

Research Article

Revolutionizing MANET Route Discovery with INTSM: An Innovative Load Balancing Approach

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Abstract

Communication challenges in ad hoc networks arise due to the mobility of nodes, causing frequent changes in connections and locations. Maintaining network equilibrium to prevent node overload and underutilization is crucial. However, imposing static behaviors on nodes to improve performance can lead to delays, especially in core nodes. Addressing these issues, this research proposes the Intermediate Node Traffic Sharing Model (INTSM) for ad hoc networks. INTSM prioritizes congestion control and load balancing during route discovery, aiming to optimize network resource utilization and traffic distribution, thereby reducing packet delays. The model employs dynamic traffic sharing algorithms that consider real-time network conditions, enabling nodes to adjust their behaviour adaptively. This approach minimizes congestion by distributing traffic loads more evenly across the network, preventing bottlenecks at central nodes. Additionally, INTSM incorporates predictive analysis to foresee potential congestion points and reroute traffic proactively, enhancing overall network stability and performance. Extensive simulations demonstrate that INTSM significantly reduces average packet delay and improves throughput compared to traditional routing protocols. The results highlight the model's efficacy in diverse scenarios, including high mobility and varying traffic loads, proving its robustness and scalability. The primary objective of this study is to enhance navigation and equilibrium mechanisms to improve the performance of ad hoc networks, contributing to more reliable and efficient wireless communication systems. The findings of this research have significant implications for the design of future ad hoc networks, particularly in applications requiring high reliability and quick adaptation to changing network conditions, such as disaster recovery, military operations, and mobile sensor networks. By addressing the critical challenges of congestion control and load balancing, INTSM offers a promising solution to enhance the resilience and efficiency of ad hoc networks.

Keywords

Ad-hoc Networks, Load Balancing, Route Discovery, Intermediate Node Traffic Sharing Model (INTSM), Congestion Management, Traffic Distribution

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1. Introduction

The MANET is a special network model called mobile ad-hoc network (MANET) [1] allows mobile devices to establish connections on their own without the assistance of humans or pre-existing infrastructure. In a MANET, each device shares roles of sender and receiver for the purpose of facilitating data packets movement among pre-established destinations.

The ability for devices to collaborate enables the network to operate without the need for fixed routers or centralized base stations. Two main methods are frequently used in wireless device communication. In the first method, resource distribution and communication are managed by a single base station. In this configuration, device-to-device communication requires routing via the central base station. Large-scale cellular networks such as GSM or UMTS are the main applications for this technique, as Figure 1 illustrates with infrastructure-based networks [2].

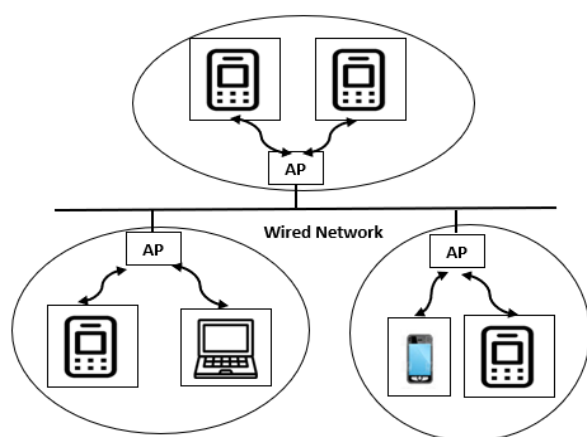


Figure 1. Network infrastructure.

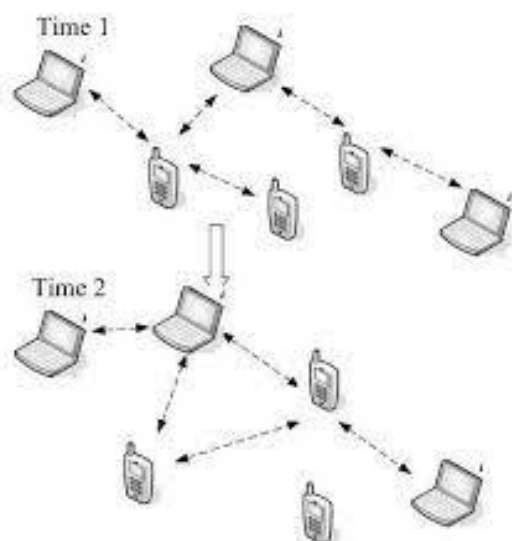


Figure 2. Networks without infrastructure.

The other technique, known as the ad hoc method, is fundamentally different as it doesn't depend on having a centralized authority or a set infrastructure. Instead, devices collaborate and pass data packets from one node to another until they get to their final destination. [3]. Every device in this configuration functions as a router, determining routing based on current network conditions. Figure 2 illustrates the idea of infrastructure-less networks.

This research aims to enhance load balancing in mobile ad hoc networks (MANETs) during the process of route discovery. Load balancing is the process of dividing up network traffic among devices in an even manner so as to avoid overloading some while leaving others idle.

The purpose of introducing the Intermediate Node Traffic Sharing Model (INTSM) is to efficiently manage network load and congestion during route formation. The objective is to enhance traffic distribution across devices by implementing the Intermediate Node Traffic Sharing Model (INTSM), ultimately improving the network's overall performance. This research significantly enhances the efficiency and dependability of route discovery procedures in Mobile Ad-hoc Networks (MANETs).

MANETs are essential for a number of applications, including data collection in difficult situations, combat decision-making, and emergency search and rescue operations. These networks have a dynamic topology, multi-hop communication, resource limitations (processor, bandwidth, battery life), and security restrictions [4]. These features make designing routing protocols for MANETs particularly difficult. The objective is to enhance traffic distribution across devices by implementing the Intermediate Node Traffic Sharing Model (INTSM), ultimately improving the network's overall performance. This research significantly enhances the efficiency and dependability of route discovery procedures in Mobile Ad-hoc Networks (MANETs) [5], are the focus of MANET routing protocols. Given the limited energy resources accessible to nodes in a MANET, optimizing energy efficiency is one of the main goals of MANET routing protocols. Important objectives include maximizing network throughput, enhancing energy efficiency, extending network lifetime, and minimizing delay.

Routing overhead is primarily measured by the number or size of routing control packets, while network throughput is often assessed using metrics such as packet delivery ratio. In hop-by-hop reactive routing protocols like Ad-hoc On-demand Distance Vector (AODV), every intermediate node determines the next hop for routing packets [6]. At each hop in this process, route requests are started via local broadcasting.

However, random flooding broadcasts for route requests can result in a large amount of duplicated packet overhead, which makes MANET routing techniques less effective.

Numerous strategies have been put out to deal with this problem, such as restricted route request broadcasting that

uses node caching to lessen route request redundancy.

