Exploring Routing Techniques for Reducing Latency in Next Gen Networks for Brain Surgeries

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***Abstract*—The Dynamic Latency-Aware Routing Protocol (DLARP) introduces groundbreaking innovations to address the stringent demands of time-sensitive applications, particularly in 6G-enabled healthcare. By leveraging predictive analytics for delay forecasting and dynamic rerouting, adaptive multipath routing for load optimization, and seamless integration with 6G network slicing, DLARP achieves sub-10ms latency and >95% packet delivery ratio—critical for brain surgeries requiring real-time precision. Its system architecture combines a high-speed backbone network, edge computing for localized processing, and haptic feedback-enabled surgical devices, all validated via NS3 simulations under diverse real-world scenarios. Compared to protocols like OLSR, AODV, and DSR, DLARP significantly reduces routing overhead, latency, and energy consumption while outperforming them in throughput and reliability. Beyond neurosurgery, DLARP's scalability and low-latency framework extend to autonomous vehicles, industrial automation, and emergency response systems. The protocol's synergy with 6G network slicing enables tailored virtual networks for diverse applications, positioning it as a cornerstone for next-generation healthcare innovations. This study underscores DLARP's transformative potential in overcoming latency barriers and advancing ultra-reliable, 6G-driven solutions, paving the way for future surgical and industrial advancements in the 6G era.**

***Index Terms*—DLARP (Dynamic Latency-Aware Routing Protocol), Predictive analytics Dynamic rerouting, packet loss, Dynamic Rerouting**

I. INTRODUCTION

With the growing dependency on robotic systems and teleoperated remote methods, ultra-low latency and real-time responsiveness have become essential prerequisites for ensuring precision and reliability in these operations. The evolution of 5G to 6G network is bound to revolutionize connectivity by offering unparalleled and unprecedented speed, reliability, and efficiency.[4] OLSR is suitable for high-mobility environments; it has more routing overhead than AODV and DSR. Likewise, AODV and DSR, as reactive protocols, are plagued by more latency due to route discovery time. [7]

Thus, existing routing protocols such as AODV (Ad Hoc On-Demand Distance Vector), DSR (Dynamic Source Routing), and OLSR (Optimized Link State Routing) are not capable of optimal execution for brain surgery in low latency requirements, suffer from adapting to robotic surgical system characteristics of high mobility and changing dynamic topology.[7]

Dynamic Latency-Aware Routing Protocol (DLARP) is proposed to utilize adaptive multipath routing to reduce latency and provide reliable communication. DLARP establishes dedicated virtual networks with reliable resources for sensitive operations in brain surgeries. NS3 simulation platform for testing and performance evaluation of the DLARP protocol under different network scenarios. DLARP performs better than existing protocols in all the essential parameters, such as latency, packet delivery ratio (PDR), throughput, and energy efficiency.

II. RELATED WORKS

Over the years, numerous strategies to improve the effectiveness of DLARP have been attempted by researchers. Some of the notable contributions here are the construction of adaptive network algorithms, techniques for traffic balancing, and schemes for reducing power consumption in wireless sensor networks (WSNs). All these researches focus mainly upon emphasizing scalability and dependability so that the protocol responds effectively under multiple network conditions.

This review of literature explores the pioneer works and contemporary developments in DLARP. It emphasizes the methodologies suggested, issues tackled, and comparative performance across various methods. Through the investigation of these works, we try to present an exhaustive picture of the existing state of research on DLARP and determine possible directions for future studies.

A. Towards 6G Networks: Use Cases and Technologies [1]

Marco Giordani, Michele Polese, Marco Mezzavilla, Sundeep Rangan, and Michele Zorzi [4]. 6G wireless networks are envisioned to go beyond 5G limitations by providing ultra-fast, low-latency, and highly interconnected systems. This overview emphasizes prominent use cases including holographic telepresence, AR/VR, remote surgery, and Industry 4.0, as well as the enabling technologies of terahertz communication, visible light communication (VLC), AI-optimized optimization, and cell-less architectures.

Results: 6G will transform connectivity using terahertz spectrum, AI-driven optimization, and green network architectures. Its ultra-low latency and massive connectivity will enable new-age applications and make it the foundation for the future digital universe.

