Comparison of Multipath Protocol Improvements in SMMSN-AOMDV and MAN-AOMDV for Stable Node Selection in Ad Hoc Networks

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Abstract: The future of the wireless networks holds a significant promise, particularly in the domain of the Mobile Ad hoc NETworks (MANETs), which continue to attract a growing academic interest. As MANET usage expands across diverse applications and user demands increase, an enhanced performance and reliability have become critical. Ensuring the Quality of Service (QoS) is essential for effective communication, with load balancing in routing protocols playing a vital role in optimizing the resource management and improving the overall network performance. In this study, two enhanced multipath routing protocols are proposed – SMMSN-AOMDV (Stable Multi-path Selection with More Stable Nodes in AOMDV) and MAN-AOMDV (Multi-path Routing with Available Nodes in AOMDV)—specifically designed to improve route stability and load distribution in MANETs. The approach introduces a novel load balancing mechanism within the AOMDV protocol by selecting the paths based on node-level parameters and dynamically distributing traffic across less congested nodes during data transmission. The proposed protocols are implemented and evaluated using NS2 (Network Simulator 2). The simulation results demonstrate that the enhanced protocols significantly improve the key performance metrics, including the packet delivery ratio, throughput, and end-to-end delay.

Keywords: AOMDV, NS-2, load balancing, QoS, wireless networks, MANETs.

1. Introduction

The Mobile Ad-hoc Network (MANET) (Mallikarjun & Kapinaiah, 2021) is a group of self-configuring (Mustafa et al., 2020), constantly changing, and multi-hop mobile devices that connects to each other wireless to create a communication network (Ahmed, 2021), without any centralization. MANET is a self-organizing network, where nodes that are within one another's communication may communicate with one another in the network (Agrawal, Jain & Mohan, 2020; Kanthimathi & Prathuri, 2020; Le, A.N. & Le, V.M., 2020; Ma & Capili Kummer, 2020). Both civilian and military settings might benefit from the use of mobile ad hoc networks. Routing is a difficult issue since the present path is rendered ineffective and impractical by the dynamic changes in the topology of MANET (Sharma, Saini & Kumar, 2018; Ma & Capili Kummer, 2020; Sharma N., Sharma, M. & Sharma, D.P., 2020; Kurumbanshi et al., 2021; Gao, Zang & Wang, 2021). Routing, security, and QoS (Quality of Service) provisioning are the core problems for the mobile Ad-hoc networks, which are mostly caused by node mobility, connection failure, and constrained bandwidth. With limited power, processing, and memory capacity, the routing issue in MANETs is to offer an efficient path for data forwarding in a shorter amount of time (Grossi, Lops & Venturino, 2016; Latchoumi et al., 2020; El-Hadidi & Azer, 2021). The issue with the current routing protocols is that traffic is not fairly distributed throughout the pathways in the network, as a result, the nodes located in densely populated regions are utilized more frequently by various paths and eventually reach their capacity, which lowers the routing protocol's performance. In order to divide the burden in the network equitably, a load balancing capability has to be introduced to the current protocols. The ad hoc on-demand multipath distance vector (AOMDV) and other multipath routing protocols can assist in maintaining backup routes in the event of a route breakage, but they do not yet offer any load balancing features because they only use the primary path for the purpose of transmitting data in less mobile environments where there is little to no chance of a route breakage.

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The method of routing involves sending packets along the most efficient link to their destination. According to the availability of the route, MANET routing is divided into two categories. 1. Proactive routing: The nodes in a wireless Ad-hoc network should maintain a list of routes to all potential destinations so that, in the event that a packet has to be sent, the route is already known and may be utilized right away. 2. Reactive routing: A node starts the network's route discovery process when it has to deliver packets to a destination but lacks a route there. Once formed, a route is kept up by a route maintenance process until the destination is further reachable or the route is further required.

This article proposes two enhanced routing protocols: (1) SMMSN-AOMDV, and (2) MAN-AOMDV. These protocols are designed to improve the efficiency and reliability of the AOMDV framework by promoting a more balanced use of a network resources and enhancing the route stability through a strategic path selection.

