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Performance Evaluation and Comparative Analysis of AODV, DYMO, IARP, and IERP Routing Protocols in Ad Hoc Networks

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Abstract: An ad-hoc network is a unique type of wireless network that forms spontaneously and dynamically among a group of mobile devices without the need for any pre-existing infrastructure or centralized administration. The nodes communicating within an ad-hoc network exchange information or resources directly when they come into proximity. These networks are characterized by their decentralized nature and the absence of a fixed infrastructure. Among the multiple routing protocols in ad-hoc networks, on-demand routing protocols such as AODV, DYMO, and ZRP component protocols such as IARP and IERP, which are based on IEEE 802.11, are assessed in relation to one another. Comparative analysis has been conducted on performance-measuring metrics such as enqueue, dequeue, peak queue length, and carried load. A simulation has been set up to evaluate the performance of routing protocols such as AODV, DYMO, IARP, and IERP. The simulation is conducted using multiple devices connected through a wireless subnet and a gateway node for analysis of metric parameters such as enqueue, dequeue, peak queue length, and carried load. Experimental results are obtained using QualNet GUI (version 9.0) and a graph analyzer.

Keywords: *Wireless Routing Protocol, Enqueue, Dequeue, Peak Queue length, Carried Load, AODV, DYMO, IARP, IERP, QualNet GUI 9.0*

1. Introduction

The enormous increase of mobile devices day by day, increasing the information demand, has been pushing enthusiasm for the utilization of multi-hop ad-hoc networks for many years [1]. Ad-hoc networks are decentralized networks formed spontaneously without needing any pre-existing infrastructure or centralized administration. These networks are dynamic and often characterized by nodes' rapid and frequent movement. A group of wireless mobile devices collaborate to establish communication paths and relay data among themselves. Ad-hoc networks are particularly useful in scenarios where a fixed infrastructure is unavailable, impractical, or costly [14], [17-20]. What makes ad hoc networks different from wired networks is that all the usual rules about fixed topologies, fixed and known neighbors, fixed relationship between IP address and location, and more are suddenly tossed out the window [9]. Routing protocols for ad hoc networks play a crucial role in determining how data is transmitted from a source to a destination across the dynamic and changing topology of these networks. These ad-hoc networks are broadly classified into three categories such as proactive (table-driven): where nodes maintain up-to-date routing protocol tables that contain information about the network topology to ensure that the path is readily available when needed, reactive(on-demand) routing protocol: where the route is established only when communication with nodes is initiated, and protocol is more bandwidth efficient wherein communication is of sporadic. The last one is the combination of the above two which aims to combine the benefits i.e. Hybrid routing protocol. Numerous protocols have been proposed for efficient routing for data packet transfer in communication. That being said it is still difficult to decide on a routing protocol based on performance metrics. In this paper, we investigate the comparative analysis of five protocols for ad-hoc networks and the graph analyzed in Qualnet. We observed the results based on scenario setup and their metric parameters such as enqueue dequeue, carried load, peak queue length and efficiency [3-5], [11].

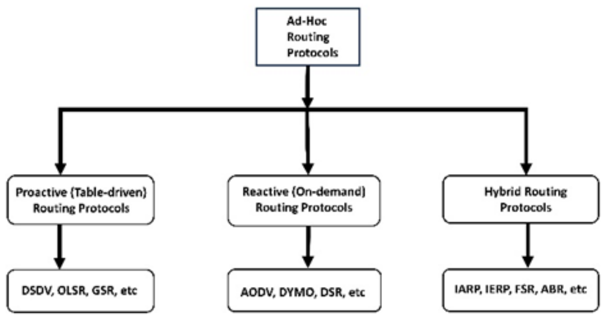

Fig.1 Types of Ad-hoc Routing Protocols

In the context of routing protocols like AODV (Ad-hoc On-Demand Distance Vector), DYMO (Dynamic MANET

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On-demand), IERP (Interzone Routing Protocol), and IARP (Intra-zone Routing Protocol), the terms enqueue, dequeue, peak queue length and carrier load refer to different aspects of packet handling: Enqueuing is the process of adding a packet to the transmission queue before it is sent over the network. Dequeuing is the process of removing a packet from the transmission queue for actual transmission. The peak queue length is a metric used to measure the highest number of items that accumulate in the queue during a specific period and provides insights into the congestion and load-handling capacity of the network, helping to assess how well the system manages the flow of data during periods of high demand. Carrier load refers to the load or utilization of the communication channel or medium (such as radio frequency) used for transmitting packets.