Moreover, strategies for workload-based adaptive load balancing have been proposed. By using these strategies, excessively loaded nodes are excluded from the route routes by selectively deleting route request packets (RREQ) based on each node's load status.

In light of these challenges, this paper presents the Intermediate Node Traffic Sharing Model (INTSM), a novel solution to load balancing issues during MANET route discovery. INTSM seeks to improve the overall effectiveness of MANET routing protocols by optimizing traffic distribution and incorporating load management and congestion into route design.

1.1. Routing Protocols

An ad hoc routing protocol defines the rules and guidelines that govern how nodes in a Mobile Ad-hoc Network (MANET) select the optimal route for transmitting packets between devices.

The two primary categories into which these protocols are usually divided are position-based and topology-based routing protocols, each of which has unique benefits and limitations. Previous research offers a comprehensive analysis of the unicast routing protocols currently utilized in MANETs. [5].

Two such routing protocols are Dynamic Source Routing (DSR) [7] and Ad-hoc On-demand Distance Vector (AODV). These protocols are often used in MANETs and have undergone a thorough review by researchers. The effectiveness of the suggested Intermediate Node Traffic Sharing Model (INTSM) can be assessed in a range of traffic scenarios using these protocols.

1.1.1. AODV

The Ad Hoc On-Demand Distance Vector (AODV) routing protocol is utilized by nodes in a reactive manner to facilitate the transfer of data packets [8]. It can send packets to one location at a time or to several destinations at once. By giving every destination a distinct destination sequence number (DestSeqNum), AODV sets itself apart from other on-demand protocols. Every destination has an entry in the route database it keeps track of, and routes that aren't used for a predetermined amount of time are removed. Route establishment begins with a request (RREQ) and is completed when a reply is received (RREP). When a link fails, a message is sent, which causes a new request to be created.

1.1.2. DSR

Route discovery and route maintenance are the two primary stages of the Dynamic Source Routing (DSR) protocol [9], which dynamically manages active routes using source routing. Differentiating itself from AODV, DSR sends error messages in response to link issues rather than routing messages often. Multiple pathways to the destination are made possible in DSR by the sequence of intermediary node IDs that are contained in the header of each packet. There are

significant differences between AODV and DSR. When a node sends a packet to a destination using AODV, the packet only includes the destination address. In contrast, when using DSR, the packet contains complete routing information, which leads to higher routing overhead compared to AODV.

1.2. Connection Types

In a MANET, devices have multiple options for establishing connections. Two common approaches will be explored here [10].

1.2.1. Constant Bit Rate (CBR)

A consistent stream of data moving over the network at a constant pace is referred to as constant bit rate, or CBR. Data packets with predefined sizes and set time intervals between each packet are transmitted via CBR. The receiving device does not transmit acknowledgment messages, and it functions without the requirement for specific device connection setups. Data travels steadily from the source to the destination during unidirectional transmission.

1.2.2. Transmission Control Protocol (TCP)

TCP, a reliable, connection-oriented transport protocol, guarantees dependable data transfer through mechanisms such as acknowledgments, timeouts, and retransmissions. Upon successful delivery of a data packet, the receiving device notifies the sender. TCP ensures data safety by initiating retransmissions if acknowledgments are not received within specified timeout periods, ensuring reliable data delivery to its destination.

1.3. Properties of an Effective Routing Protocol

For an ad hoc network utilizing multiple descriptions coding, an effective routing protocol must possess several essential features. Here are the main characteristics [11], described in more basic terms:

1. Multiple Complete Paths: In the event of a path failure, the routing protocol should give backup choices in addition to multiple complete paths to destinations.
2. Loop Prevention: For effective packet delivery, loop-free routes must be maintained.
3. Non-Overlapping Paths: In order to preserve connectivity in the event that one link is interrupted, the protocol should ideally provide non-overlapping paths.
4. Multipath Support: Enabling the usage of many pathways at once balances network traffic and enhances efficiency.
5. Complete Knowledge: In order to transmit data effectively, the source node must be fully aware of all accessible paths.
6. Quality of Service Metrics: To aid in path selection, the protocol should provide quality of service (QoS) metrics for each route, such as bandwidth, delay, and cost.
7. Node Mobility Support: In mobile environments, it's

critical to support networks comprising 50 to 200 nodes moving at pedestrian speeds, typically less than 5 m/s.

8. Clock Independence: Nodes ought to function autonomously, not depending on a shared clock source such as GPS for synchronization.
9. Practical Implementation: For hands-on practice and experimentation, a simple implementation of the routing protocol should be readily available.

These characteristics guarantee that the routing protocol works well in ad hoc networks that support multiple description codes.

1.4. Classification of Load Balancing Protocols in MANET

Ad hoc network-specific load balancing methods [12] are engineered to effectively manage workload distribution and enhance route discovery, accommodating diverse traffic situations [13]. When discussing load balancing, the load can be categorized into several types:

Channel load: Channel load is the quantity of activity or traffic on the communication channel that results from several nodes vying for access to the shared medium. In order to guarantee fair and efficient use of channel resources, load balancing methods consider channel load.

1. Nodal load: The workload of a particular node, which includes computations, processing jobs, and other processes, is referred to as nodal load. The goal of load balancing protocols is to evenly divide the burden among nodes so as to avoid overloading any one of them.
2. Neighboring Load: Control packets, data packets, and communication overhead are all included in the load that is produced by communication between adjacent nodes. In order to prevent congestion and bottlenecks, load balancing techniques take into account neighboring load and spread communication operations among nearby nodes equally.

In MANETs, load balancing protocols continuously adjust to evolving traffic conditions to ensure reliable and efficient routing, optimize resource utilization, and enhance overall network performance.

1.5. Load Balancing Metrics

By taking into account a variety of parameters, as detailed in, load balancing routing methods in MANETs seek to ensure equitable and effective load distribution [14]. These measurements are essential to load management:

1. Active Path: This measure shows how many active routing paths a node is capable of supporting. A greater count denotes a node with higher activity and predicts increased data traffic handling.
2. Traffic Size: This statistic aids in workload evaluation and capacity planning by calculating the volume of data traffic at a node and its nearby nodes.

3. Packets in Interface Queue: This measure indicates interface congestion and the node's capacity to handle packet traffic by counting the packets kept in its incoming and outgoing interfaces.
4. Channel Access Probability: This measure, which is related to competition for channel access amongst nearby nodes, shows the chance of a successful wireless channel access.
5. Node Delay: This measure helps assess the total packet delay in the network by capturing packet delays resulting from processing, queuing, and successful transmission at a node.

1.6. Load Balancing Protocol Types

Based on their methodologies [15], load balancing protocols can be categorized into three distinct groups, as depicted in Figure 3:

Delay-Based: By avoiding nodes with long network delays, these protocols concentrate on load balancing. To improve overall performance, they give priority to routes with shorter waits.