The paper is organized as follows: Section 2 reviews the related work relevant to this study. Section 3 details the proposed methodology, including the design and implementation of SMMSN-AOMDV and MAN-AOMDV using NS-2 (Network Simulator 2) with C++ modules. Section 4 presents the simulation setup, scenarios, and analysis of the results. Finally, Sections 5 and 6 provide the conclusion and outline the potential directions for future research.

2. Related work

Several approaches have been proposed to achieve the load balancing in multi-path routing for MANETs. The paper (Sarhan, Shahenda & Sarhan, Shadia, 2021) introduced the Elephant Herding Optimization (EHO) algorithm, which divides node populations into two groups based on their energy levels – a process referred to as the separation operator. EHO aims to optimize the energy usage by assigning high-energy nodes to one group and the remaining nodes to another. The nodes in the first group have more energy than required to forward the complete packet load, while the second group contains the lower-energy nodes.

Compared to protocols like ACO-FDRPSO (a combination of Ant Colony Optimization - Fitness Distance Ratio Particle Swarm Optimization) and AOMDV (Ad hoc On-demand Multipath Distance Vector), the routing overhead in the proposed EHO-AOMDV protocol increases more gradually. Among the three bio-inspired algorithms – EHO, ACO-FDRPSO, and FF-AOMDV (Fitness Function-AOMDV) – all exhibited higher delay than AOMDV. However, EHO-AOMDV demonstrated a lower energy consumption, while AOMDV had the highest energy usage.

In terms of routing overhead, packet delivery ratio, average energy consumption, and the number of dead nodes, EHO-AOMDV outperformed ACO-FDRPSO, FF-AOMDV, and the original AOMDV. However, AOMDV exhibited a better performance in the end-to-end delay. This difference is attributed to the lower computational complexity of AOMDV, which requires less processing to discover and maintain routes. The authors recommend using EHO-AOMDV in the application domains such as banking, marketing, and management, where the high packet delivery rates and energy efficiency are prioritized over latency.

(Masruroh et al., 2020) explored the impact of the malicious nodes on the energy efficiency of the AOMDV protocol. Their study showed that as the number of malicious nodes increases, the frequency of the routing process also increases due to the packet drops caused by these nodes. Consequently, the throughput decreases, the packet loss increases, and the energy consumption rises because more packets are dropped and must be retransmitted. Interestingly, the lifetime of the nodes increases as they consume less energy when not actively forwarding packets – since packets are discarded early. However, the resulting decrease in throughput degrades the overall network performance.

(Soni et al., 2020) proposed the DREAM Multipath Routing (DMR) protocol, which improves upon multipath routing by maintaining the latest positional data of each node relative to others. DMR performs better under dynamic conditions than the traditional AOMDV, particularly under heavy network loads. DMR uses a reactive routing mechanism, meaning that the routing information is removed from the memory after the routing process is complete.

(Bhardwaj & El-Ocla, 2020) introduced a new fitness function (FFn) in conjunction with the AOMDV protocol to determine the optimal paths between the source and the destination nodes. They proposed two variants: AOMDV-FFn, which integrates the FFn directly into the AOMDV without genetic algorithm (GA) operations like crossover or mutation, and the AOMDV-GA, which combines the AOMDV with the GA techniques. The FFn selects paths based on the shortest distance, maximum residual energy, and minimal congestion. To support this, the authors also introduced the TCP Congestion Control Enhancement for Random Loss (TCP CERL), which can distinguish between the random and the congestion-related packet losses. The routing protocols using FFn showed an improved performance in the throughput, packet delivery ratio, energy efficiency, and end-to-end delay, particularly under the conditions involving random loss and congestion. In summary, the AOMDV-FFn and the AOMDV-GA outperform the traditional routing protocols in simulations, making them strong candidates for the dynamic MANET environments.