2. Literature Review

A few years ago, dynamically reconfigurable wireless ad hoc networks to interconnect mobile users for applications ranging from disaster recovery to distributed collaborative computing. Multicast tree structures are fragile and must be readjusted continuously as connectivity changes. Furthermore, typical multicast trees usually require a global routing substructure such as link state or distance vector. It used the concept of forwarding group, a set of nodes responsible for forwarding multicast data on shortest paths between any member pairs, to build a forwarding mesh for each multicast group [13]. An overview on MANET can be described as a self-designing infrastructure less engineering, which can deal with the correspondences in an exceptionally dynamic network topology. MANET can offer the freedom to build up a quick and cost-effective network than another network. Every node can move from one place to another during communication and this mobility is having its impact on the performance of the network. The number of parameters like number of packets delivered, no. of link breaks and End to End delay are describing the reason of variation in performance [1]. Selecting routing protocols was another task and that can be done by understanding how a datagram is forwarded among routers along an end-to-end path from the source host to the destination host. Prior to the routing protocols studied in this paper, previous version of was DSDV, of which AODV is an improvement, it minimizes the number of route broadcasts by creating route on an on-demand basis [7][15]. The Dynamic MANET On-demand (DYMO) is a reactive, multi-hop, unicast routing protocol that does not update route information periodically. DYMO has a small memory that stores routing information and generates Control Packets when a node receives a data packet from the route path [2]. IARP is a link-state protocol that maintains up-to-date information about all nodes within the zone. IERP is another type of Zone routing protocol which is used beyond the borders of familiar territories unlike IARP, transcending the confinement of localized maps [7]. To analyze the network, we have utilized performance metrics such as Enqueue, Dequeue, Peak queue length and carried load. Simulation mitigates risks by experimenting with scenarios, identifying potential issues without real consequences, aiding informed decisions. It saves costs by eliminating physical prototypes, reducing material and operational expenses, minimizing downtime. Simulation evaluates performance, optimizing designs, improving efficiency, identifying bottlenecks. QualNet is crucial for simulating communication networks, aiding researchers, engineers, and network professionals in modeling complex architectures and protocols. It creates realistic environments, essential for accurate testing and analysis, and supports the development and testing of network protocols, ensuring effectiveness and efficiency [12]. Simulating networks facilitates safe experimentation with configurations, traffic patterns, and failure scenarios, preemptively addressing issues and saving resources. It simplifies complex network interactions, unveiling dependencies and bottlenecks often overlooked. Through measuring metrics like latency and throughput, simulations predict network performance under various conditions. They also prototype new technologies, evaluate designs, and plan for scalability, optimizing decision-making processes. Simulations are invaluable for teaching and research, allowing for experimentation, visualization, and deeper understanding of networking concepts. They validate theories, compare algorithms, and aid in developing specialized protocols for diverse domains like wireless and sensor networks [6], [21-27].

3. Methodology

3.1. Research Objective:

The research objective of this study is to conduct a comprehensive performance evaluation and comparative analysis of prominent routing protocols—AODV, DYMO, IARP, and IERP—in the context of Ad Hoc Networks. The primary focus will be on assessing and contrasting their efficiency, reliability, and suitability for dynamic and self-organizing ad hoc communication environments. Specific performance metrics such as enqueue, dequeue, peak queue length carried load and including but not limited routing overhead, and energy consumption, will be systematically analyzed to gain insights into the strengths and weaknesses of each protocol. By employing realistic network scenarios and varying traffic conditions, the objective is to provide a nuanced understanding of how these routing protocols perform under different circumstances. The comparative analysis aims to identify the protocol that excels in specific performance criteria and to uncover trade-offs between different metrics.

