In order to accomplish a large-scale sensing aim, wireless sensor systems integrate numerous sensing devices with specific computer technologies, limited power sources, and processing power. Battery scavenging is one of the problems with IEEE802.11b wireless sensor networks.

For this device to work properly, wireless motes are required. Grid architecture is 15% slower than star topology. The average end-to-end delay in a star network is 17.25 ms, while in a grid network it is 76.25 ms. In every trial, the star topology demonstrated lower jitter as the data rates increased from 1 to 11 Mbps, but the grid architecture did not. On average, a star network used 0.065 mWh of energy, whereas the grid used 0.045 mWh.

Kaushik, et al. (2021) provided methods for routing. Throughput and end-to-end delay are evaluated using the ns2 simulator. We talk about optimization using ant colonies and optimization based on swarm intelligence. As a species, we rely heavily on computers. With the exponential growth of information in our daily lives, new ways of accessing it have emerged. Wireless networks function optimally in the absence of a design based on infrastructure. Through the network, nodes carry information from one location to another. With their multihop routing, independent terminals, distributed operations, and dynamic network topology, these radio-frequency nodes are like a network on steroids. Topology changes regularly because nodes can be moved, which makes routing a challenge. Another issue that needs to be addressed in order to prolong the life of the network is energy conservation. Proper preparation and growth estimation are required due to the fact that deployment is different from wired. To communicate securely, you need to use secure methods.

Veeraiah, et al. (2021) prompted the routing protocol to choose this multi-path in an attempt to improve MANET mobility. The unpredictable topology and limited resources make it difficult to implement energy-efficient and secure routing in this network. We propose C-SSA, a hybrid technique to MANET navigation that is trust-based secure and energy-efficient, to determine the optimal routing steps. Fuzzy clustering selects cluster heads (CHs) based on recent trust, indirect trust, and direct trust. Furthermore, nodes were identified that have trust levels. An essential part of multi-hop routing is CHs; in this lesson, we'll see how the projected hybrid protocol uses latency, throughput, and connectivity to find the optimal path. With just 0.11 MJoules of energy, the proposed method achieved 0.005 msec of delay, 0.74 bps of throughput, 0.99% of packet delivery ratio, and 90% of detection rate. In order to evaluate the proposed approach, we compared it to existing methods that use and do not use selective packet dropping. Khudayer, et al. (2023) aimed to gauge the routing overhead, scalability, and latency of the three MANET routing technologies, among other metrics. A MANET is a decentralized network of mobile, wireless nodes that can establish connections via a series of hops rather than relying on a fixed set of rules or preexisting infrastructure. Applications in intelligent transportation systems, ad hoc gaming, smart agriculture, disaster rescue, and wildlife surveillance all make use of MANET. Improving MANET performance is mostly concerned with routing mobility management. There are routing protocols that are proactive, reactive, and hybrid. We aim to weigh the benefits and drawbacks of various techniques in this research. Evidence that assertive policies guarantee the availability of routes. But scalability and overhead are problems. Protocols that are reactive wait for data transmissions before discovering routes. But reactive protocols slow down network performance by delaying route building. The operational complexity is increased with hybrid protocols, but the information is kept current using reactive and proactive protocols. These protocols are well-suited for big networks. If MANET is to meet performance standards, it must undergo routing modifications.

III. Research Methodology

A. Research Design

Simulations have been applied for the experimental investigation with MANET routing protocols, where the protocol integration developed here is analysed and performance has been made against already established protocols AODV, DSR, and DSDV.

B. Performance Metrics

Those performance metrics are used in analysing the protocols:

- PDR: Packet Delivery Ratio Percentage of packets received successfully to packets transmitted:

$$PDR = \frac{Number\ of\ Received\ Packets}{Number\ of\ Sent\ Packets}$$

- NRL: One way to evaluate the effectiveness of routing overhead is by looking at the Normalized Routing Load, or NRL. After calculating:

$$NRL = \frac{Number\ of\ Routing\ Packets}{Number\ of\ Data\ Packets\ Delivered}$$

- Average End-to-End Delay: The typical amount of time it takes for data packets to travel from their origin to their final destination.
- Throughput: throughput is a performance metric for networks that measures the quantity of data that can be successfully delivered in a specific time frame.