Traffic-Based: By distributing traffic load equally among network nodes, these protocols improve load balancing by avoiding any one node from becoming overwhelmed.

Hybrid-Based: These protocols integrate elements of delay-based and traffic-based strategies. By considering both traffic load and delay factors, they strive for a balanced load distribution.

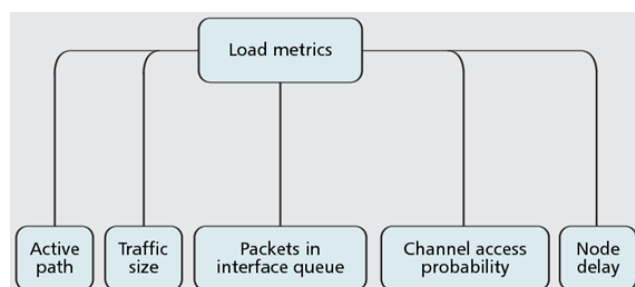
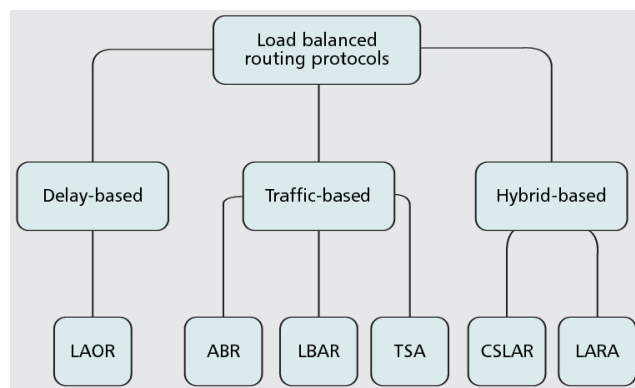


Figure 3. Categorization of load-balanced routing protocols based on load metrics.

Routing systems in MANETs effectively manage network load, optimize resource consumption, and enhance overall performance and fairness by employing various load balancing measures and fitting approaches.

2. Literature Survey

The study [16] proposes a dynamic mechanism or algorithm to tackle load balancing challenges in ad hoc networks by efficiently allocating network traffic among available nodes. This approach aims to alleviate congestion, enhance network throughput, and elevate Quality of Service (QoS) by ensuring balanced resource utilization and optimizing overall network performance. The study likely includes evaluations comparing this approach with existing load balancing strategies to demonstrate its effectiveness in achieving load balancing and improving network efficiency.

Another paper [17] addresses two main themes: data security in MANETs and energy-efficient load balancing techniques to enhance the AOMDV routing protocol. The survey examines various energy-saving load balancing strategies, discussing their advantages and limitations. Additionally, it explores specialized data security protocols and methodologies tailored for MANETs, assessing their effectiveness in safeguarding data confidentiality, integrity, and availability. Researchers and practitioners focusing on MANET data security, innovations in AOMDV routing, and energy-efficient load balancing will find valuable insights in this study.

The paper [18] introduces a routing protocol designed to enhance resource utilization and network performance by evenly distributing network traffic across nodes. It prioritizes nodes with lower loads or higher capacities for data transmission, aiming to optimize overall Quality of Service (QoS) in MANETs. The protocol's goals include reducing congestion, minimizing packet loss, and mitigating delays, thereby extending network longevity and improving performance through effective load balancing.

The paper [19], delves into shortest-path routing protocols tailored for Mobile Ad hoc Networks (MANETs), specifically focusing on integrating load balancing techniques. It investigates strategies like multipath routing, load-aware routing metrics, and proactive load balancing to achieve efficient load distribution in MANETs. Emphasizing the importance of optimizing resource usage and equitably distributing network traffic, the study suggests that integrating these load balancing techniques into shortest-path routing protocols can enhance traffic management, alleviate congestion, and boost overall network performance in MANETs.

This paper [20], introduces a novel load balancing technique tailored for Mobile Ad hoc Networks (MANETs). The approach partitions network traffic and employs the Fibonacci sequence to determine the number of pathways. By leveraging multiple pathways and Fibonacci-based traffic distribution, the technique aims to enhance resource efficiency, alleviate congestion, and boost overall network performance in MA-

NETs. The study likely includes evaluations comparing this strategy with alternative approaches.

The paper [13] provides a comprehensive analysis of load balancing and energy efficiency strategies in mobile ad hoc networks (MANETs). It covers energy harvesting, load balancing methods, sleep scheduling, energy-aware routing, and adaptive routing protocols. The survey evaluates these strategies' performance metrics such as fairness, throughput, network longevity, and routing overhead. Researchers and practitioners focusing on optimizing energy efficiency and achieving load balancing in MANETs will find this survey to be a valuable resource.

In the paper [21], an extensive review of load balancing routing techniques for mobile ad hoc networks (MANETs) is provided. It examines several load balancing methods proposed in the literature, discussing their respective advantages, disadvantages, and performance evaluations. The review aims to guide further research directions and enhance the understanding of load balancing approaches among scholars and practitioners in the field of MANETs.

This paper [22] explores approaches for congestion control and load balancing in mobile ad hoc networks (MANETs). It examines numerous mechanisms proposed in the literature and assesses how well they work to improve network performance. The study examines the connection between load balancing and congestion control and emphasizes the significance of load balancing for effective resource use. By taking into account measures like throughput, delay, packet loss, fairness, and routing overhead, it offers insights into the evaluation and performance analysis of these approaches. In order to alleviate congestion issues and enhance network performance in MANETs, this paper is a great resource.

The paper [23] delves into load balancing and congestion control in Mobile Adhoc Networks (MANETs), exploring multiple proposed mechanisms and assessing their efficacy in improving network performance. It not only investigates the interplay between load balancing and congestion control but also underscores the critical role of load balancing in optimizing network resource utilization. The study provides insights into the evaluation and analysis of different methods using metrics such as routing overhead, throughput, latency, packet loss, and fairness. Researchers and practitioners aiming to enhance network performance and address congestion challenges in MANETs will find this paper to be a valuable reference.

In this paper [24], a routing protocol for MANETs that prioritizes load balancing and link break prediction is introduced. To improve performance and reliability, the protocol attempts to split traffic equally and foresee any network failures. It combines link break prediction algorithms with load balancing strategies to maximize resource usage and improve network resilience. The protocol's performance is probably evaluated and compared to other routing techniques in the study. All things considered, it offers a method for load balancing and link break prediction that allows for dependable

and efficient data transfer in MANETs.