Ultimately, the research seeks to contribute valuable knowledge for network designers, engineers, and researchers in making informed decisions regarding the selection and optimization of routing protocols for Ad Hoc Networks, thereby enhancing the overall efficiency and reliability of communication in dynamic and resource-constrained environments.

3.2. Simulation Environment and Tools

For a comprehensive analysis of various routing protocols, we utilized QualNet, a highly effective network simulation software recognized for modelling and analyzing communication networks. QualNet offered a versatile and customizable platform, emulating real-world environments and allowing in-depth scrutiny of networking intricacies. Leveraging its capability to simulate various wireless routing protocols in a network. There are numerous routing protocols available in QualNet which enabled exploration of diverse scenarios and standards relevant to routing protocols [7][12].

3.3. Technical Description

3.3.1. AODV:

Ad Hoc On-Demand Distance Vector (AODV) is a routing protocol designed for mobile ad hoc networks (MANETs), where nodes dynamically establish networks without the need for a pre-existing infrastructure. AODV falls under the category of reactive or on-demand routing protocols, meaning that routes are created only when needed. It is based on the distance vector algorithm that measures the distance or cost to reach the destination node in terms of hops. Each node maintains a routing table that stores information about the routes to other nodes. AODV is essentially a combination of both DSR and DSDV. It borrows the basic on-demand mechanism of Route Discovery and Route Maintenance from DSR, plus the use of hop-by-hop routing, sequence numbers, and periodic beacons from DSDV [10],[16]. When node wants to communicate, the Algorithm follows as:

- Initialization.
- Route Discovery – When a node communicates with a new node and the route is not present in the routing table, the node creates an RREQ packet containing source and destination addresses with the source’s sequence number.
- Receiving RREQ – When a node receives an RREQ packet, it checks if it has seen the RREQ packet before, if yes, it will ignore it else it updates its routing table. If the node is the destination or has a fresh enough route to the destination, it sends a Route Reply (RREP) to the source.
- Forwarding RREQ - When a node receives an RREQ packet if they have not seen it before they update their routing table and forward the RREQ to neighbors, unless they are the destination or have a route to the destination.
- Route Reply (RREP) – When the destination or a node with a route to the destination receives the RREQ, it generates the reply packet (RREP) with its sequence number and sends it back to the source. Nodes in the reverse path update their routing tables with the information from the RREP.
- Forwarding RREP – Intermediate nodes between source and destination forward the RREP back towards the source.
- Sequence Numbers – They are used to ensure the freshness of route information. When a node receives a control packet with a higher sequence number, it updates its information.
- End.

3.3.2. DYMO:

Dynamic MANET On-demand (DYMO) emerges as a sophisticated routing protocol expressly crafted for the intricacies of mobile ad hoc networks (MANETs). Operating as a reactive or on-demand routing solution, DYMO dynamically forges routes exclusively when necessitated by data transmission, showcasing a distinct focus on simplicity, adaptability, and resource efficiency. Functioning in stark contrast to proactive counterparts, DYMO minimizes the routing overhead by creating and sustaining routes only in response to the dynamic demands of MANET environments. When a source node seeks to dispatch data to a destination, DYMO orchestrates a meticulous algorithm as below:

- Initialization. – Initialize routing tables and set up parameters such as route discovery timeout, route maintenance interval, etc.

- Route Discovery – When a source node needs to send a packet to a destination, it checks the local routing table for a valid route. If no route is found, initiate a route discovery process by broadcasting a Route Request (RREQ) packet to neighbors. The packet includes source, destination, and a unique identifier in the RREQ. Set a timer for waiting responses.

- Route Request Forwarding – The intermediate nodes receiving the RREQ packet check if they have a route to the destination in their tables and forward the RREQ if they don’t have a valid route. It also updates the reverse route table entry for the source node.

- Route Reply (RREP) Generation - The destination node or an intermediate node with a valid route to the destination generates an RREP. Include the route information and send it back to the source node. Intermediate nodes update their routing tables with information from the RREP.

- Route Maintenance - Periodically check the status of active routes. If a link or node failure is detected, remove, or repair the affected routes. Use Route Error (RERR) packets to notify other nodes about broken routes.
- Local Connectivity Maintenance - Continuously monitor the local neighborhood for changes in connectivity. Update routing tables based on changes in neighbor availability.
- Adaptation to Network Changes - Ensure the protocol can adapt to dynamic changes in network topology and traffic conditions.
- End.