3. Proposed methodology

AOMDV preserves many pathways for data transfer, but it only utilizes one path while it is still active and stores the others as a backup. If the primary path does not fail and the other pathways are never utilized if the primary path remains valid, this might result in substantial overhead on a single path and resource waste. To overcome this problem, we propose two Protocols: 1 - A Suitable Multi-path of More Stable Nodes on AOMDV (SMMSN-AOMDV), 2 - A Multi-path of Available Nodes on AOMDV (MAN-AOMDV). In order to distribute the data and the load along the paths, the first Protocol considered the hop count, source path number, destination path number, and the current node as a metric for suitable path selection by more stable Nodes in the path eliminating a potential bias of the path usage in the network. The second protocol considered the hop count and Source path number to get the multi-path depending on the available Nodes. Furthermore, in the RREQ (Route Request Phase) packet, the hop count and Source path number fields are added. These parameters in the request are used to determine the route. The key variables used in the pseudocode of the SMMSN-AOMDV and MAN-AOMDV algorithms—along with their definitions—are listed in Table 1. The term routing table refers to a local data structure maintained by each node in the MANET, which stores the information about known routes to various destinations, including path identifiers and node IDs, and is used to make the forwarding decisions.

Table 1. Key Variables and Their Descriptions in SMMSN-AOMDV and MAN-AOMDV Algorithms

Variable	Description
Source_path_number	Unique ID for a reverse path initiated by the source
Destination_path_number	Unique ID for the forward path back to the source
Current_Node	Node currently processing the control packet
Hop_Count	Number of hops from the source to the current node
Table_Source_path_number	Stored path number in routing table used for comparison
Table_Current_Node	Node ID from stored reverse path in routing table
Index	Unique node identifier
RREQ	Route Request packet
RREP	Route Reply packet

3.1. SMMSN-AOMDV

The Source node starts to send the RREQ packet to transmit the data while there is no specific route selected to the destination. Then each neighbor node assigns a self Id in the Source path number of the RREQ to identify the current reverse path which is the path number that defers from another reverse path. The Source neighbor node is assigned when the hop count equals to zero.

By the time the node receives the RREQ, if there is a fresh route, then it sends a reply to the source, otherwise, it compares the available reverse path in the routing table with the Source path number and the current Node (Neighbor Node) in the RREQ to obtain a fresh route.

The node will accept and forward the RREQ if it is the first time or if it exists in the same path of the routing table. This shows that the current node is stable, otherwise, the node will not be selected due to its high mobility, which means the node came from a different path. As a result, the quality of the path will be affected by confusing the sequence of the nodes and it leads to chaos. The same process happens during the RREP control Packet if the destination node sends the RREP and stores the Destination path number. Here each node sends the next reply to the same source node only with the same RREP destination path number or the first RREP.

SMMSN-AOMDV Algorithm

```
// Route Request (RREQ) Phase
Initialize Source_path_number = 0
Send RREQ()

if RREQ_Hop_Count == 0 then
   Source_path_number ← Index  // Assign path ID at source neighbor
end if

Insert_RREQ_path(Source, Source_path_number, Current_Node, Hop_Count + 1)
Current_Node ← Index  // Update current node

if RREQ_Destination == Index OR lookup(RREQ_Destination == Table_Destination) then
   Initialize Destination_path_number = 0
   Send RREP()
end if

// Node stability check
if Source_path_number ≠ Table_Source_path_number AND Current_Node ≠ Table_Current_Node
then
   Delete(path)     // Node considered unstable
   Drop RREQ        // Discard unstable path
end if

// Route Reply (RREP) Phase
if RREQ_Hop_Count == 0 then
   Destination_path_number ← Index  // Assign destination path ID
end if

Insert_path(Destination, Destination_path_number, Current_Node, Hop_Count + 1)
Current_Node ← Index  // Update current node
```

3.2. MAN-AOMDV

The Source node sends the RREQ packet to find the route to destination. Every neighbor node assigns its self Id in the Source path number of the RREQ to identify the current reverse path which is the path number that defers from another reverse path. While the node receives the RREQ, if it is a fresh route then it sends a reply to the source node, otherwise it compares the available reverse path in the routing table with the source path number in the RREQ to obtain the route. In case this was the first RREQ, the node will accept the RREQ and update the routing table information for the second RREQ of the same path. Furthermore, the exact procedure will happen at the RREP control Packet. If the node is a destination node, then it sends the RREP and stores the destination path number. Here each node sends the next reply to the same source only with the same RREP Destination path number.