The paper [25] introduces LAPU, a load balancing method tailored for MANET geographic routing. LAPU employs adaptive position updates to dynamically adjust the frequency of position updates according to network load conditions. This approach aims to minimize control overhead, improve routing efficiency, and evenly distribute traffic load across the network. The paper likely includes performance assessments comparing LAPU with alternative routing protocols. These evaluations are expected to highlight LAPU's advantages in terms of throughput, delay, packet loss, and control overhead, demonstrating its effectiveness in optimizing geographic routing in MANETs.

The paper [26] introduces a novel load-balancing routing protocol for ad hoc networks that integrates ant-colony optimization and cross-layer design. This protocol is designed to address congestion issues, improve overall network performance, and achieve balanced traffic distribution. By leveraging ant-colony optimization, the protocol identifies efficient routes, while incorporating information from various network layers enhances the decision-making process. The paper likely includes comparisons with alternative protocols and performance evaluations to demonstrate the effectiveness of this approach. Overall, the protocol represents a comprehensive solution combining cross-layer design principles with ant-colony optimization for efficient load balancing in ad hoc networks.

The paper [27] investigates strategies to enhance the energy efficiency of Mobile Ad hoc Network (MANET) routing protocols using load balancing techniques. It explores various load balancing strategies and evaluates their effects on routing overhead. The research examines the trade-off between load balancing and energy consumption, discussing potential optimizations and challenges associated with these approaches. The primary objective is to improve overall network efficiency by ensuring fair distribution of traffic and minimizing Routing Overhead in MANETs.

The paper [28], explores topology control strategies for ad hoc wireless networks using the NS-2 network simulator. It investigates various approaches aimed at optimizing performance and managing network connectivity. The study assesses the impact of these strategies on key parameters such as throughput, latency, energy efficiency, coverage, and network connectivity. It delves into implementation specifics, identifies limitations, and proposes possible enhancements for these strategies. Through NS-2 simulations, the research evaluates the effectiveness of topology control mechanisms with the overarching goal of comprehensively understanding and assessing their applicability in ad hoc wireless networks.

The paper [29] introduces a framework designed for wireless ad hoc network topology control within the NS-2 network simulator. This framework incorporates modules, tools, and algorithms aimed at optimizing link scheduling, power control, and node placement. It explores the architecture and implementation of these components and evaluates their ef-

fectiveness through simulations conducted in NS-2. The primary objective is to improve network performance by efficiently managing network topology using this approach.

3. Problem Statement

One important aspect affecting network load is the transmit power of individual nodes, which has a direct effect on how a network is configured topologically. When the topology of the network is very dense, meaning that nodes have a lot of neighbors, there are a lot of routing options. But increasing density also means that power consumption goes up. Alternatively, the number of routing choices reduces for overly sparse topologies with fewer links. Potential node overloads and an increase in the average number of hops between end nodes could result from this sparse configuration. The main objective is to use the suggested Intermediate Node Traffic Sharing Model (INTSM) efficiently to produce a well-balanced network architecture through intermediate node traffic sharing.. This equilibrium should minimize Routing Overhead while also meeting end-user requirements. The basic idea is that nodes actively forward packets based on neighboring nodes' positions by using intra- and inter-route discovery procedures. The underlying premise of current node load balancing solutions is that route requests only need to reach one destination rather than all nodes. But these protocols have also revealed several underlying problems, like:

1. Uneven distribution during peak traffic times, which causes some nodes to have higher traffic loads than others.
2. lower delivery ratios, higher overhead, and higher end-to-end latency in high-density scenario situations.
3. Because intermediate nodes mistakenly report transient transmission problems as real link failures, the source node receives repeated reports of route breakdown. This strains the network, reduces efficiency, and messes with throughput.
4. collisions and issues with hidden nodes that result from using an unshared load media.
5. Insufficient load balancing, with intermediate nodes experiencing the majority of the congestion.
6. inadequate success in achieving route stability.

These problems underline the urgent need for a better load balancing strategy that addresses these problems and guarantees a more effective and dependable network performance.

4. Proposed Solution

A novel approach is proposed to address load balancing during route discovery in mobile ad hoc networks (MANETs), known as the Intermediate Node Traffic Sharing Model (INTSM). This approach aims to tackle the mentioned challenges by focusing on congestion control at the Media Access Control (MAC) layer and detecting network access delays

[30]. Additionally, a threshold value is integrated to guide intelligent routing decisions, aimed at optimizing energy efficiency in routing.

The INTSM methodology begins by prioritizing less congested paths, considering factors such as the number of transmitted packets per node and their flag statuses. Nodes identify underutilized and heavily burdened nodes through periodic exchange of hello messages with neighbouring nodes.

The process of load balancing using INTSM unfolds as follows:

- 1) Nodes continuously monitor their neighbours to track their load and flag statuses.
- 2) Regular hello messages are sent to nearby nodes for status updates.
- 3) Multiple routes are established through flooding for information dissemination.
- 4) Source nodes broadcast route request messages that include load information.
- 5) Nodes update their routing tables upon receiving hello messages containing load statistics.
- 6) Traffic flow is classified to identify overloaded and underutilized nodes.
- 7) Traffic diversion (load sharing) is executed based on traffic flow classification.
- 8) The destination node employs a route discovery mechanism to select the optimal route.
- 9) Vigilant network monitoring is implemented to minimize disruptions.

To support load-based routing decisions, various algorithms for load computation will be developed across different nodes, including source, intermediate, and destination nodes.

To illustrate the approach, consider the network model depicted in Figure 4: A source node initiates a route request message to transmit data packets to a destination node. Nodes within transmission range forward this message until it reaches the destination, which calculates the path's load and responds with a route reply. Upon acknowledgment by the source node, intermediate nodes set their flag statuses and continue forwarding the reply until data transmission commences.

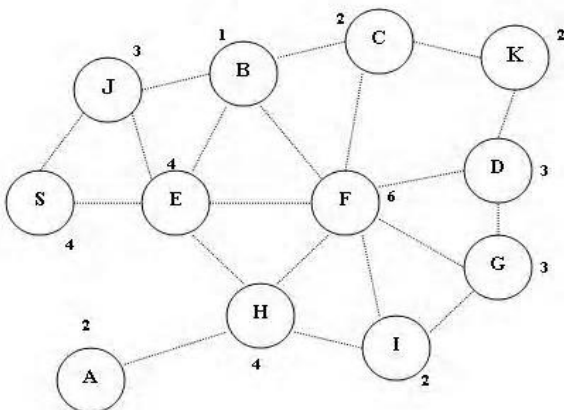


Figure 4. Network model.