3.3.3. IARP:

Managing large-scale networks efficiently can be challenging because of their dynamic nature. IARP emerges as a beacon of optimized communication within localized network segments. As opposed to its global counterparts, IARP meticulously maps out each domain for faster data delivery. In these carefully defined territories, proactive route sharing ensures immediate access to neighboring devices. IARP empowers nodes to act confidently with local expertise instead of waiting for distant routing updates. IARP is a link-state protocol that maintains up-to-date information about all nodes within the zone. For any given node X, X's peripheral nodes are defined to be those nodes whose minimum distance to X is the zone radius [8]. It follows below algorithm:

- Initialization. – Initialize routing tables and set up initial routes based on some default strategy or static routing.
- Periodic Monitoring - Continuously monitor network conditions, including link quality, latency, and available bandwidth. Collect metrics related to network performance.
- Adaptive Metric Calculation - Dynamically calculate or update routing metrics based on the monitored network conditions. Consider factors such as link reliability, congestion, and latency.
- Route Selection - Evaluate the available routes based on the adaptive metrics. Choose the route that best satisfies the current network conditions.
- Dynamic Route Updates - Periodically update routing tables with the latest metrics and information. Trigger updates based on significant changes in the network, such as link failures or improvements.
- Load Balancing - Implement load balancing strategies to distribute traffic across multiple paths. Consider factors such as link utilization and available capacity.
- Fault Tolerance - Implement mechanisms to handle link failures or node failures. Dynamically reroute traffic in the case of a failure to maintain connectivity.
- Security Considerations - Integrate security mechanisms to protect against attacks, such as routing table poisoning or manipulation.
- Feedback Mechanism: Implement a feedback mechanism to collect information on the effectiveness of chosen routes. Use feedback to further optimize the adaptive routing algorithm.
- End.

3.3.4. IERP:

The Interzone Routing Protocol (IERP), a pivotal component of the Zone Routing Protocol (ZRP) framework designed explicitly for mobile ad hoc networks (MANETs), emerges as a solution addressing the inherent challenges of both proactive and reactive routing protocols in this dynamic environment. Situated within the broader ZRP framework, IERP strategically combines the strengths of proactive and reactive strategies to optimize routing efficiency. ZRP utilizes the Interzone Routing Protocol (IERP) for discovering routes to destinations outside of the zone. For route discovery, the notion of bordercasting is introduced. Once a source node determines the destination is not within its zone, the source bordercasts a query message to its peripheral nodes.[8] Operating within a zone-based organization, IERP divides the MANET into routing zones with a typical 2-hop radius, employing the proactive Intrazone Routing Protocol (IARP) for intrazone communication and the reactive. With advantages ranging from scalability to applications in diverse fields such as military networks, disaster relief, sensor networks, wireless mesh networks, and vehicular networks, IERP plays a crucial role in optimizing routing solutions within the ZRP framework for efficient MANET operation. However, considerations like zone radius impact and security vulnerabilities underscore the need for careful implementation and ongoing optimization in IERP's role within ZRP. It follows below algorithm:

- Initialization. – Initialize routing tables and set up parameters such as route discovery timeout, route maintenance interval, etc.
- Zone Identification - Define and identify zones within the network. Assign zone identifiers to nodes based on their geographical or logical location.

- Zone-to-Zone Connectivity Establishment - Establish connectivity information between different zones. Update routing tables with interzone connectivity information.
- Interzone Route Discovery - When a source node needs to send a packet to a destination in a different zone it checks the local routing table for a valid interzone route. If no route is found, initiate an interzone route discovery process. Broadcast an Interzone Route Request (IRREQ) packet to neighboring zones. Include source, destination, and a unique identifier in the IRREQ. Set a timer for waiting responses.
- Interzone Route Request Forwarding: Intermediate nodes in the source zone receiving the IRREQ will check if they have a valid interzone route in their tables. Forward the IRREQ if they don't have a valid route. Update the interzone routing tables with information from the IRREQ.
- Interzone Route Reply (IRREP) Generation: The destination zone or an intermediate zone with a valid route to the destination generates an IRREP. Include the interzone route information and send it back to the source zone. Intermediate zones update their interzone routing tables with information from the IRREP.
- Interzone Route Maintenance - Periodically check the status of active interzone routes. If a link or node failure is detected, remove, or repair the affected interzone routes. Use Interzone Route Error (IRERR) packets to notify other zones about broken interzone routes.
- Local Connectivity Maintenance: Continuously monitor the local neighborhood for changes in connectivity.Update routing tables based on changes in interzone and intrazone connectivity.
- End.