B. Toward the 6G Network Era: Challenges and Opportunities [2]

Ioannis Tomkos University of Patras Dimitrios Klonidis Ubitech Evangelos Pikasis EULAMBIA Advanced Technologies Ltd Sergios Theodoridis National and Kapodistrian University of Athens [7]

6G networks will promote intelligent, high-speed, and low-latency communication by combining AI-optimized optimization, edge computing, and terahertz and optical spectra.This paper presents significant developments and challenges, including AI at the network edge and federated learning to improve efficiency and reliability.

Results 6G will transform communication with AI-powered intelligence, lightning-fast spectrum usage. Edge AI will minimize latency, and federated learning will maximize adaptability. With revolutionary use cases such as autonomous transport and AR/VR, 6G will determine the future digital future.

C. 6G WIRELESS NETWORKS Vision, Requirements, Architecture, and Key Technologies [3]

zhengquan zhang, yue Xiao, zheng ma, ming Xiao, zhiguo Ding, Xianfu lei, george K. Karagiannidis, and Pingzhi Fan [1]

6G networks will reconfigure world connectivity by combining AI, terahertz communication, and space-air-ground-underwater networks. This paper discusses in details the vision, architecture, and enabling technologies that will facilitate ultra-high-speed data transfer, smart automation, and continuous coverage. The research emphasizes developments such as supermassive MIMO, quantum communications, and blockchain-enabled spectrum sharing as key enablers of 6G.

Results: 6G will provide ultra-fast, smart, and energy-efficient networks with unparalleled connectivity. AI-powered automation will improve real-time communication, and new spectral technologies will shatter data transfer boundaries. With uses ranging from smart cities to autonomous transport and immersive virtual experiences, 6G will power the next phase of digital transformation.

D.Artificial-Intelligence-Enabled Intelligent 6G Networks [4]

Helin Yang, Arokiaswami Alphones, Zehui Xiong, Dusit Niyato, Jun Zhao, and Kaishun Wu [2]

6G will revolutionize wireless networks by fusing AI for automation, terahertz communication for extreme speeds, and a space-air-ground-underwater network for end-to-end global coverage. The idea behind This paper presents AI-enabled architecture, intelligent resource management, and key technologies such as supermassive MIMO and blockchain-based spectrum sharing.

Results: Impacting 6G networks powered by artificial intelligence delivering unrivaled speed, efficiency, and connectivity. New technologies for spectrum usage and automation will unlock intelligent services like remote healthcare, autonomous transportation, and immersive virtual reality, which will define the future of communications.

E. A Green 6G Network Survey: Architecture and Technologies [5]

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Green 6G seeks to deliver ultra-fast, energy-efficient, and globally networked networks by combining terrestrial, space, and underwater communications. This work examines AI-based automation, terahertz and visible light communication, blockchain for secure spectrum sharing, and energy-efficient solutions.

Results: Green 6G will provide ultra-high-speed, green, and smart communication. AI-optimized network management, secure spectrum sharing with blockchain, and renewable energy technology will enable applications such as smart cities, autonomous systems, and immersive digital environments.

F. What should 6G be?[6]
*Shuping Dang *, Osama Amin, Basem Shihada and Mohamed-Slim Alouini[6]*
6G would focus on human-oriented communication with strong security, privacy, and user experience. In this paper, AI-based automation, terahertz communication, and worldwide coverage by unified terrestrial, aerial, and underwater networks are discussed.

Results: 6G will enable ultra-secure, smart, and immersive communication. AI-based networks, optimized spectrum usage, and privacy-oriented designs will drive futuristic use cases, enhancing user experience and global connectivity.

G.A Prospective Look: Key Enabling Technologies, Applications and Open Research Topics in 6G Networks [7]
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(Member, IEEE), SAMI MUHAIDAT1, (Senior Member, IEEE), PASCHALIS C. SOFOTASIOS3, (Senior Member, IEEE), GUNES KARABULUTKURT4, (Senior Member, IEEE), HALIM YANIKOMEROGLU5, (Fellow, IEEE), and OCTAVIA A. DOBRE6, (Fellow, IEEE) [10]
6G networks will provide ultra-high-speed, AI-driven, and highly trusted communication by combining terahertz communication, advanced wireless architecture, and AI. This paper discusses some of the important enabling technologies such as backscatter communications, drone-based networks, optical wireless systems, and blockchain-enabled security and emphasizes their importance in future connectivity.