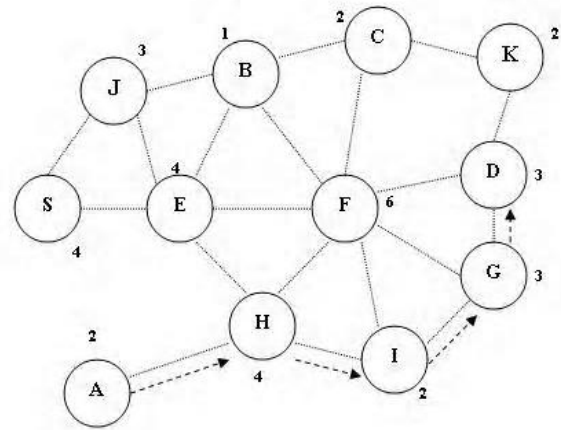


Figure 5. Illustration of Route Construction.

In Figure 5, A visual representation of the route construction process is provided. This diagram illustrates how a path is established between the source node (Node A) and the destination node (Node D).

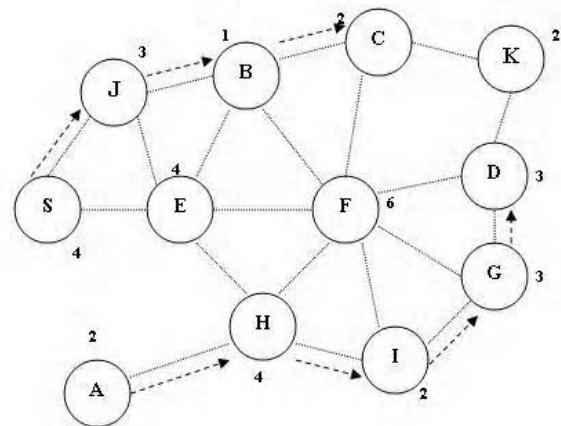


Figure 6. Route Construction Between Node Pair S and D.

Figure 6 illustrates the process of route construction between node pair S and D, providing a visual representation of how routing tables evolve at different nodes during data transmission.

Routing Table Legend:

The routing tables depicted in these figures utilize specific symbols and notations to convey essential information:

1. "#": Represents the unique node ID.
2. "\$": Indicates neighboring nodes.
3. "\$ttl": Signifies the calculated Time to Live (TTL) value associated with the flag bit.

4.1. Practical Scenario

In a practical scenario, Node A and Node D are already communicating, and Node S wishes to establish communication with Node C. Using the algorithm and referencing the

routing table details at each node, Node C selects the route C-B-J-S.

It's crucial to highlight that Node E currently chooses not to forward the route request message because of the flag bit status of its neighbouring node H.

Path Selection Metrics:

The selection of the data transmission path is based on a combination of metrics and their corresponding weight values. These metrics include:

1. Route Energy: Reflects the maximum battery power available at each node along the path.
2. Traffic Queue: Indicates the maximum number of packets awaiting transmission at a node.
3. Hop Count: Represents an optimal hop count for efficient data transmission.

Unlike many routing algorithms that prioritize hop count as the primary criterion for path selection, the proposed algorithm considers additional metrics. This approach addresses performance issues related to congestion and aims to optimize data transmission in scenarios with multiple available paths.

Table 1. Routing Table at a Node.

Destination	Source	Incoming Intermediate Node	Outgoing Intermediate Node	distance
G	A	H	I	D1
C	S	B	J	D2
G	A	D	H,I	D3

To complement the understanding of the routing approach, Table 1 presents an example of a routing table at a node. This table is calculated based on directed paths, as illustrated in Figure 7. It provides insights into how nodes determine their routing decisions to facilitate efficient data routing and delivery.

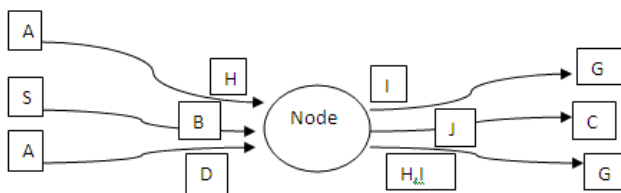


Figure 7. Calculation of Node Routing table according to directed paths.

To enhance efficiency and effectiveness in dynamic network environments, the INTSM (Intermediate Node Traffic Sharing Model) protocol introduces significant improvements to existing load balancing protocols in mobile ad hoc net-

works (MANETs). The key adjustments implemented by INTSM are as follows:

1. Path Selection Based on Hops and Queue Length
INTSM's path selection strategy considers two critical variables: the total number of hops and the queue length at each intermediate node.

INTSM looks at both variables to choose routes that have the best hop counts and enough capacity to process packets quickly.

2. Load balancing via Alternate Paths:

When a node's queue length beyond a predetermined threshold, INTSM uses alternate paths to keep traffic distribution balanced.

By diverting traffic to less crowded paths, this technique avoids node overload and congestion, improving network performance as a whole.

3. Dynamic Forwarding or rejecting:

Based on observed queue lengths at intermediate nodes, the INTSM protocol includes a dynamic method for forwarding or rejecting route request packets.

Based on reasonable queue lengths, nodes determine whether to forward or delete packets in an effort to maximize route discovery and selection while preventing needless network congestion.

The INTSM protocol seeks to improve load balancing performance in MANETs by taking into account variables such as hop count, queue length, and energy efficiency.

It ensures that routing decisions are in line with practical hop counts by giving preference to pathways that have sufficient energy resources and capacity for handling data traffic efficiently.

In conclusion, the INTSM protocol offers a novel method of load balancing in MANET route finding. By using dynamic packet handling algorithms and metrics-based path selection, it improves load distribution efficiency for more dependable data delivery. These modifications are designed to maximize network efficiency in ad hoc, dynamic contexts.

Specifically designed for mobile ad hoc networks (MANETs), the Intermediate Node Traffic Sharing Model (INTSM) technology is a complete framework aimed at optimizing load balancing and traffic distribution inside networks. Through the active participation of intermediate nodes in traffic sharing, INTSM guarantees effective resource use. An algorithmic summary of INTSM's main features is presented below.

4.2. The Intermediate Node Traffic Sharing Model (INTSM) Protocol's Algorithm is as Follows

The INTSM protocol integrates several algorithms to efficiently manage traffic sharing, load balancing, route optimization, and network resource utilization in dynamic ad hoc network environments. It significantly enhances network performance and reliability by actively managing traffic based on real-time load conditions.