4. Simulation Setup

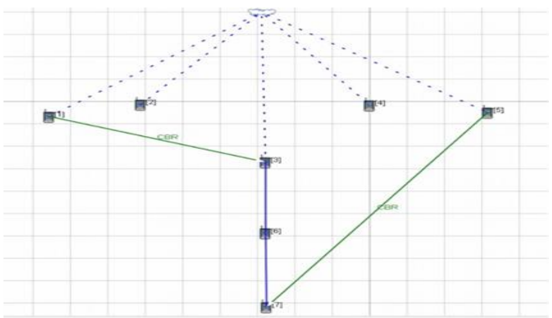


Fig. 2 Topology Diagram.

The network simulation is set up with seven nodes and one wireless subnet. Each node is labelled with a number (1, 2, 4, 5, 6, 7) and is positioned within the coverage area of the wireless subnet. The central node (number 3) is configured as the gateway node which acts as the interface between wireless and wired nodes. Different types of routing protocols were used in the mobile devices such as AODV, DYMO, IARP & IERP. Node 1communicates with Node 3 with a constant bit rate (CBR) to demonstrate wireless communication and Node 5 communicates with Node 7 with a constant bit rate (CBR) to demonstrate wireless to wired communication. Based on these simulations, we observed changes in metric parameters such as Enqueue, Dequeue, Peak Queue length and Carried load.

5. Results& Comparative Table

5.1. Results

5.1.1. Enqueue:

The Enqueue graph reveals a clear disparity in the number of packets entering the queues of different nodes in the network, suggesting varying levels of traffic injection and potential load imbalances among the routing protocols being tested. AODV consistently enqueues the most packets across all nodes, indicating a higher rate of packet generation or reception compared to the other protocols. DYMO follows a similar trend, but with a noticeable gap compared to AODV, suggesting a slightly lower volume of traffic being introduced into its queues. IARP and IERP exhibit significantly lower enqueue rates, implying a more conservative approach to packet injection or potentially a lower level of network activity associated with these protocols. The enqueue rates vary across different nodes, with certain nodes (such as N1, N4, and N7) experiencing higher rates than others. This points to potential influences of network topology or traffic patterns on packet injection behaviour.

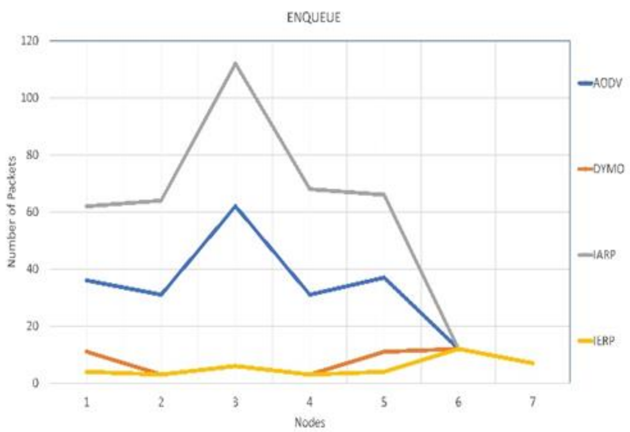


Fig.3 Enqueue Comparison for different wireless routing protocols.