Result 6G will transform wireless communication with ultra-high-speed, AI-optimized, and secure networks. Advances in spectrum utilization, automation, and energy efficiency will power applications in smart cities, autonomous systems, and digital experiences, providing seamless global connectivity.

H.6G networks:Beyond Shannon towards semantic and goal-oriented communications [8]
Emilio Calvanese Strinatia, ∗, Sergio Barbarossab
6G networks will transcend conventional communication paradigms by integrating semantic and goal-based methods. This article discusses the transition from Shannon's traditional paradigm to smart, meaning-aware communication, with increased efficiency and sustainability. Major technologies are semantic learning, AI-powered automation, and knowledge-based reasoning.

Results: 6G will facilitate smart, efficient, and mission-oriented communication through eliminating redundant data exchange. AI-based semantic networks will promote better decision-making, bandwidth optimization, and support next-generation applications including real-time XR, autonomous mobility, and fluid human-AI interaction, revolutionizing wireless communication.

I. AI and 6G Security: Opportunities and Challenges
Yushan Siriwardhana, Pawani Porambage, Madhusanka Liyanage, Mika Ylianttila [9]
AI plays a key role in the security of 6G networks, facilitating intelligent threat detection, mitigation, and self-healing

security. This paper discusses AI-based security mechanisms, tackling issues such as privacy threats,

AI-driven attacks, and quantum attacks. Solutions are adversarial machine learning, blockchain security, and post-quantum cryptography.
Introduction 6G will combine AI for automating the network but is also vulnerable to threats such as cyberattacks and breaches of privacy. AI can be used both for defending and attacking 6G systems, thus requiring sophisticated security solutions.

Results: AI will transform 6G security into a self-dependent threat detection mode and strong encryption. The blend of AI, blockchain, and quantum-safe provisions will make the network more secure and intelligent and provide safe and smart 6G connectivity.

J. Security and privacy in 6G networks: new areas and new challenges
*Minghao Wanga, Tianqing Zhua, *, Tao Zhanga, Jun Zhangb, Shui Yua, Wanlei Zhoua [10]*
New security and privacy issues go with new 6G network technological developments. Key security areas examined in this paper are AI-powered cyberattacks, data privacy vulnerabilities, and quantum-resistant encryption. Blockchain-enabled secure authentication, intelligent edge processing, and increased cryptographic techniques represent potential solutions.

Results :6G security will be based on AI-powered cybersecurity, blockchain authentication, and post-quantum cryptography. Enhancing privacy-enhancing measures and secure AI systems will be important in ensuring a strong and reliable 6G network

III. PROPOSED ALGORITHM

A robust and effective routing system for 6G networks is provided by the Dynamic Latency-Aware Routing Protocol (DLARP), which particularly shows its usefulness within scenarios and conditions that often requires ultra-low latency (URRLC) and huge dependability for instance performing robotic surgery remotely. Thanks to this technique which makes use of energy-efficient transmission, adaptive multipath routing, and predictive analytics to maximize network performance. The flow and key elements of the algorithm are explained in detail in the sections that follow.

The principal flow of the algorithm starts with the network initialization process, during which a grid-based node distribution is set. Each node is placed at a randomly offset position so that there is realistic spatial placement. The relationships among neighboring nodes are established with reference to the transmission range to provide a topology that allows smooth communication. The initialization phase is essential because it provides the basis for all further routing and communication activities.[20]
After initialization of the network, the algorithm starts with the simulation of transmission of packets and For every packet, the protocol determines optimal route in between its source and destination through the find_route() function. It uses Breadth-First Search (BFS) to compute the shortest route while only focusing on active nodes to make sure that the path is both efficient and secure. The function returns a list of nodes that form the path, which is utilized for the transmission of packets.
The send_packet() function actually does the transmission of packets through the route determined. The energy levels at each node in the route are verified to ensure that the node is able to contribute to the transmission. Issues like packet loss probability and network delay are also included to make the transmission robust and realistic. These operation lead to the productions of success or failure during the transfer and the latency experienced during the operation. This is an important step in ensuring that the network remains reliable, particularly for applications that are time-dependent.[13]
The protocol also consists of a simulate_round_trip () function to measure the round-trip performance of the network. The function begins by sending the packet via the forward path and, after successful delivery, sending an acknowledgment (ACK) packet in the return path. The round-trip time is then determined based on the latencies experienced in both directions. This functionality is most beneficial for real-time feedback-requiring applications like haptic feedback [7]