The algorithm for the INTSM Protocol is well-structured and delineates essential steps in its operation within a mobile ad hoc network (MANET):

1. Initialization: Set up network parameters and data structures.
2. Node Load Monitoring and Sharing:
 - a) Each node maintains information on neighbouring nodes, including load, flag status, and routing table.
 - b) Periodically broadcast hello messages to exchange load and status information.
 - c) Upon receiving a hello message, update the routing table with load and status details.
 - d) Classify traffic flows to identify underutilized (low load) and overloaded (high load) nodes based on load analysis.
3. Traffic Diversion and Load Balancing:
 - a) Identify underutilized nodes with low load for potential additional traffic.
 - b) Identify overloaded nodes with high load for traffic diversion.
 - c) Reroute data packets from overloaded nodes to underutilized nodes, considering alternate paths when feasible.
 - d) Update routing tables to redirect traffic to selected paths based on load analysis.
4. Route Discovery and Data Transmission:
 - a) Source node broadcasts a route request message with load information and intermediate node details.
 - b) Intermediate nodes receive and forward route request messages while updating their routing tables with load information.
 - c) Destination node calculates path load based on intermediate node load values and sends a route reply to the source node.
 - d) Intermediate nodes set flag statuses and forward route replies to neighbouring nodes.
 - e) Upon receiving the route reply, the source node initiates data transmission along the established route.
5. Network Monitoring:
 - a) Continuously monitor the network to minimize collisions and ensure efficient data transmission.

This algorithm provides a systematic overview of the INTSM Protocol's operation, facilitating its understanding and implementation in MANET environments.

5. Results and Discussion

5.1. Simulation Parameters

The tool chosen for measuring protocol performance was the event-driven ns2.35 simulator. In the simulation, nodes were randomly distributed within a 1507 m x 732 m rectangular region using a random mobility model. The network's TCL script's many parameters were carefully set up to create the simulation. A comprehensive overview of the particular

simulation settings used in the studies is provided in Table 2:

Table 2. Simulation Parameters.

Scenario Elements	Values	Unit
Number of nodes	100	Nodes
Node speed	10	Meter/second
Queue size	50	Packets
Simulation area	1507 * 732	Meter^2
Routing protocols	AODV, DSR, INTSM	Protocol
Mobility model	Random way point	-
Packet size	512	Bytes
Traffic type	CBR	-
Transmission power consumption	0.035	Joules
Receive power consumption	0.035	Joules
Idle Power	0.100	Joules
Sense Power	0.0175	Joules
Simulation time	100, 150, 200, 250	seconds

5.2. Performance Metrics

To assess the protocol's behavior across various simulation durations, several essential performance metrics were computed. These metrics furnish valuable insights into the efficacy and performance of the protocol:

I. Packet Delivery Ratio (PDR): This metric assesses the percentage of data packets successfully delivered from the source node to the destination node. PDR is calculated by dividing the number of received packets by the number of sent packets and then multiplying by 100.

$$\text{PDR} = (\text{Number of packets received} / \text{Number of packets sent}) * 100$$

II. Throughput: Throughput measures the data transfer rate across the network, indicating the amount of data effectively received at the destination node.

$$\text{Throughput} = (\text{Number of bits received} / \text{Time taken for reception})$$

III. End-to-End Delays: This metric represents the time required for a data packet to travel from the source node to the destination node, encompassing various delays encountered during transmission (e.g., propagation delay, queuing delay, processing delay).

End-to-End Delay = Time taken for a packet to reach the destination - Time at which the packet was sent

IV. Routing Overhead: Routing overhead quantifies the additional control messages and signaling necessary for routing operations. It includes the extra network traffic generated by routing protocols to establish and maintain routing paths.

Routing Overhead = (Number of routing control messages / Number of data packets sent) * 100

5.3. Results and Discussion

The results produced by the simulations are presented. Experiments were conducted across a range of simulation times using the NS2.35 simulator with the INTSM algorithm included. [11]. The simulations considered a large number of parameters in order to enable a thorough assessment and study of the protocol's performance. Figure 8 shows network topology snapshots after protocols are implemented in the NS2.35 simulator.

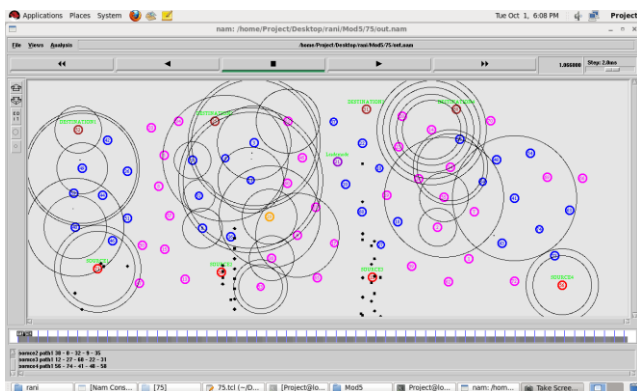


Figure 8. Network Simulator Windows.

5.3.1. Packet Delivery Ratio (PDR)

The packet delivery ratio (PDR) represents the percentage of data packets successfully transferred from the source node to the destination node. It is calculated using the formula:

$$\text{PDR} = (\text{Number of packets received} / \text{Number of packets sent}) \times 100.$$

This is done by first dividing the number of sent packets by the number of received packets.

Table 3 depicts how the PDR varies for the INTSM, AODV, and DSR protocols across different simulation periods. Despite occasional failures or routing disruptions, the INTSM protocol consistently maintains a high PDR. With increasing simulation duration, there is a noticeable improvement in PDR, indicating enhanced efficiency in packet delivery. Notably, the INTSM protocol often outperforms both AODV and DSR protocols in terms of PDR, highlighting its effectiveness in ensuring reliable data packet delivery throughout the network.

Table 3. Comparison of PDR.

Simulation Time (seconds)	Protocols		
	AODV	DSR	INTSM
100	40.123	32.234	54.543
150	37.543	30.123	59.432
200	35.678	32.89	48.754
250	33.89	34.543	58.432

Table 4. Packet Delivery Ratio comparison of INTSM with AODV and DSR.

Simulation Time	100	150	200	250	AVERAGE/OVERALL
INTSM compared to AODV	26.43%	36.83%	26.82%	42.00%	33.42%
INTSM compared to DSR	40.90%	49.31%	32.53%	40.88%	41.31%

A comparison of the throughput performance of the DSR, AODV, and INTSM protocols is shown in Table 4. It displays the percentage throughput gain achieved by INTSM over AODV and DSR for various simulation times (100, 150, 200,

and 250 seconds). When compared to AODV and DSR, INTSM increases throughput by an average of 33.42% and 41.31%, respectively. These results demonstrate the INTSM protocol's higher data transfer efficiency.

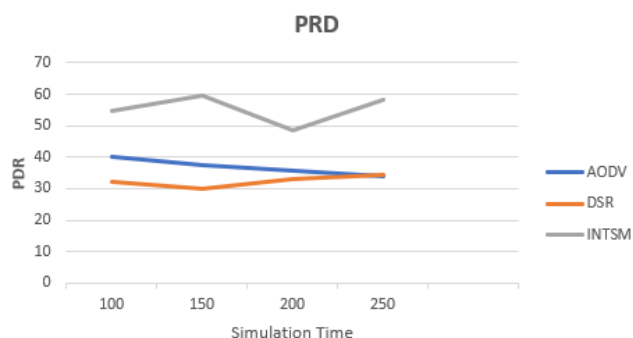


Figure 9. Graph of Packet Delivery Ratio with simulation time.