5.1.2. Dequeue:

The Dequeue graph highlights a clear variation in the -

number of packets processed across different nodes in the network. Notably, AODV exhibits the highest packet dequeuing rate, followed by DYMO, IARP, and IERP, in that order. This suggests that AODV is likely demonstrating greater efficiency in handling and forwarding packets compared to the other protocols within

this specific network configuration. AODV consistently maintains a lead in packet dequeuing across all nodes. DYMO follows a similar trend but with a noticeable gap compared to AODV.IARP and IERP exhibit significantly lower dequeuing rates, suggesting potential bottlenecks or inefficiencies in their packet-handling mechanisms

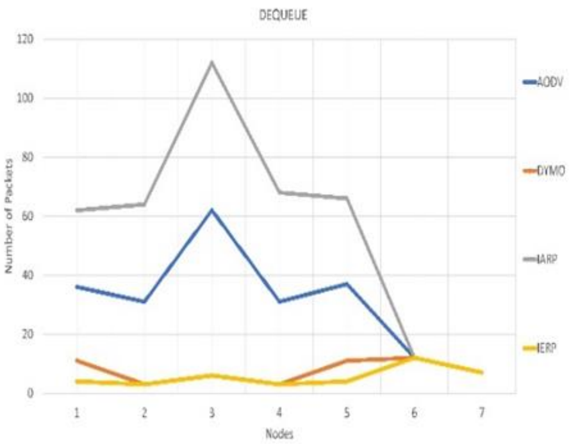


Fig.4 Dequeue Comparison for different wireless routing protocols.

5.1.3. Peak Queue Length:

The Peak Queue Length graph reveals significant differences in how packets accumulate at various nodes within the network suggesting diverse performance characteristics among the routing protocols being evaluated.

AODV consistently demonstrates the highest peak queue lengths across all nodes, indicating a tendency to buffer more packets before forwarding.

DYMO exhibits lower peak queue lengths compared to AODV, suggesting a potentially more efficient packet-handling approach. IARP and IERP exhibit the lowest peak queue lengths, implying a more conservative packet buffering strategy.

Interestingly, peak queue lengths vary across different nodes, pointing to potential network topology or traffic pattern influences.

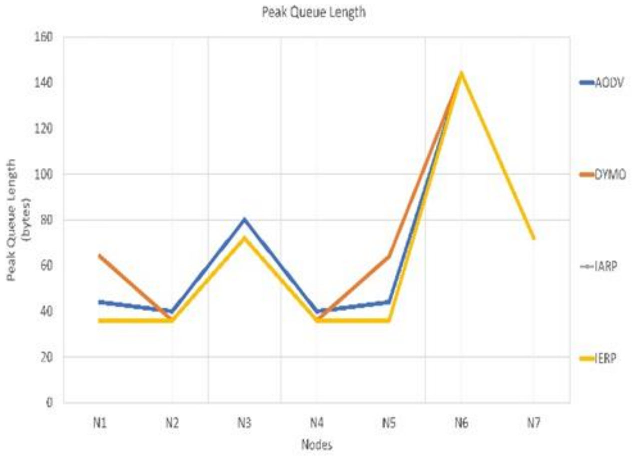


Fig.5 Peak Queue Length Comparison for different wireless routing protocols.

5.1.4. Carrier Load:

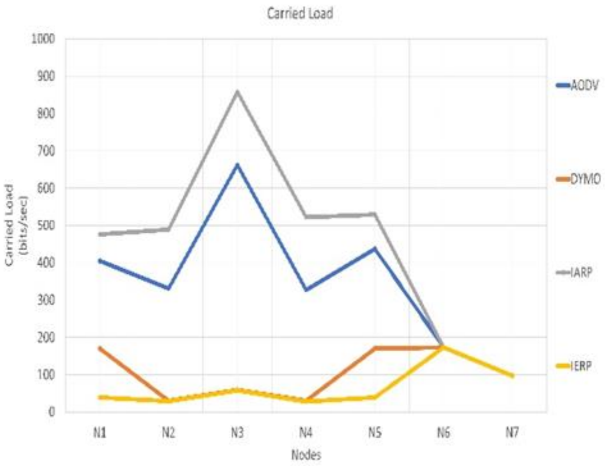
The Carried Load graph illustrates a varied distribution of traffic load across different nodes in the network, with distinct patterns emerging for each routing protocol.

AODV carries the highest load overall, consistently handling the most packets at each node.