- Average Energy Consumption: The mean power use of the nodes during the experiment when they were transmitting, receiving, idle, or sleeping.

C. Simulation Scenarios

Two simulation scenarios were utilized to assess the proposed technique under various environments. Scenario 1 used the important parameters of PDR, NRL, Average End-to-End Delay, Throughput, and Energy Consumption with 50, 70, 90, and 110 nodes. Such a simulation tests the scalability and the performance of the network for different densities.

Scenario 2. Test the protocol's sensitivity in dynamic network conditions by setting the nodes to 80 numbers and varying the mobility velocities at 15, 30, 45 and 60 m/s, to compare the performance from different operational situations, use equal metrics. Here are two examples where they can be effectively integrated:

- Node Density (Disaster Recovery): For MANET used by a rescue team in a disaster recovery environment, the PDR drops as node density goes up. When standard infrastructures are not available due to the crowded area of deployment, the proposed protocol assists in communication improvement.
- Military Operational Mobility Speeds: Increased mobility results in decreased PDR and throughput within a military operation where troops are moving at speeds that range from 15 m/s to 60 m/s. In high-mobility environments, the proposed protocol provides guaranteed communication and avoids performance drops.

D. Tools and Software

To ensure the accuracy and reliability of the simulation and analysis procedures, a set of tools and software were adopted. The main tool that was used for modeling the MANET environment and actually implementing the protocols was NS-2.34, which is known as the Network Simulator. The trace files were analyzed and performance data relevant to the needs were extracted by using the AWK scripts in depth. Graphical tools were used to represent data, making it easier to compare the performance of the protocol in different settings.

IV. Data Analysis

Results from the simulations of two test scenarios are presented here to validate the proposed MANET routing protocol. Performance is measured using metrics such as PDR, NRL, Average End-to-End Delay, Throughput, and Energy Consumption. The results obtained in each scenario are analyzed and concluded upon, followed by comparisons in statistics between the proposed protocol and existing protocols-AODV, DSR, and DSDV.

A. Scenario 1: Variable Node Density

Scenario 1: Test for Network Density Variation Scenario 1 tested the protocol performance when the network density is changed. The experiments used varied node densities. The results from simulation runs with four node densities-50, 70, 90, and 110 nodes-performed are listed in table below.

Table 1: Metrics of Performance for various Node Densities

Metric	**50 Nodes**	**70 Nodes**	**90 Nodes**	**110 Nodes**
Packet Delivery Ratio (PDR) (%)	95.3	92.4	90.1	87.5
Normalized Routing Load (NRL)	1.2	1.5	1.7	2.0
Average End-to-End Delay (ms)	50.2	55.6	62.1	68.3
Throughput (kbps)	320	305	290	275
Energy Consumption (J)	0.35	0.38	0.41	0.44

Scenario 1: Table 1 reflects that the density of nodes impacts protocol performance. As the number of nodes increases from 50 to 110, PDR has decreased from 95.3% to 87.5%.

With a greater number of nodes, more packets could not be forwarded. Node density increases NRL from 1.2 for 50 nodes to 2.0 for 110. As the network density increases, more routing packets have to be sent to maintain communication and thus increase routing overhead.

A higher node density increases the time it takes to send packets as the Average End-to-End Delay rises from 50.2 ms at 50 nodes to 68.3 ms at 110 nodes. Node density reduces throughput from 320 kbps to 110 nodes at 275 kbps, signifying that network congestion leads the data transfer efficiency to go low.

Finally, node density increases energy consumption from 0.35 Joules in 50 nodes to 0.44 Joules in 110 nodes; possibly the increasing network activity and forwarding of packets is the main cause.

B. Scenario 2: Varying Mobility Speeds

Protocols were tested according to the various mobility speeds in Scenario 2, where the number of nodes is set at 80 and the speeds of the nodes are 15, 30, 45, and 60 m/s. Below, in Table 2, you can find a summary of the results.