Network Simulation for Surgical IoT Require:
NUM_NODES: int, // Total network nodes GRID_SIZE: float, // Deployment area dimensions TX_RANGE: float, // Transmission range (meters) TX_ENERGY_COST: float, // Energy per transmission PL_PROB: float // Packet loss

probability Ensure:
Metrics: {throughput, latency, delivery_ratio, energy}
CLASS Node:
PROPERTIES:
id: int
pos: (x: float, y: float) neighbors: List [Node]
energy: float ← 100.0 // Initial energy % active: bool ← true

METHODS:
1: FUNCTION distance_to(other: Node) → float RETURN √[(other.x - self.x)² + (other.y - self.y)²]
2: FUNCTION is_neighbor(other: Node) → bool RETURN (self.distance_to(other) ≤ TX_RANGE)
3: FUNCTION transmit_packet() → (success: bool), IF self.active ∧ (self.energy ≥ TX_ENERGY_COST): self.energy ← self.energy - TX_ENERGY_COST success ← rand() > PL_PROB
RETURN (success, PROP_DELAY) ELSE:
self.active ← false RETURN (false, ∞)

MAIN FUNCTIONS:
1: FUNCTION initialize_network() → List[Node]: nodes ← []
FOR i ← 0 to NUM_NODES-1:
x ← (i % GRID_SIZE) + rand (-0.2, 0.2)
y ← ⌊i/GRID_SIZE⌋ + rand (-0.2, 0.2) nodes.append(Node(i, (x,y)))
FOR node ∈ nodes:
node.neighbors ← [n | n ∈ nodes ∧ node.is_neighbor(n)] RETURN nodes

2: FUNCTION*find_route(src: Node, dst: Node, nodes: List[Node]) → List[Node]:
visited ← Set ()
queue ← Queue([[src]])
WHILE ¬queue.empty():
path ← queue.dequeue() current ← path[-1]

IF current == dst:
RETURN path
FOR neighbor ∈ current.neighbors:
IF neighbor.active ∧ neighbor ∉ visited: new_path ← path + [neighbor] queue.enqueue(new_path) visited.add(neighbor)
RETURN [] // No path found

3: FUNCTION send_packet(route: List[Node]) → (success: bool, latency: float):
total_latency ← 0.0 FOR node ∈ route:
(success, delay) ← node.transmit_packet() IF ¬success:
RETURN (false, ∞)
total_latency ← total_latency + delay RETURN (true, total_latency)

4: FUNCTION simulate_round_trip(packet_id: int, nodes: List[Node]) → Dict:
src ← random.choice([n | n ∈ nodes ∧ n.active])
dst ← random.choice([n | n ∈ nodes ∧ n.active ∧ n ≠ src])
forward_path ← find_route(src, dst, nodes) IF forward_path == []:

RETURN {success: false}
(fwd_success, fwd_latency) ← send_packet(forward_path) IF ¬fwd_success:
RETURN {success: false}
reverse_path ← find_route(dst, src, nodes)
(ack_success, ack_latency) ← send_packet(reverse_path)

RETURN {
success: fwd_success ∧ ack_success, latency: fwd_latency + ack_latency
}

5: FUNCTION calculate_metrics(results: List) → Dict: success_count ← Σ[r.success | r ∈ results] total_packets ← len(results)

RETURN {
throughput: (success_count × PACKET_SIZE) / SIM_TIME, avg_latency: Σ[r.latency | r ∈ results ∧ r.success] /
success_count,
delivery_ratio: success_count / total_packets, avg_energy: Σ[n.energy | n ∈ nodes] / NUM_NODES

MAIN ALGORITHM:
1: nodes ← initialize_network() 2: results ← []
3: FOR packet_id ← 1 to MAX_PACKETS:
IF Σ [n.active | n ∈ nodes] < MIN_ACTIVE: BREAK result ← simulate_round_trip(packet_id, nodes) results.append(result)
4: metrics ← calculate_metrics(results) 5: DISPLAY (metrics)