MAN-AOMDV Algorithm

```
// Route Request (RREQ) Phase
Initialize Source_path_number = 0
Send RREQ()

if RREQ_Hop_Count == 0 then
   Source_path_number ← Index  // Assign path ID at source neighbor
end if

Insert_RREQ_to_Node_Table(Source, Source_path_number, Hop_Count + 1)

if RREQ_Destination == Index OR lookup(RREQ_Destination == Table_Destination) then
   Send RREP()  // Begin route reply
end if

// Node stability check
if Source_path_number ≠ Table_Source_path_number then
   Delete(path)    // Inconsistent path info
   Drop RREQ       // Discard packet
end if

// Route Reply (RREP) Phase
if RREQ_Hop_Count == 0 then
   Destination_path_number ← Index  // Assign destination path ID
end if

Insert_RREP_to_Node_Table(Source, Destination_path_number, Hop_Count + 1)

if Destination_path_number ≠ Table_Destination_path_number then
   Drop RREP  // Inconsistent reply path, discard packet
end if
```

The proposed SMMSN-AOMDV and MAN-AOMDV algorithms enhance the classical AOMDV protocol by integrating mechanisms for both the intelligent load balancing and the stable node election. Unlike the traditional approaches that rely heavily on a single primary path, the enhanced protocols utilize multiple disjoint paths simultaneously, thereby distributing the network traffic more evenly and preventing node overutilization and congestion. This multi-path utilization is guided by metrics such as the hop count and the unique source path identifiers embedded within the RREQ packets, enabling informed and adaptive routing decisions.

Additionally, the SMMSN-AOMDV introduces a novel stability-checking mechanism that elects intermediate nodes based on their mobility behavior and consistency across the routing paths. By filtering out the high-mobility or path-inconsistent nodes during the route discovery process, the algorithm ensures that only stable nodes are included in the active routes. This significantly reduces the likelihood of route breakages, leading to an improved packet delivery, reduced end-to-end delay, and better overall network performance. Through this dual enhancement strategy, the proposed algorithms offer a robust and efficient routing solution for the dynamic MANET environments, supporting the improved Quality of Service (QoS) through optimized resource utilization and increased route stability.

4. Simulations and results

To minimize the issue of the hidden terminals in wireless networks, a comprehensive simulation model based on NS2 is utilized to conduct virtual sensing and medium reserve. With a maximum data rate of 2 Mbit/s and a 250 m radio range, Wave LAN is modeled as shared media. Traffic sources with a CBR (Continuous Bit Rate) are employed. The source-destination pairings are disseminated at random over the network. The data packet size is 512 bytes. The mobility model employed uses random waypoints with 60 nodes in a 1500 by 1500 square-foot rectangular space. The node has a distinct mobility that involves brief halt followed by rapid movement. There are 300 simulated seconds in the simulation run. Table 2 provides a thorough overview of the simulation scenario.

Table 2. SMMSN-AOMDV and MAN-AOMDV parameters

0Parameters	0**Value**
Simulator	NS2
Channel Type Wireless Channel	Wireless Channel
MAC Layer Protocol	IEEE 802.11
Number of Nodes	60 Nodes
Simulation Time	300 Second
Data Packet Size	512 Bytes
Traffic Type	Constant Bit Rate (CBR)
Simulation Area	1500*1500
Routing Protocols	SMMSN-AOMDV and MAN-AOMDV

Performance indicators:

1. Packet delivery ratio: In this simulation, the ratio of packets received by the CBR at the destination to those transmitted by sources with (CBR, application layer). It indicates the packet loss rate, which restricts the network's top throughput.
2. End-to-end delay: This indicator shows the average end-to-end latency and the time it takes for a packet from the source to the destination's application layer.
3. Throughput: The total number of packets successfully delivered through all time to each particular destination. Table 2: Dimensions of the parameters utilized in the simulation are 1500 x 1500 x 1500 (m x m). number of nodes 60 simulation time 300 traffic type CBR number of connections 20, packet size 512 bytes MAC layer IEEE802.11b.