The comparison of the Packet Delivery Ratio (PDR) for different simulation durations between DSR, AODV, and the INTSM protocol is shown in Figure 9. Load balancing and congestion mitigation are made possible via the Intermediate Node Traffic Sharing Model (INTSM) protocol, which continuously displays a higher PDR. By redirecting traffic from overcrowded nodes to underutilized nodes, INTSM effectively reduces packet loss and enhances the overall efficiency of packet delivery. On the other hand, AODV finds it difficult to sustain a high PDR, mostly because of its poor capacity to adjust to shifting network conditions.

These outcomes highlight INTSM's ability to maintain an exceptional Packet Delivery Ratio (PDR) through efficient congestion control and traffic distribution optimization. On the other hand, AODV has trouble adjusting to changing network conditions, which eventually leads to a decrease in PDR performance.

Analysis of Packet Delivery Ratio

An essential metric for assessing the effectiveness of delivering data packets from source to destination nodes is the Packet Delivery Ratio (PDR). Continuous evaluation demonstrates that the INTSM protocol outperforms both AODV and DSR protocols in this regard. This superior performance remains evident even in the presence of path failures or interruptions. The INTSM protocol leverages the Intermediate Node Traffic Sharing Model, which provides advanced capabilities in load balancing and congestion control, contributing significantly to its success.

By constantly moving traffic from overcrowded nodes to idle ones, INTSM achieves its exceptional PDR and significantly lowers packet loss. This effective traffic management greatly

raises the efficiency of packet delivery as a whole. On the other hand, the AODV protocol struggles to sustain a high PDR because of its inability to adjust to changing network conditions.

As a result, the research clearly shows how successful INTSM is in providing the network with dependable and effective packet delivery.

5.3.2. Throughput

A crucial indicator called throughput gauges how well bits are received at the destination node and represents the velocity of data transfer and reception via the network.

Table 5 clearly shows that during the course of the simulation, INTSM performs better in terms of throughput than both AODV and DSR. Network capacity is enhanced and data transmission is optimized as a result of INTSM's capacity to balance traffic across nodes and distribute it equally. INTSM improves performance by locating underutilized nodes and rerouting traffic from congested ones. On the other hand, as traffic needs increase over time, AODV and DSR find it difficult to keep up, which lowers throughput.

With increased data transfer rates, INTSM clearly outperforms other throughput methods, as Table 5 illustrates. This noteworthy improvement in performance highlights how well INTSM manages data transport.

To sum up, the findings clearly illustrate how effective INTSM is at increasing throughput and how skilled it is at enabling better data flow throughout the network.

Table 5. Comparison of Throughput.

Simulation Time (seconds)	Protocols		
	AODV	DSR	INTSM
100	80.32	64.61	191.85
150	115.1	92.73	199.2
200	103.73	135.2	262.87
250	143.27	129.2	230.41

Table 6. Throughput comparison of INTSM with AODV and DSR.

Simulation Time	100	150	200	250	AVERAGE/OVERALL
INTSM compared to AODV	58.13%	42.21%	60.53%	37.81%	49.97%
INTSM compared to DSR	66.32%	53.44%	48.56%	43.92%	52.30%

A thorough comparison of the throughput performance of DSR, AODV, and INTSM is shown in Table 6. With an amazing 52.30% improvement over DSR and an average improvement of 49.97% over AODV, INTSM regularly beats both methods. These findings unequivocally confirm INTSM's higher efficiency in terms of data transmission speeds.

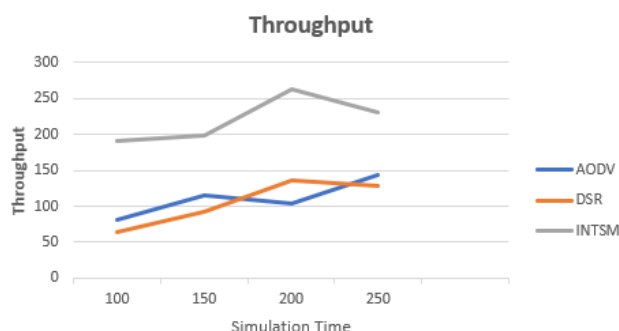


Figure 10. Throughput Variation Over Simulation Time.

The dynamic nature of throughput with regard to the INTSM protocol, AODV, and DSR is visually depicted in Figure 10. It clearly demonstrates the better throughput performance that the INTSM protocol achieves over other protocols. This graph provides as an illustration of how INTSM can increase overall network efficiency and facilitate faster data transmission rates.

Furthermore, the INTSM protocol continuously maintains its advantage in throughput over the other protocols as the simulation time increases. This continued supremacy highlights how well INTSM works to enable effective data flow inside the network, even as simulation times rise.

Throughput Analysis: It is evident from this analysis that the INTSM protocol consistently performs better than both AODV and DSR. This outstanding performance is attributable to INTSM's extremely efficient load-balancing and traffic-sharing systems. These mechanisms greatly increase the overall network capacity while also optimizing data transfer. By contrast, as traffic loads increase over time, AODV and DSR have significant difficulties that cause their throughput

to noticeably decrease. To sum up, the INTSM protocol's constantly high throughput highlights its remarkable effectiveness in enabling smooth data movement over the network.

End-to-End Delay: This term refers to the average amount of time that a data packet takes to travel from its source to its destination. It includes a number of different latency components, including packet propagation, buffering, interface queuing, routing latency, and transfer time.

Table 7 clearly shows that over various simulation durations, the INTSM protocol continuously maintains lower Average End-to-End Delays than both AODV and DSR. The efficient traffic control and load-balancing systems of INTSM are responsible for this reduction in delay since they lessen traffic and cut down on delays. INTSM increases network efficiency by locating underutilized nodes and rerouting traffic from crowded locations. Furthermore, INTSM's proactive strategy for path prediction and connection breakages helps to minimize disruptions and further reduce delays. On the other hand, as simulation duration increases, AODV experiences increasing delays, mostly because of its restricted capacity to adjust to changing network conditions.

Table 7. Analyzing the Differences in End-to-End Delay.

Simulation Time (seconds)	Protocols		
	AODV	DSR	INTSM
100	579.79	1061.11	256.695
150	940.768	1079.9	87.9443
200	662.81	1008.82	177.819
250	535.12	1182.67	68.5571

Figure 11 displays a graph showing the variation of end-to-end delay over simulation time for the INTSM protocol, alongside AODV and DSR protocols.

Table 8. End-to-End Delay comparison of INTSM with AODV and DSR.