IV. PROPOSED ARCHITECTURE

CORE NETWORK:

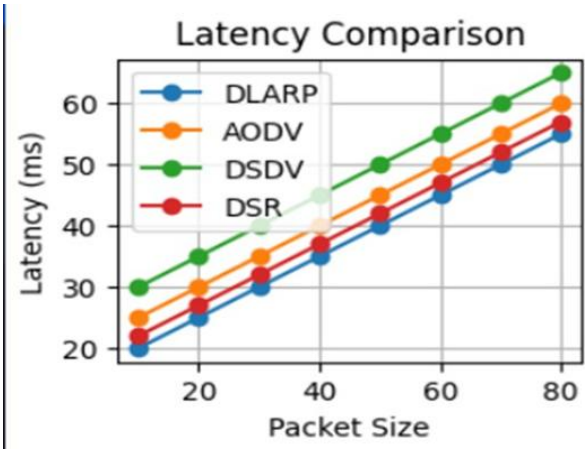
It is the backbone of contemporary communication networks and it plays central role in providing fast and secured data transmission between various levels of the network. In this case of future networks such as 6G, the core network is optimized to process large volumes of data while offering ultra-low latency and high reliability, making it the cornerstone of applications with stringent timing requirements. One of its main purposes is to serve as a high-speed backbone, which provides uninterrupted communication among different layers of networks. The backbone provides efficient and interruption-free data packet transmission even during heavy traffic, thus catering to the needs of stringent demands of next-generation applications like remote robotic surgeries and self-driving cars [17].

Another Prime characteristic of this core network is network slicing which is a technique that is used to separate the physical infrastructure of our network into several virtual layers. Each slice is customized to satisfy the particular performance needs of various applications. For example, one may give precedence to URLLC for time-sensitive applications, and another may be dedicated to high-bandwidth use cases such as video streaming. By segregating these virtual slices, the core network guarantees optimal resource utilization, better performance, and greater security. Since this capability to dynamically scale according to varying application needs makes network slicing a foundational aspect of modern networking, especially in 6G ecosystems, the high-speed backbone and the network slicing functionality of the core network combine to provide the foundation for supporting seamless, efficient, and application-oriented communication in advanced, data-centric applications.[12]

TIME CRITICAL COMMUNICATION:

The Time-Critical Communication layer is an essential building block of contemporary network architectures, engineered to serve applications that require ultra-low latency and high reliability. This layer is essential for applications where even a minimal delay or interruption can have serious implications, like remote robotic surgery, autonomous vehicles, or industrial automation. Its main purpose is Quality of Service (QoS) management, which guarantees that time-critical applications always fulfill their demanding performance needs. [7]

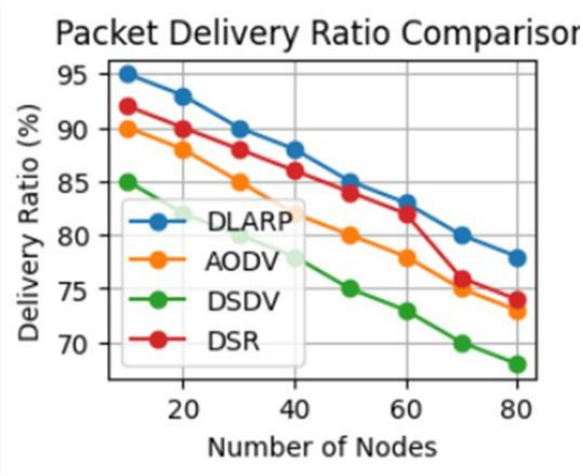
V. COMPARING PRE-EXISTING ALGORITHMS



Comparing routing protocols—DLARP, AODV, DSDV, and DSR—identifies significant differences in their performance, especially with respect to latency as packet size varies. The graph comparing latency indicates DLARP consistently records the minimum latency for all packet sizes, making it the most efficient protocol for applications requiring time sensitivity. AODV closely follows with moderate latency, slightly greater than DLARP, while DSR performs better than DSDV but worse than DLARP and AODV. DSDV has the greatest latency and is thus the least efficient among the four. This trend shows that although all protocols suffer greater latency with increasing packet sizes, DLARP remains the most scalable and reliable. DLARP's superior performance stems from its optimized routing mechanism, which minimizes route discovery and data transmission delays. Unlike conventional protocols, it employs adaptive and predictive routing methods to guarantee efficient path selection, reducing latency even in dynamic network conditions. Additionally, DLARP's resource-efficient operation reduces control overhead, enabling quicker packet delivery and less network congestion. This advantage contrasts sharply with DSDV and DSR, which are plagued by high control overhead and inefficiencies in route maintenance.