SMMSN-AOMDV and MAN-AOMDV are being evaluated in a situation where there are mobile connections between the network nodes. The addition of a new field in the RREQ packet results in an overhead; however, it can be accepted as normal as we employ paths with minimal load as well as the amount of the packet loss in the network will decrease. Furthermore, since the field is only added in route request packets, which are only sent out when a route discovery is necessary, it won't have a significant impact on the network's performance unless there is a path breakage.

One can note from Figure 1, that the packet delivery ratio is roughly identical when using paths with minimal network load; however, as the load in the network increases, the performance of the MAN-AOMDV declines and the SMMSN-AOMDV takes control as the load in the network is low. the network load balancing is not necessary because the resources in the network can meet the needs of the communications. However, when the network traffic grows and one link cannot support the communication with sufficient resources, the load balancing becomes necessary. The SMMSN-AOMDV distributes traffic to several pathways that are selected based on reliable nodes to share the load on the network, thus improving the packet delivery.

In contrast, the SMMSN-AOMDV has a higher throughput since it uses multiple paths and distributes the traffic, which lowers the chances of packet drops. The end-to-end delay findings for the SMMSN-AOMDV and the MAN-AOMDV are shown in Figure 2. The end-to-end latency also increases when a node leaves the channel and chooses a different path since only delivered packets are taken into account when calculating the end-to-end delay.

The throughput of the network for both the SMMSN-AOMDV and the MAN-AOMDV is almost the same in Figure 3, but when the load on the network grows, the throughput drops because a high load causes congestion, and as a result the packets are not received by their destinations. Therefore, when using a node for transmission, the possibility of a packet dropping is high when congestion occurs along that path, which is the reason that the throughput of the MAN-AOMDV drops. The throughput data are displayed in Figure 3. As we use less loaded pathways with fewer packets, the throughput and packet delivery ratio rise. As the SMMSN-AOMDV has more robust Intermediate Nodes than the MAN-AOMDV, there have been less packet losses, which has improved the network performance and the packet delivery. The comparison of the MAN-AOMDV and the SMMSN-AOMDV with regard to the packet deliver ratio utilizing perfect pathways is shown in Figure 3. The SMMSN-AOMDV chooses the stable Intermediate Nodes since they allow for less packet processing at each node, which improves the packet delivery ratio. The chances of a packet dropping at the intermediate node are even lower as more stable intermediate nodes are added and the packets are distributed because any congestion will be avoided until the most stable intermediate nodes are chosen to receive perfect paths with low loads and achieve the highest packet delivery ratio. The primary advantage of the suggested plan is that the protocol may offer an acceptable improvement in the average end-to-end delay without sacrificing any other QoS metrics.