This suggests its effectiveness in routing traffic efficiently within this network scenario. DYMO follows a similar trend, but with a noticeable gap compared to AODV, indicating a slightly lower capacity for load distribution. IARP and IERP exhibit significantly lower carried loads, suggesting potential limitations in their ability to handle high traffic volumes or potential underutilization in this specific setup.

The load distribution across nodes is not uniform, with some nodes (such as N1, N4, and N7) experiencing higher loads than others. This hints at the potential influences of network topology or traffic patterns on load distribution.

Fig.6 Carried length comparison for different wireless routing protocols.



5.2. Comparison Table

Table 1 – Different Routing Protocols.

Aspect	**AODV**	**DYMO**	**DSR**	**IARP**	**IERP**
Routing Mechanism	Utilizes on-demand routing, establishing routes only when needed. Employs sequence numbers to ensure the freshness of routing information.	On-demand protocol that dynamically maintains routes using sequence numbers. It is designed for mobile ad hoc networks (MANETs) with frequent topology changes.	Source routing protocol where the sender determines the complete route to the destination and includes it in the packet header.	A proactive routing protocol that maintains routing information for all nodes within the same zone.	Proactive protocol responsible for maintaining routing information between different zones.
Route Discovery and Maintenance	Employs route discovery by flooding route request packets and route maintenance through periodic route updates.	Utilizes route discovery and maintenance mechanisms similar to AODV but with optimizations for MANETs	Dynamic route discovery, where nodes cache and use discovered routes. Routes are maintained using route error packets.	Proactive, maintaining routes continuously to all nodes within the same zone.	Focuses on maintaining routing information between different zones in a proactive manner.
Overhead and Scalability	Moderate overhead during route discovery due to RREQ/RREP flooding. Good scalability for moderate network sizes	Lower overhead than AODV due to proactive zone updates. Good scalability for larger networks due to zone-based approach.	Tends to have higher overhead, especially in large networks, as it relies on source routing information. Limited scalability due to overhead with longer paths.	Moderate overhead from zone updates, additional overhead for source routing in inter-zone. Highly scalable for large, hierarchical networks.	Moderate overhead from ZRP, but zone configuration can impact efficiency. Designed for large, hierarchical networks, not suitable for smaller ones.

Adaptability to Mobility	Handles mobility well through local repair mechanisms.	Adapts well to moderate mobility due to zone-based proactive updates.	Highly adaptable to dynamic topologies thanks to source routing, but sensitive to frequent movement.	Adapts well to zone-based movement, may struggle with frequent individual node mobility.	Designed for controlled mobility within zones, not ideal for highly dynamic networks.
Security Considerations	AODV is vulnerable to Route request (RREQ) flooding attacks, black hole attacks, wormhole attacks. It uses sequence numbers for loop-free routing offer some protection.	DYMO is vulnerable to similar attacks as AODV and additionally susceptible to zone routing manipulation. Also, zone-based approach can limit attack spread, but requires secure zone configuration.	DSR is vulnerable to source routing manipulation attacks, replay attacks due to lack of central authentication. Path validation mechanisms can offer some protection against source routing attacks.	Vulnerable to: Attacks exploiting both proactive and source routing functionalities. Security features: Zone-based routing provides some isolation but requires secure zone configuration.	Vulnerable to: Similar attacks as IARP, additionally susceptible to inter-zone routing manipulation. Security features: Zone-based routing and ZRP offer some protection but require robust security measures.
Energy - Efficiency	It is considered moderately efficient as it consumes more energy during route discovery, but power-saving features can mitigate this. Power-saving features are limited, typically requires additional mechanisms.	DYMO is considered more energy-efficient due to proactive routing within zones. Power-saving features may include sleep modes and duty cycling within zones.	DSR can be energy-efficient for short paths but becomes less efficient with longer routes. Power saving features are limited and depends on specific implementations.	Like DYMO, IARP is also considered energy efficient due to proactive routing within zones. Zone-based approach can allow for power-saving within zones.	Like AODV, IERP consumes more energy during route discovery and as IARP, Zone-based routing can facilitate power-saving within zones.