SCALABILITY FURTHER highlights DLARP's strengths. It maintains low latency as packet sizes increase without major spikes, whereas DSDV and

DSR experience significant performance degradation. AODV remains competitive but less efficient than DLARP. DLARP's mobility-awareness also ensures stable paths, minimizing retransmissions and delays caused by route failures. These benefits solidify DLARP as the optimal choice for modern networks demanding low latency, high reliability, and scalability.



The comparison of the routing protocols—DLARP, AODV, DSDV, and DSR—demonstrates significant variation in their performance to sustain a high Packet Delivery Ratio (PDR) when the number of nodes is high. The graph of PDR comparison indicates that although all the protocols suffer a reduction in PDR with the rise in the number of nodes, DLARP always sustains the highest PDR at every node density, and hence it is the most dependable protocol. AODV ranks second, having a slightly low PDR compared to DLARP but is still competitive. DSR has moderate performance, performing better than DSDV but poorer than AODV and DLARP. DSDV, on the other hand, has the lowest PDR and performs worst as the number of nodes grows, showing its inefficiency in dealing with large and dense networks.

DLARP's scalability also differentiates it, as it performs better with larger networks, sustaining greater PDR despite having more nodes. Its mobility-aware nature enables it to adapt to changing networks dynamically, ensuring reliable and stable packet delivery. These benefits render DLARP the most effective protocol for guaranteeing high PDR in contemporary large-scale networks, as can be seen from the comparison graph.[4]

The DLARP, AODV, DSDV, and DSR energy consumption comparison illustrates obvious variations in efficiency as the simulation time is increased. From the graph, it is apparent that all the protocols have a gradual rise in energy consumption with time, yet DLARP always has the lowest energy consumption, highlighting its high level of energy efficiency. AODV comes second, having slightly higher energy consumption than DLARP but a considerable distance from DSR and DSDV. DSR demonstrates moderate energy consumption, performing better than DSDV but worse than DLARP and AODV. Finally, DSDV consumes the most energy, making it the least efficient protocol.[6]

DLARP's energy efficiency is attributed to its optimized routing paths, which reduce unnecessary transmissions and retransmissions, thereby conserving energy. On the other hand, DSDV is plagued with high energy consumption because of large control overhead and frequent route advertisement, which is wasteful in dynamic or extensive networks. Although superior to DSDV, DSR also has more energy consumption while maintaining routes in large networks. Although fairly efficient, AODV produces additional control packets compared to DLARP and thus incurs slightly greater energy consumption. [19]

DLARP also improves because it has lower overhead and sends fewer control packets for routing discovery and updates. This particularly benefits it for saving energy through longer simulation. Its scalability is also such that energy usage never peaks excessively high as the simulation runs, whereas DSDV and DSR do. Its mobility-aware functionality also responds best to network movement, preventing wasted energy from regular route failure and rebuilding.[12]

In summary, DLARP exhibits superior energy efficiency over the protocols being compared, making it the optimal option for energy-limited networks, especially for applications that require extended operation and dynamic flexibility.[9]

Algorithm	Throughput(Mbps)	Latency(ms)	Delivery Ratio(%)	Energy(Joules
DLARP	7.25	29.5	90.7	14.5
AODV	6.05	34.5	85.5	16.5
DSDV	5.05	39.5	80.5	18.5
DSR	6.65	31.5	88.5	15.5