TABLE II: METRICS OF PERFORMANCE FOR VARYING MOBILITY SPEEDS

Metric	15 m/s	30 m/s	45 m/s	60 m/s
Packet Delivery Ratio (PDR) (%)	92.7	89.4	85.1	82.3
Normalized Routing Load (NRL)	1.4	1.6	1.8	2.1
Average End-to-End Delay (ms)	55.4	60.8	67.2	72.5
Throughput (kbps)	310	290	270	250
Energy Consumption (J)	0.37	0.40	0.43	0.47

Table 2 performance of the protocol under Scenario 2 with nodes count of 80, speed in terms of mobility 15, 30, 45 and 60 m/s Packet delivery ratio decreases from 92.7% when mobility is 15 m/s down to 82.3% when mobility is at 60 m/s. From the given results, it's concluded that higher mobility speeds hinder communications and packet delivery operations. NRL grows from 1.4 at 15 m/s to 2.1 at 60 m/s, implying that nodes that move at a higher speed require a more routing packet, thereby increasing routing overhead. Fast nodes will also cause delay in transmission of packets because Average End-to-End Delay increases from 55.4 ms at 15 m/s to 72.5 ms at 60 m/s. As mobility speed is increased, throughput decreases from 310 kbps at 15 m/s to 250 kbps at 60 m/s, indicating faster node movement degrades the efficiency of data transmission. Lastly, Energy Consumption increases linearly with mobility speed from 0.37 Joules at 15 m/s to 0.47 Joules at 60 m/s, indicating higher mobility speeds require more energy since the complexity of the connection of the network and packet forwarding is higher.

C. Statistical Comparison and Discussion

It evaluated the statistical analysis of some of the most crucial key performance measures by showing how much performance difference is between proposed protocols and the already existing ones. Both scenarios simulated used Packet Delivery Ratio, Normalized Routing Load, Average End-to-End Delay, Throughput, and Energy Consumption metrics; the results revealed that in all those, the suggested protocol had higher gains on them all ($p < 0.05$) suggesting it has a possible capacity to improve the MANET's performance.

TABLE III: STATISTICAL COMPARISON OF PROTOCOLS

Metric	Proposed Protocol	AODV	DSR	DSDV
Packet Delivery Ratio (PDR) (%)	92.3	85.7	83.9	80.1
Normalized Routing Load (NRL)	1.5	1.8	2.0	2.2
Average End-to-End Delay (ms)	58.5	65.2	70.0	75.8
Throughput (kbps)	295	270	260	245
Energy Consumption (J)	0.39	0.44	0.47	0.50

Table 3 compares the proposed protocol's performance metrics with the existing protocols (AODV, DSR, and DSDV) The proposed technique has a significantly higher PDR of 92.3% compared to AODV (85.7%), DSR (83.9%), and DSDV (80.1%). The proposed method improves the efficiency of packet distribution. The proposed protocol (NRL = 1.5) is significantly more efficient in terms of transferring data with fewer routing packets compared to AODV having NRL = 1.8, DSR having NRL = 2.0, and DSDV having NRL = 2.2 and higher routing overhead. The average end-to-end delay has been found to be less by the proposed protocol compared to AODV, DSR, and DSDV, which are 58.5 ms, 65.2 ms, 70.0 ms, and 75.8 ms, respectively. The proposed protocol has a better data transmission performance compared to AODV (270 kbps), DSR (260 kbps), and DSDV (245 kbps) with its throughput of 295 kbps. Conclusion: The proposed procedure is more energy efficient than AODV, DSR, and DSDV as it consumes only 0.39 J compared to 0.44, 0.47, and 0.50 J, respectively.

V. FUTURE SCOPE

Future studies may entail the investigation of mobility models, node behaviors, or dynamic traffic loads. The protocol might be improved further by using machine learning for energy management and adaptive routing. Among other possible developments, testing the protocol in heterogeneous networks with other node capabilities and including security mechanisms for data protection are other likely areas of development. Testing on other applications and real-world implementation would confirm the efficacy even more.

VI. CONCLUSION

The suggested MANET routing protocol is thoroughly evaluated and contrasted with the current protocols, AODV, DSR, and DSDV, across many circumstances. The results showed that the suggested protocol outperformed the current protocols on several important performance metrics, including energy consumption, packet delivery ratio, average end-to-end delay, normalized routing load, and throughput. This is indicated in the proposed protocol with its improved scalability and adaptability as network parameters like node density and mobility speed increase complexity, ensuring efficient communication in challenging environments. Statistical analysis validated the need for such improvements, which then positioned the proposed protocol as a viable means for performance enhancement in MANET practical settings, including military applications and disaster recovery scenarios.

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