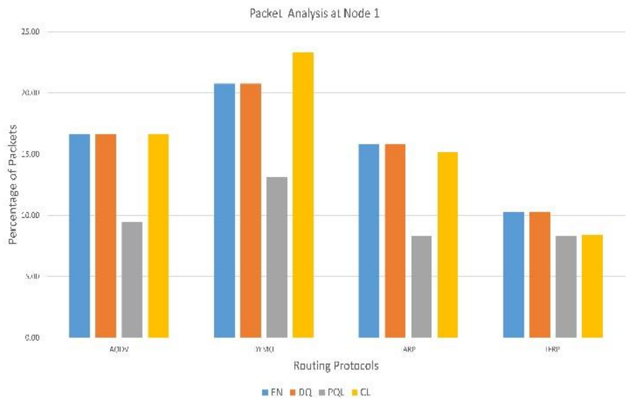


Fig.7 Packet Analysis at Node 1**.**

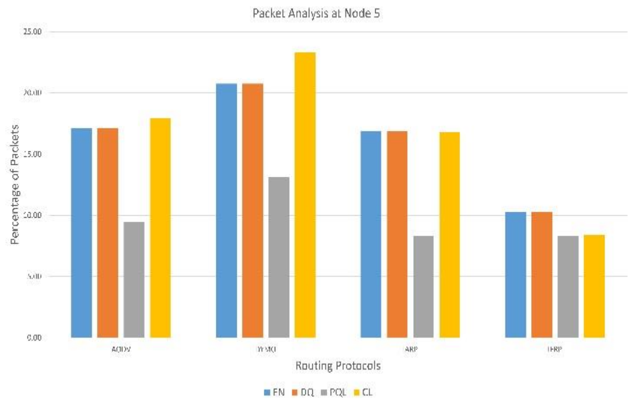


Fig.8 Packet Analysis at Node 5**.**

6. Conclusion

In conclusion, the network simulations conducted with seven nodes and a wireless subnet, employing different routing protocols (AODV, DYMO, IARP, and IERP), have provided valuable insights into the performance characteristics of each protocol in terms of Enqueue, Dequeue, Peak Queue Length, and Carried Load metrics. We observed for a topology with fewer than 10 nodes, the IERP routing protocol demonstrates the best performance, followed by IARP, AODV, and DYMO. Concerning the Enqueue & Dequeue parameter, we note that the DYMO protocol exhibits the highest packet accumulation at the client device N1, accounting for 20.75% of the total packets sent. Subsequently, AODV follows with 16.67%, IARP with 15.85%, and IERP with the least packet accumulation at 10.25%. Similarly, for peak queue length parameter again we note that DYMO protocol exhibits highest value at N1 implying more traffic, accounting 13.11% of the maximum number of packets present in the queue, followed by AODV with 9.48% lastly IARP & IERP exhibit similar behaviour with 8.34% of the maximum number of packets and for carried load, as we observed that as enqueue & dequeue values for DYMO protocol were highest amongst AODV, IARP & IERP hinting highest network utilization – 23.31% which was followed by AODV – 16.65, then IARP – 15.13% & lastly least was IERP – 8.42%.

Like Node 1 (N1), node 5 (N5) also exhibits same behaviour suggesting that the performance characteristics of IERP protocol in terms of Enqueue, Dequeue, Peak Queue Length, and Carried Load metrics was best for a topology with fewer than 10 nodes.

For Enqueue & Dequeue parameter, we note that the DYMO protocol exhibits the highest packet accumulation at the client device N1, accounting for 20.75% of the total packets sent. Subsequently, AODV follows with 17.12%, IARP with 16.87%, and IERP with the least packet accumulation at 10.25%.

Similarly, for peak queue length parameter again we note that DYMO protocol exhibits highest value at N5 implying more traffic, accounting 13.11% of the maximum number of packets present in the queue, followed by AODV with 9.48% lastly IARP & IERP exhibit similar behavior with 8.34% of the maximum number of packets and for carried load, as we observed that as enqueue & dequeue values for DYMO protocol were highest amongst AODV, IARP & IERP hinting highest network utilization – 23.31% which was followed by AODV – 17.96, then IARP – 16.82% & lastly least was IERP – 8.42%.

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