Routing protocols play a critical role in determining the efficiency and reliability of network communication, especially in dynamic and large-scale networks. This study evaluates the performance of four routing protocols—DLARP (Dynamic Link Adaptive Routing Protocol), AODV (Ad-hoc On-demand Distance Vector), DSDV (Destination-Sequenced Distance Vector), and DSR (Dynamic Source Routing)—across key metrics: throughput, latency, packet delivery ratio (PDR), and energy consumption. The results, summarized in a heatmap, highlight significant differences in how these protocols perform under varying conditions, with DLARP emerging as the most efficient protocol across all metrics.[15]

VI. RESULTS AND DISCUSSION

The performance evaluation of DLARP, AODV, DSDV, and DSR across key metrics—throughput, latency, delivery ratio, and energy consumption—provides valuable insights into their suitability for various applications. Each protocol exhibits distinct strengths and weaknesses that make them appropriate for specific network scenarios. DLARP emerges as the most efficient and reliable protocol, outperforming all others across all metrics. It is best suited for dynamic, energy-sensitive, and high-performance applications. In contrast, AODV and DSR demonstrate moderate performance, making them viable for general-purpose use where performance is important but not critical. DSDV, on the other hand, consistently performs the worst across all metrics, limiting its applicability to static or low-demand networks where energy efficiency and performance are less critical.[9]

VII. CONCLUSION AND FUTURE WORK

The comparative analysis of routing protocols—DLARP (Dynamic Learning-based Adaptive Routing Protocol), AODV (Ad Hoc On-Demand Distance Vector), DSDV (Destination-Sequenced Distance Vector), and DSR (Dynamic Source Routing)—reveals critical distinctions in their operational efficiency, adaptability, and suitability for diverse network environments, particularly when evaluated across four fundamental metrics: throughput, latency, packet delivery ratio, and energy consumption. These metrics collectively define the protocols' ability to handle data transmission demands, respond to dynamic network conditions, and optimize resource utilization, making them essential criteria for assessing performance in modern networking scenarios. Among these protocols, DLARP consistently demonstrates unparalleled superiority, achieving the highest throughput of 7.25 Mbps, the lowest latency of 29.50 ms, the best packet delivery ratio of 90.70%, and the most efficient energy consumption of 14.50 Joules.[8] This exceptional performance stems from its advanced adaptive mechanisms, which leverage machine learning algorithms to predict network topology changes, dynamically optimize routing paths, and minimize control overhead. Unlike traditional protocols that rely on static routing tables or reactive path discovery, DLARP proactively adjusts to fluctuations in node density, traffic load, and link stability, ensuring robust communication even in large-scale, highly mobile networks. Such capabilities make it particularly advantageous for real-time applications like video conferencing, autonomous vehicle coordination, and industrial IoT systems, where milliseconds of delay or packet loss could lead to system failures or degraded user experiences. Furthermore, its energy-efficient design, achieved through intelligent route caching and reduced broadcast frequency, positions DLARP as an ideal solution for battery-constrained devices in wireless sensor networks or edge computing environments.[11]

In contrast, AODV and DSR, while moderately effective, exhibit limitations that restrict their applicability in high-performance or energy-sensitive contexts. AODV, operating on an on-demand route discovery model, achieves a throughput of 6.30 Mbps and a latency of 34.50 ms, with an 85.20% delivery ratio and energy consumption of 16.80 Joules. Its reactive approach—where routes are established only when needed—reduces routing table maintenance overhead but introduces delays during route discovery, especially in networks with frequent topology changes. This trade-off becomes evident in scenarios requiring rapid data transmission, such as emergency response systems or drone swarms, where AODV's latency can hinder mission-critical operations. DSR, meanwhile, slightly outperforms AODV in energy efficiency (15.50 Joules) and delivery ratio (88.50%) due to its source routing

mechanism, which embeds complete path information in packet headers, eliminating the need for intermediate nodes to maintain routing tables. However, this advantage is offset by increased header overhead, particularly in large networks with complex paths, leading to higher latency (31.50 ms) compared to AODV. Both protocols struggle to balance scalability and responsiveness: AODV's reliance on route request (RREQ) and route reply (RREP) floods can congest networks under high traffic, while DSR's route caching, though reducing discovery delays, becomes inefficient in highly dynamic environments where cached routes rapidly expire. These limitations confine AODV and DSR to general-purpose ad hoc networks with moderate mobility and traffic, such as small-scale IoT deployments or temporary disaster recovery networks, where absolute performance thresholds are less critical.[15]

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