Simulation Time	100	150	200	250	AVERAGE/OVERALL
INTSM compared to AODV	55.72%	60.65%	63.17%	67.18%	68.25%
INTSM compared to DSR	65.80%	61.85%	62.37%	64.20%	66.35%

A comparison of the end-to-end delay performance of DSR,

AODV, and INTSM is shown in Table 8. When compared to

both protocols, INTSM continuously shows considerable end-to-end latency savings, with average reductions of 68.25% over AODV and 66.35% over DSR. This demonstrates how well INTSM is able to reduce data transmission time.

The graph shows how well the INTSM protocol performs compared to AODV and DSR, especially when it comes to end-to-end latency. This is accomplished by INTSM through the use of various routes and energy-efficient routing algorithms that efficiently resolve transmission delays. This notable enhancement in end-to-end latency leads to quicker and more efficient delivery of data packets across the entire network.

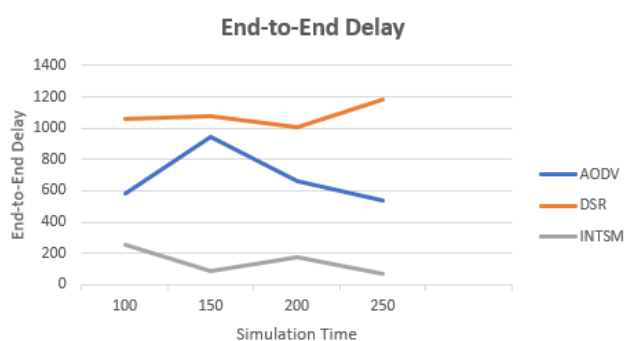


Figure 11. Graph of End-to-end delay with simulation time.

End-to-End latency Analysis: The analysis clearly demonstrates how well the INTSM protocol performs in terms of reducing end-to-end latency when compared to DSR and AODV. This advantage results from INTSM's effective load balancing, congestion reduction, and traffic flow control, all of which reduce delays. Route rediscovery delays are also significantly reduced by INTSM's proactive strategy of foreseeing link failures and proactively identifying alternate routes. On the other hand, AODV has high latency because of its intrinsic flexibility constraints. To put it simply, the INTSM protocol's decreased end-to-end latency greatly improves the effectiveness and speed of data packet transmission throughout the network.

Routing Overhead: In terms of routing overhead, Table 9 shows that INTSM has a little larger overhead than AODV and DSR over a range of simulation times. This increased overhead is a result of the Intermediate Node Traffic Sharing Model of the INTSM protocol, which requires nodes to communicate more routing information. It is important to remember, nevertheless, that the considerable improvements in network performance brought about by the efficient load balancing and congestion avoidance techniques used by INTSM more than justify this expenditure. Conversely, as simulation time increases, AODV encounters greater difficulties in managing the rising routing overhead.

Table 9. Comparison of Routing Overhead.

Simulation Time (seconds)	Protocols		
	AODV	DSR	INTSM
100	117346	46965	39014
150	83997	45868	16690
200	141451	48592	14987
250	125109	32447	12511

Table 10. Comparison of Routing Overhead between INTSM, AODV, and DSR.

Simulation Time	100	150	200	250	AVERAGE/OVERALL
INTSM compared to AODV	66.75%	60.13%	69.40%	69.99%	62.21%
INTSM compared to DSR	16.92%	53.61%	59.15%	51.44%	52.21%

Table 10 presents a comparison of routing overhead among INTSM, AODV, and DSR. INTSM demonstrates significantly lower routing overhead, with average reductions of 62.21% compared to AODV and 52.21% compared to DSR, surpass-

ing both protocols combined in efficiency. This shows how much more effective INTSM is at exchanging control information during the routing process.

A graphic representation of these differences in Routing

Overhead between the three protocols can be found in Figure 12. Routing Overhead is one area where the INTSM protocol excels over both AODV and DSR, demonstrating how well it optimizes control information transmission in the network.

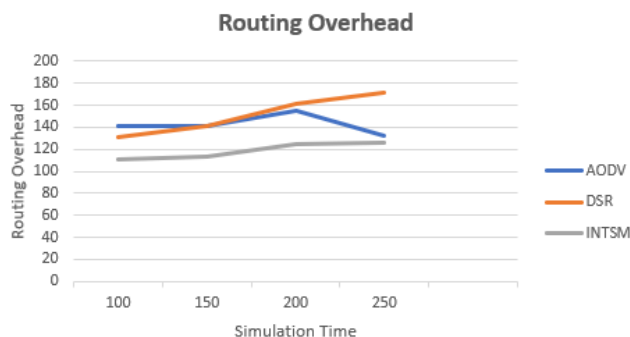


Figure 12. Graph of Routing Overhead with simulation time.

Routing Overhead Analysis: Throughout the simulation, continuous analysis indicates that the INTSM protocol consistently maintains lower routing overhead compared to AODV and DSR. While INTSM involves more routing information exchange, leading to slightly higher overhead, its superior network performance in load balancing and congestion management offsets this cost. INTSM's ability to maximize resource utilization and optimize routing while minimizing overhead significantly contributes to improved network efficiency. Overall, INTSM outperforms both AODV and DSR in terms of Routing Overhead, highlighting its effectiveness in enhancing network efficiency.

6. Conclusion

In conclusion, the Intermediate Node Traffic Sharing Model (INTSM) algorithm offers a promising approach to addressing load balancing and route discovery challenges in ad hoc networks. Its objectives include enhancing data transmission, achieving a balanced network topology, and effectively managing network congestion. The algorithm's direct route balancing and controlled flow categorization techniques are pivotal for optimizing network traffic. Through comprehensive simulations and performance assessments, continuous enhancements in network reliability and performance with the INTSM algorithm are anticipated.

The research significantly contributes to advancing ad hoc network protocols, ultimately enhancing network effectiveness and efficiency.

Future INTSM algorithm-related projects will involve:

1. Carrying out in-depth performance assessments in a variety of network settings.
2. Assessing the algorithm's efficacy and advantages by contrasting its performance with current protocols.
3. Putting the algorithm into practice and testing it in ad

hoc networks in the real world to see how well it performs.

4. Examining how scalable the algorithm is in bigger network settings.
5. Investigating energy-saving optimizations designed for network situations with power constraints.

The goal is to further enhance the algorithm's performance and significantly advance load balancing and route-finding methods in ad hoc networks by addressing these important areas.

Abbreviations

BMI	Body Mass Index
UV	Ultraviolet
HV	Vickers Hardness
HS	Shrinkage According Height
DS	Shrinkage According Diameter

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Rani Sahu: Conceptualization, Methodology, Formal Analysis, Investigation, Writing – original draft, Writing – review & editing

Neetu Sahu: Data curation, Methodology, Validation, Visualization

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Conflicts of Interest

The authors declare no conflicts of interest.

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