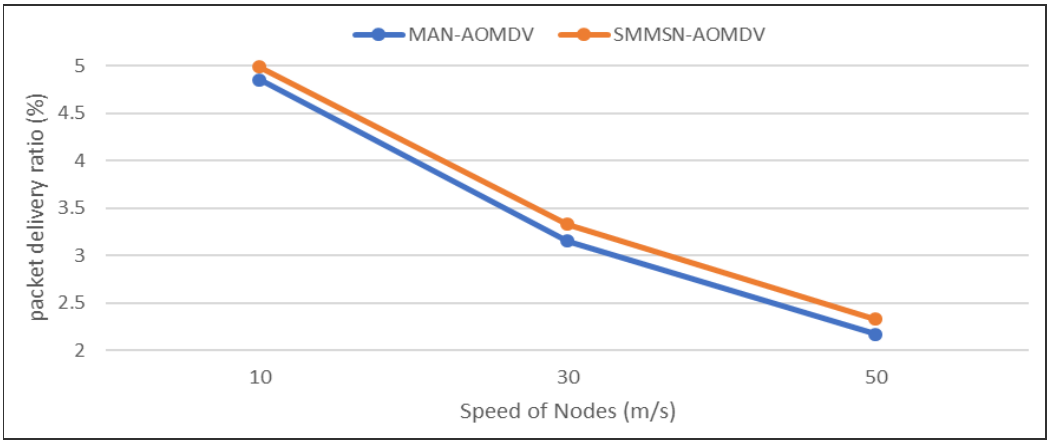

Figure 1. Packet delivery ratio

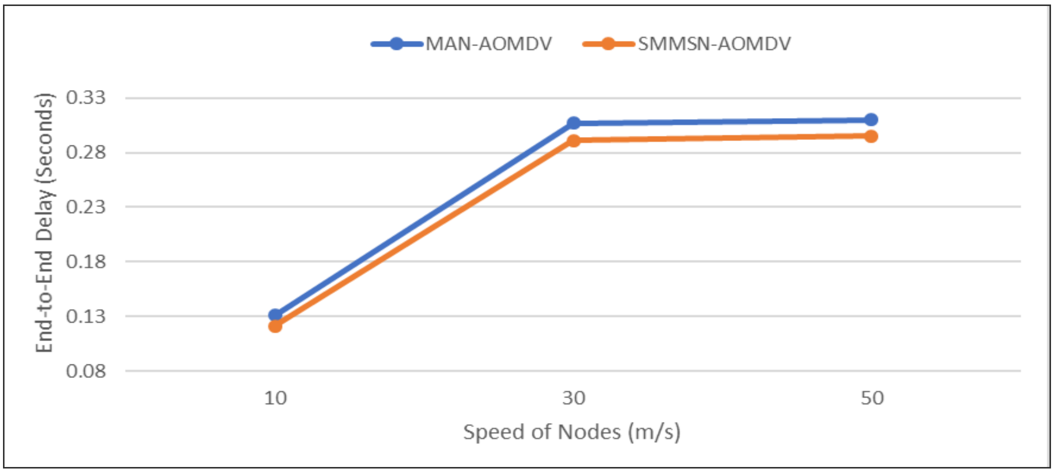

Figure 2. End-to-End Delay

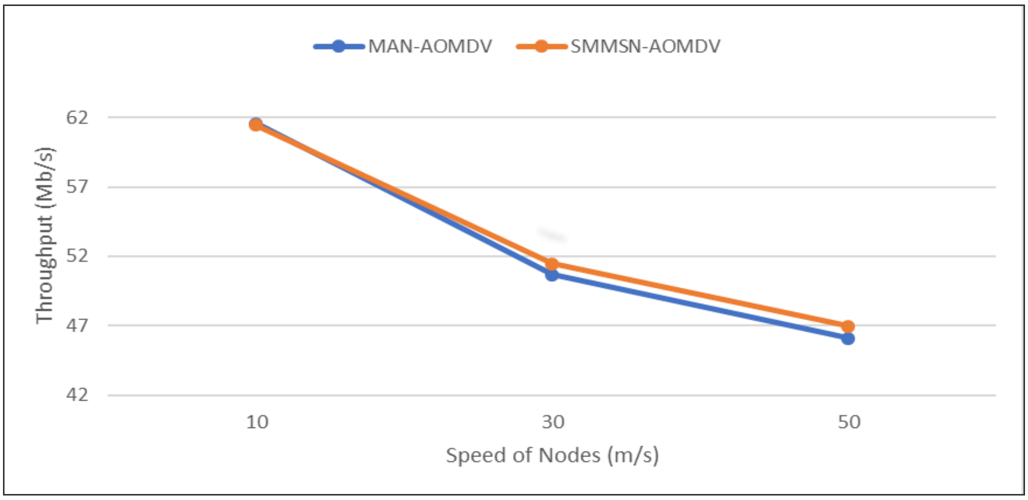

Figure 3. Throughput

5. Conclusion

As the AOMDV only uses one path at a time, the suggested technique improves the MAN-AOMDV protocol at higher loads. In contrast, the SMMSN-AOMDV divides traffic into several suitable paths, which helps distribute the load across more nodes, which is leads to a better resource utilization, and increases the network lifespan as well as promotes a balanced power consumption.

6. Future work

The suggested method outperforms the AOMDV, but it could perform even better by using routine updates on the node and the packet information of the nodes in the paths so that the nodes could make dynamic decisions about using better routes while the data is being transmitted, which can result in even better use of the network resources. The proposed approach can help in extending the network lifetime if energy is additionally employed as a path selection parameter.

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